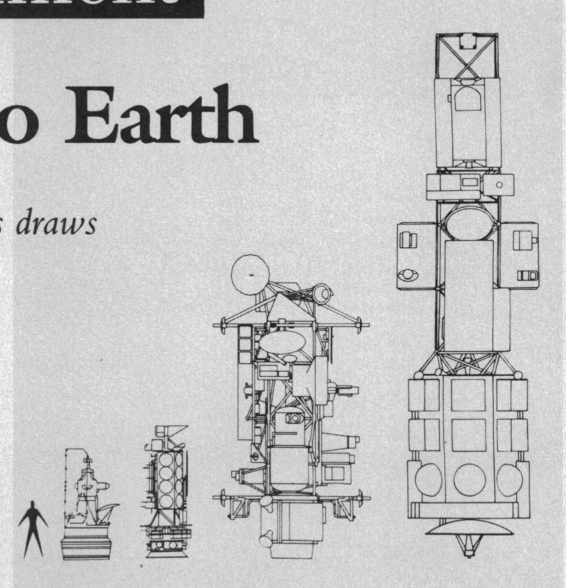
Bringing NASA Down to Earth

A $15- to $30-billion earth observing program for the 1990s draws fire for spending too much on hardware, too little on science



Growing, growing . . . . *Earth-monitoring satellites, from the 1960s Nimbus-7 to the 1990s Earth Observing System, are increasing in size and cost.*

It was not a warm embrace but a cool inquisition that greeted U.S. space officials this spring when they appeared at the Goddard Space Flight Center in Maryland before an audience of 500 scientists. They had come to address an exclusive club, the principal investigators in a massive new research program that will use satellites to track changes in the earth's environment.

Called the "Earth Observing System" or EOS, the project is the brainchild of the National Aeronautics and Space Administration (NASA) and the outgrowth of more than 5 years of planning by earth and space scientists working under the White House science office and the National Academy of Sciences. In January it got a special nod from the President, who endorsed it in a report he sent to Congress urging more money for global environmental studies. NASA's piece of the action, according to its own plan, would be an unprecedented $15- to $30-billion investment in satellite-based research over the next two decades, starting in 1991.

The prospect of sharing in this kind of funding, one might guess, would stir even the chilliest researcher's heart. But at least one skeptic in the audience at Goddard rose to ask whether the plan really represented a commitment to science or rather to satellite building. His challenge was greeted with applause.

One NASA scientist who asked not to be named called the meeting at Goddard "a 'rah-rah, let's go!' sort of session." What baffled him and other doubters was what they see as a compulsion to spend billions of dollars on new technology, even if it produces "horrendous" floods of digital data, at a time when the information system is already swamped and support for creating new scholars to use the data is "minimal." Before pouring money into flashy new hardware, the critics argue, the government should shore up basic research and help the existing earth-monitoring systems, especially those with archives that could be used in climate research.

The core of EOS—or the Mission to Planet Earth, as NASA calls the entire portfolio through 2010—is a large polar platform to be launched in 1996. It will carry a medium-resolution spectrometer to observe broad changes in vegetation and temperature, a high-resolution (30-meter) imager that will examine small features of the landscape with very fine discrimination (196 spectral bands as opposed to 6 on the existing Landsat), a laser range finder to track shifts in the earth's tectonic plates, and 16 other instruments. Japan and the European Space Agency are committed to flying similar platforms in the 1990s, and these will include U.S. instruments. If funding allows it, the United States will launch a second polar platform in 1998, and possibly a geostationary platform in 1999. To handle all this, EOS demands a new data management system costing half a billion dollars.

Before the big platform goes up, NASA has tentatively scheduled some smaller earth-watching projects for launch, including the Upper Atmosphere Research Satellite in 1991, a joint NASA-France ocean observing satellite known as TOPEX/Poseidon in 1992 or 1993, and a radar-based "scatterometer" to measure wind stress on the ocean in 1995 or 1996, on a Japanese platform. NASA would also like to fly a series of small earth probes to monitor, among other things, the ozone layer and tropical rain formation.

Earth scientists will be delighted to get these new gadgets in the 1990s, but in the meantime they worry that the existing space network will decay. Several key systems are tottering toward extinction, and plans to replace them are in limbo.

Best known, perhaps, are the problems of the aging Landsats 4 and 5, the civilian land scanners that were almost turned off this spring for lack of funds (*Science*, 24 February, p. 999). These orphans were rescued in May by the White House, and Landsat 6 has been fully funded. But the program still has not found a welcoming bureaucratic home.

