RADAR FROM SPACE: THE SIGHTSEEING PLANS OF SIR-B

From the forests of Bangladesh to the lost city of Ubar

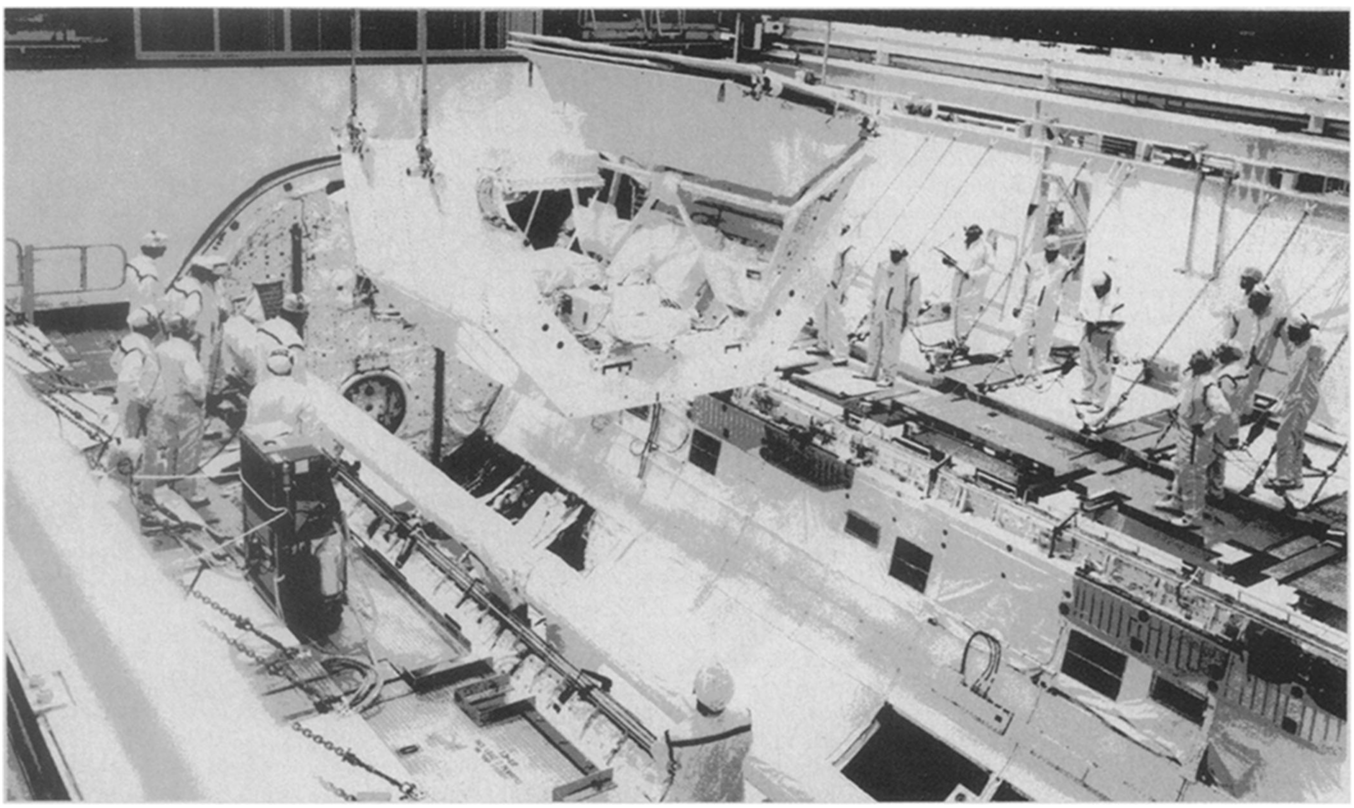
By JONATHAN EBERHART

A satellite called Seasat, launched in 1978 by the National Aeronautics and Space Administration, was intended, not surprisingly, to study the sea. It would measure wave heights, water-surface temperatures, currents, tides and more, and it included among its sensors a device called synthetic-aperture radar (SAR) to track wave patterns, ice packs and other phenomena. Designed to operate for a year or more, Seasat succumbed to an apparent "massive and progressive" short circuit after only 100 days, but not before delivering a significant message from the SAR: that there was potentially at least as much of interest for it to "see" of the dry land as there was over the oceans.