Another space waif is a device called Sea-WIFS, a chlorophyll sensor that tracks plankton in the ocean. The last of these, flying on the aged Nimbus-7 satellite, died in 1985. Its replacement was due to fly on Landsat 6, which itself is late. However, in the brouhaha over funding, Landsat's foster-parent, EOSAT, a company that operates the system for the government, decided to throw Sea-WIFS off Landsat 6. Now NASA is seeking a new home for it. In addition, plans to replace the senescent ozone monitor on Nimbus-7 (the one that picked up the famous view of the ozone hole) are less than firm. NASA is trying to hitch a ride on a Soviet vehicle.

The weather service has its own troubles. The two-satellite geostationary system that watches hurricanes has been limping along with just one satellite (called GOES), which must be shifted around with seasonal changes to cover shifting areas of concern. Its life is finite. But the replacement for GOES has run into technical troubles, fallen off schedule, and run up extra development costs. When it is ready for launch—in 1991 at earliest—some scientists fear it may produce less reliable data than the old version. "Everyone will breathe a sigh of relief if we get data of similar quality," says Francis Bretherton of the University of Wisconsin, Madison.

So while 21st-century scientists will be endowed with a wealth of detailed information on tropical rain, ozone in the upper atmosphere, and forest growth, the present cadre may have to make do with static resources. One who has gone public with criticisms of NASA's priorities—and who thinks the agency "is mad at me" for doing so—is James Hansen, director of NASA's Goddard Institute for Space Studies at Columbia University in New York and a sometime maverick (see *Science*, 2 June, p. 1041). He blasted NASA's plan at the meeting, saying more thought should be given to the underlying science. "The organizers thought I should make these points in private, not in public, but they are ignored if you make them in private," he says. Afterwards, he wrote a strong letter to Dixon Butler, NASA's program scientist for the Earth Observing System.

The letter, dated 27 March, speaks about the need to build up "brain power" before deploying machines. The Mission to Planet Earth, Hansen wrote, "is described in terms of the number of pieces of hardware in the sky." He was concerned that the scientific disciplines will be "squeezed to allow support of EOS research." Available sources of earth science data are now "underutilized" he contended, yet even the winners of the EOS competition have been told they will be funded at just one-third the requested level. This limit cannot be justified on grounds that R&D for equipment will require more funding in the early years, Hansen wrote, because "development of scientific manpower and understanding will take longer." He said that if science gets the "short end" at the outset, "we can expect that situation to continue as inevitable hardware cost overruns occur."

Since March, NASA has not responded to the letter, but has adjusted the EOS plan a bit. Butler, an expert on Venus's ionosphere who says he is now excited by the public service aspects of space science, agrees with Hansen's main point: "I think Jim was right on the mark. I had been so busy worrying about other things that I hadn't backed up from the trees enough to think about [the forest]." In his view, Hansen is saying, "This is a whole new space age, you're about to take us into, and you're not making the community infrastructure investments that are required." As a remedy, Butler has proposed that a 0.25% "tax" be imposed on the EOS program and that the funds be set aside for graduate fellowships. He thinks it would pay for about 100 students a year—tuition plus a modest stipend—and would go a long

Low-Tech Earth Observation

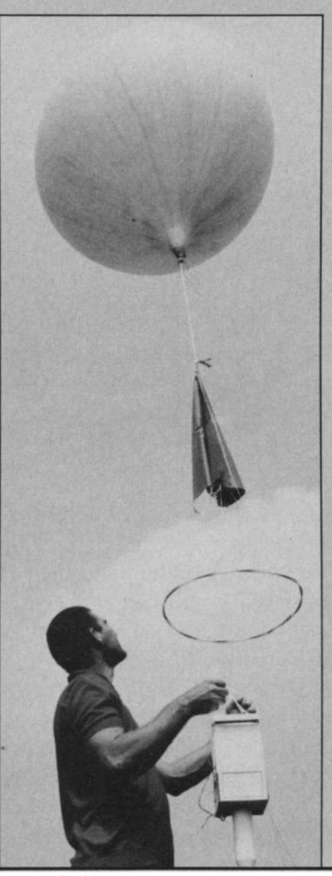
Twice every day—when the sun stands exactly at noon over Greenwich, England, and when it reaches the opposite global position (midnight, Greenwich time)—small balloons climb in unison from more than 700 points over the earth's surface and penetrate the upper atmosphere. They burst at a height of 7 to 8 miles, falling down to the surface again.

This carefully orchestrated event, which to an alien eye might look like a bizarre natural phenomenon peculiar to the planet Earth, is part of the daily routine of the world's weather services. The release of these atmospheric "sounding" balloons has been going on for decades (though not in such large numbers). And the information on temperature, pressure, and humidity radioed back from the little balloons has produced a database that is valuable to students of climate change.