Only a small fraction of Seasat's coverage was overland, but the spectacular geologic detail found in the images reconstructed from its data made an impression, confirming what geologists had suspected and hoped from earlier airborne studies. And when NASA's next SAR, called Synthetic-aperture Imaging Radar A (SIR-A), went into space for a few days on the second test flight of the space shuttle in November of 1981, about 90 percent of its targets were on dry land.

It scanned mountain ranges, fault zones, rolling plains and more, but just as the water-oriented Seasat had provided a bonus with its crisp readings of solid ground, SIR-A yielded a startling extra of its own. In looking over the instrument's images of the Sahara Desert in southern Egypt and Sudan, researchers with the U.S. Geological Survey (USGS) in Flagstaff, Ariz., noted what appeared to be a vast array of dry riverbeds, channels and tributaries. But photos taken of the same region by Landsat, as well as personal experience from repeated field trips, said there should be only the trackless sand sheet. Yet the features identified by the SAR appeared to be real, though barely a trace of them was visible to either the camera or the human eye. How could radar see things that didn't appear to be there? SIR-A, the scientists determined, had been "seeing" *through* the sand.

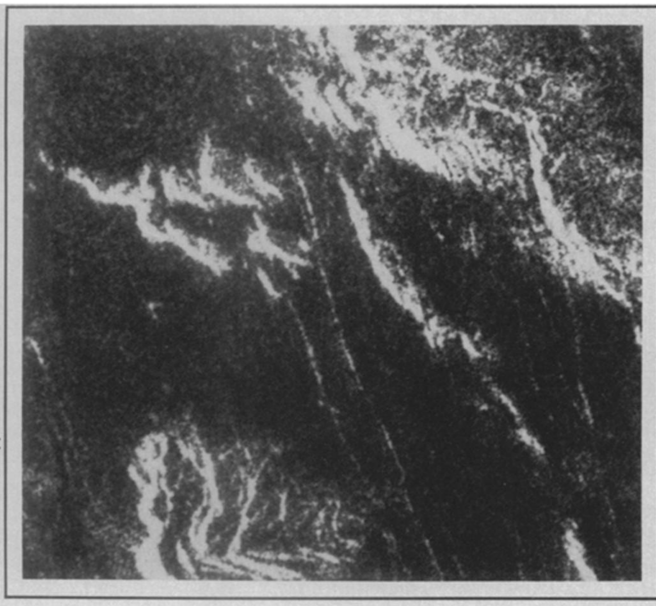
Unexpected as the dramatic conclusion was, there had been nothing in theory to rule it out — except that several demanding conditions had to be met. It depended on the sand surface being smooth enough to appear "dark" on radar images, while the underlying topography was rough so that it would stand out as "bright." The other essential was that the sand, besides being fine-grained, would have to be *extremely* dry, because even a little moisture would reduce the energy of the incoming radar beam so that there would not be a strong enough signal reflecting from the underlying terrain. And, says Carol Breed of the USGS, the "aridity index" (or Budyko ratio, a comparison between the sun's heat at a given site and the amount of rain that falls there) of that part of the Sahara is 200 — while Death Valley rates a 7. Are there any other such spots on the globe, with



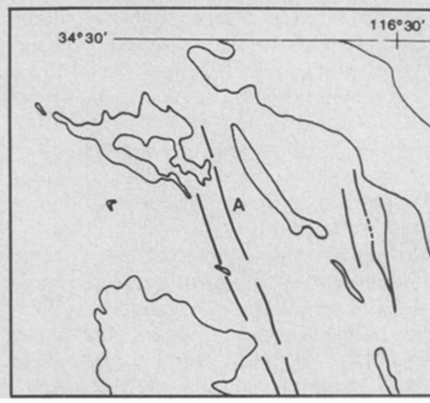
NASA

Pallet containing the SIR-B imaging radar is loaded into the space shuttle Challenger's cargo bay.