The little balloons contrast sharply with the multi-hundred-million-dollar satellites that will be used in the Earth Observing System (EOS), if NASA has its way. But some meteorologists worry that in a rush to build new technology we may neglect invaluable—and cheap—systems already in place, like the balloons.

Although these and other weather station records are collected for immediate forecasts, they have been gathered in a fairly consistent fashion over the decades and form a good long-term record. However, in recent years, says Thomas Karl of NOAA's National Climatic Data Center in Asheville, North Carolina, control of systematic bias has declined. Karl says that the data could be managed better than at present. It is more important than ever to identify differences in historic methods of data collection, for the search is on for tiny signals—as small as a 1°C change in a century.

Climate watchers have been aided tremendously by satellites, but the new gadgets also introduce new problems, Karl says. For one thing, satellites are relatively short-lived and must be replaced after a few years. Changes in sensors may introduce subtle discontinuities in the data, which must be identified and taken into account. In addition, Karl says, no satellite is more accurate than ground-based observations because each sensor is calibrated to "ground truth." Errors in ground data will be echoed in the satellite.



Karl thinks the government could get an excellent return for its investment in climate research by paying to gather and tidy up the existing data from ground stations. Thus far, for example, the World Meteorological Organization (WMO) has had little success in a small project aimed at getting nations to record the most basic weather information in digital form on personal computers donated by the WMO. "It's been 4 years since the program started," Karl says, "and we've seen no data yet." He adds that the Soviet Union has data "we would love to get our hands on," but so far there has been no breakthrough.

Another field in which federal dollars would make a big difference is ocean research. Information on changes in sea level is critical for studies of global temperature change and ice melting, but little has been spent to extend ocean monitoring to remote areas of the globe. For example, Klaus Wyrtki of the Sea Level Center at the University of Hawaii in Honolulu has been trying to establish a small set of tide gauges in the Pacific and Indian oceans for years. His colleague Gary Mitchum says they are appreciative of every bit of federal support they get but it is hard to maintain a 20-year monitoring project "when you have to worry about funding every 6 months."

Using technology from the late 19th century (stilling wells) connected to 20th-century transmitters, they maintain a network across a vast expanse of water, contributing to an archive whose longest records go back 150 years. It is important to have broad coverage to be certain that increases in water height are not just local anomalies. Each season they face a dilemma: should they push forward and set new gauges or protect the ones in place? "They require continual care and feeding; as soon as you stop, they go away," says Mitchum.

The work done at the center "falls between the cracks" of the federal sponsors, he says, because it looks like routine monitoring to research agencies, and like research to operational agencies. ■ E.M.

Early Data: Losing Our Memory?

Researchers are of one mind when it comes to judging the accessibility of the most important earth surveillance program to date—Landsat. "A national disgrace," says Francis Bretherton, director of the Space Science and Engineering Center at the University of Wisconsin at Madison.

In an attempt to "commercialize" Landsat, the government in 1984 turned over all of the system's data, past and future, to a private firm called EOSAT. As a result, researchers claim, the cost of using the data has risen tenfold and the usage by scientists has plummeted.

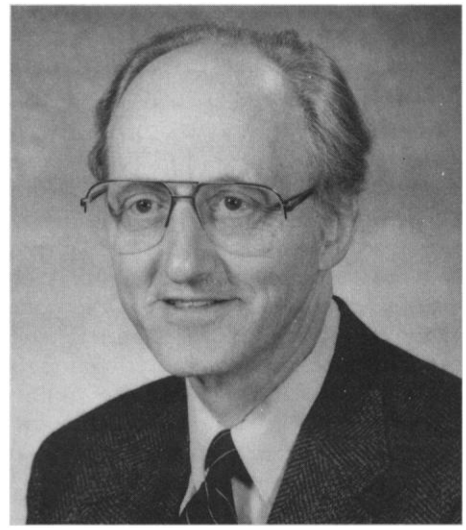
Richard Williams, a map maker and analyst of global ice patterns at the U.S. Geological Survey (USGS), says, "Most researchers have a very small budget for data acquisition, $1500 to $2000; Landsat images are now priced totally out of the range of an individual scientist. . . . If you want the scientific community involved, you must make the data available at an affordable price."

Because Landsat is subsidized by the government and data are priced at commercial rates, Bretherton concludes, "We have the worst of all possible worlds: we are both spending the money and making sure that we get nothing out of it."

Meanwhile, managers of the 17-year-old Landsat archive, an excellent historical record, are struggling to overcome barriers created by obsolete computers and broken tape decks. Allen Watkins, director of the USGS center in Sioux Falls, South Dakota, where Landsat tapes are kept, says, "90% of the data collected before 1979 are now inaccessible." The reason: the data tapes were recorded on old Xerox computers which can no longer be operated. In addition, the satellite location and timing data were recorded on a kind of video tape deck that no longer exists. Tape renewal is another problem that looms in the future. Magnetic images "bleed" through the layers as time passes, and tapes must be recopied at least once every 10 years to make them usable. Watkins says the task is already formidable, and wonders what will happen when the Earth Observing System begins sending back the equivalent of an entire Landsat archive every 2 weeks.

Helen Wood, satellite data chief at the National Oceanic and Atmospheric Administration in Washington, D.C., says that NOAA's centers are already "drowning in data," and the task of making it usable today "is a challenge to say the least." NOAA's archives are not as well funded as the USGS system, she says, and the cost of storing the new EOS data will be "staggering." The system is so bogged down even now that people call the data centers "data cemeteries."

Roy Jenne, a researcher at the National Center for Atmospheric Research in Boulder, Colorado, has made a second career of helping people find their way around the weather archives. His own list includes some low-cost improvements: filling in the gaps of missing ocean and temperature data for the World War I and II periods ($1 million), initiating a comprehensive exchange with the Soviet Union, giving wider distribution to military satellite images of polar ice and snow ($150,000 to start), and preserving 12,000 tapes of older NOAA satellite data, recently stashed in a warehouse where they were exposed to water. ■ **E.M.**



University of Wisconsin

Francis Bretherton: *Problems in accessing Landsat data are "a national disgrace."*

way toward solving the manpower shortage. These awards would be made specifically for research on global change or EOS-related work. However, Butler says the idea has not been approved by the Office of Management and Budget.

As for satellite data management, Butler agrees that the record of the past is "horrible" and that the demands of the future will be "a big challenge." Few people realize just how big. Allen Watkins, director of the Earth Remote Observation System data center in Sioux Falls, South Dakota, keeper of Landsat records for the U.S. Geological Survey, anticipates that NASA's new earth-watching satellites of the 1990s, if launched, will create as much data every 2 weeks as Landsat has created in its entire 17-year lifetime.

Butler is full of hope, nevertheless, because he expects the cost of electronic data systems will keep falling and their sophistication will keep growing. "You would not expect a computer of 10 years ago to assimilate the data from EOS in a reasonable way," says Butler, but "if you look ahead to what you're going to be able to do 10 years from now, you say, 'Hey, the technology is there, the infrastructure is there. . . . Now it's up to us to get the intellectual wherewithal together to pull it off.' " Already, NASA centers have started publishing large sets of processed earth observation data on CD-ROM disks, the same laser-coded devices used for recording music. "I have a complete set of the Antarctic ozone hole observations on a disk sitting on my file cabinet," says Butler.

Hansen is not impressed: "Somebody at the Goddard meeting made the mistake of saying that the data you'd get in 1 year from EOS would fill a building the size of a football field, seven stories high." But, Hansen notes: "Information is not proportional to the amount of data." It is not enough to turn the data over to computer wizards; the information must be interpreted by specialists, and these are few in number.

The structure of the data system used by EOS will be significantly better than previous ones, according to Butler and Wesley Huntress, Jr., special assistant to the director of NASA's earth sciences division. It has been designed from the outset to be comprehensive and highly accessible. Researchers who participate in EOS will be compelled to use a common format (with data-processing algorithms submitted before launch), and they will have to pool their data in a common archive for wide distribution. In return, NASA is promising to let investigators keep their records confidential for 18 months—at least in the case of one yearly mission, the Upper Atmospheric Research Satellite (1991). But on later projects, after EOS begins in earnest in 1996, researchers will be expected to release data immediately.

This approach will require not just the cooperation of individuals, but of competitive agencies like NASA, the National Oceanic and Atmospheric Administration (NOAA—the weather agency), and the U.S. Geological Survey. The agencies have agreed in principle to play the game as NASA directs, and negotiations are going well, Butler says. "I have yet to see the kind of acrimony that is just endemic to bureaucracy, although there are tense moments." He adds: "There is a sense that there is enough work for everybody."

A more guarded appraisal is offered by Francis Bretherton, director of the Space Sciences and Engineering Center at the University of Wisconsin at Madison, and one of NASA's chief academic advisers. He points out that NOAA has already declined to join NASA on the first EOS platform scheduled for launch in 1996 because it is concerned about potential delays. NOAA is an operational agency providing regular services to a broad clientele. It takes the position that it cannot risk any gaps in coverage, the kind that it sees in NASA's recent record. NOAA may decide in 1997 to jump aboard a later platform, after the system has proved itself. Meanwhile, the two agencies are designing their instruments and orbit profiles for full compatibility.

At the top level, Bretherton says, everyone agrees that NOAA is on board the program spiritually if not physically. At the working level, however, one encounters the view that "NOAA has dropped out, so forget 'em." The discrepancy may simply be a problem of poor communication, but Bretherton says it is "very, very important" that it be resolved quickly. Failure to reach agreement would endanger not just the quality of the data bank but the monitoring program itself. It would be fatal for NASA and NOAA to seek duplicate instruments to collect similar atmospheric data. "We could end up with a situation in which neither approach is viable on its own, and yet we've got two separate approaches," Bretherton says. "I'm not sounding any major alarms yet," but he is worried.

NASA officials believe these rumblings are normal for a program in the early stages of formation. They are certain that NOAA's special concerns can be accommodated. And they say they have begun to work on the problems of scientific direction raised by Hansen and others. They insist that existing global research projects will not be asked to make sacrifices, but that, on the contrary, they will benefit because of the increased attention given to the Earth Observing System.

The test of these commitments and of the government's good faith may come soon. If the existing earth observing projects—such as Landsat and the ocean and weather monitors run by NOAA—are not given better support in the next budget than they have received in the past two administrations, promises of future growth in space-based environmental research will be hard to credit. ■ ELIOT MARSHALL

German Biotech Firms Flee Regulatory Climate

A law that puts roadblocks in the way of new facilities is causing many firms to locate production plants overseas; the government has responded with a less onerous proposal

Ludwigshafen, West Germany

ALFRED VELLUCCI would probably appreciate the irony. A decade after the feisty mayor of Cambridge, Massachusetts, fought bitterly—and unsuccessfully—for the right to impose local controls on recombinant DNA research, the West German chemical company BASF has announced plans to open a new biotechnology laboratory in Boston, on Cambridge's very doorstep. The reason: BASF sees the Boston area as a safe haven from the public opposition the project may face back home.

"We were faced with the decision of whether to invest in Germany, in order to make biotechnology grow here, or to go to the U.S.," says the company's director of biotechnology research, Rolf-Dieter Acker. "We decided to do both; to develop some biotechnology facilities here, but also to build up a research group in the U.S., just to be on the safe side."

BASF's decision to set up shop in Boston, where a group of 60 scientists will eventually work in a brand new research institute on the development of anticancer drugs, follows a similar decision by the Bayer company. Bayer recently announced plans to open a facility for the production of recombinant Factor VIII in Berkeley, California, rather than closer to its home base of Leverkusen, outside Cologne.

These two moves have dramatically brought home to West German politicians the extent to which the country's large chemical companies are finding genetic engineering to be a "no go" area at home. Faced with public concerns about both the safety and ethical aspects of genetic engineering, the nation's biotechnology industry has been contending with growing regulatory problems for several years, which is why even some politicians are joining German scientists in warning that something must be done quickly, since many of the best and brightest young molecular biologists are already fleeing the motherland for the United States.

What drives the corporate leaders to distraction is an amendment that was added last September to existing environmental legislation. It requires that proposals for all new production facilities using genetically engineered organisms—whether they are inherently pathogenic or not—be put to public debate. That may not seem too onerous, but the problem is that there are few administrative guidelines on how the law should be put into practice, and this has resulted in a kind of regulatory limbo. No new production facilities have been approved in the 8 months since the amendment was passed. A related and, to the companies, no less disturbing aspect of the legislation is its implicit threat to commercial secrets that they claim are embedded in the requirement for full public disclosure.

One consequence of all this is that many companies have put on ice any development plans that include the use of recombinant DNA techniques. Another is that they have virtually stopped recruiting molecular biology graduates until the situation is clarified. "Students finishing their Ph.D.'s in molecular biology now tend to look to American or Swiss companies [for jobs]. They are voting with their feet," says Hermann Bujard, director of the University of Heidelberg Center for Molecular Biology.

> ***"Some people feel that they cannot always trust the scientist."***
>
> —Ernst-Günter Afting

And few U.S. biotechnology companies are willing to risk joint ventures (as they have done elsewhere in Europe) in a country where full public discussion of their proposed activities is required. Last year, for example, when Genentech set up a Research Institute of Molecular Pathology with the German company Boehringer Ingelheim, the U.S. firm insisted that the new institute be located outside Germany, and a site was found near Vienna. Indeed, "no U.S. company has invested over the past year in anything related to genetic engineering in Germany," says Acker.