Blom, Elachi/JPL; Crippen/UC Santa Barbara



Looking through the sand: Researchers were startled when SIR-A spaceborne radar images of the Sahara Desert revealed widespread dry riverbeds and other fluvial features that did not show at all in Landsat photos of the surface. Here, in a similar case, a Seasat radar image (above left) shows bright linear features in Means Valley of California's Mojave Desert that have no counterpart in aerial photos (above right). Not even walking across the surface showed anything that corresponded to the radar-apparent lineaments, which appear to be igneous dikes covered by the sand. The feature marked A in the map at right approximately follows the southeast trending portion of a drainage pattern visible on the sand, but it shows no correlation when the surface pattern turns west. One significant aspect of the Means Valley findings is that the Mojave is not nearly so arid as the eastern Sahara, although 1978, when the Seasat image was made, was a particularly dry year for the Mojave. This raises the possibility that other arid regions may allow radar penetration of the sand even if they are not so dry as the Sahara, which scores 200 on an aridity scale that gives even Death Valley a mere 7.



hidden surprises awaiting the SAR's gaze?

Early in October, the shuttlecraft Challenger will be launched into orbit from Cape Canaveral, carrying, among other things, the next generation of NASA's SARs, SIR-B. And the plans for SIR-B are diverse indeed, involving a team of 43 principal scientists and about 200 other collaborators whose activities will range from hunting for lost cities to tracking oil spills to worrying about tigers in the night.

A key element, of course, will be exploring the potential of imaging through the sand. At least one other example has been identified besides SIR-A's Sahara discovery. In the course of an ongoing study of California's Mojave Desert, Robert E. Crippen (no relationship to the astronaut) of the University of California at Santa Barbara spotted some prominent linear features in Seasat's 1978 data that have no visible counterpart in airborne photographs. That happened to be a particularly dry year for the Mojave, however, and in the summer of 1983, airborne radar studies over the same region failed to detect even some deliberately buried radar reflectors, possibly because of previous rainfall.

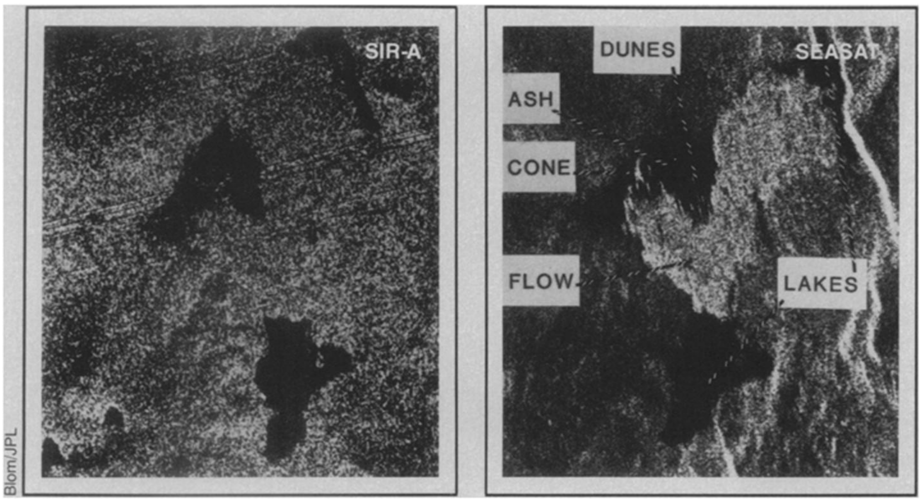
Some years ago, says Ronald G. Blom of Jet Propulsion Laboratory (JPL) in Pasadena, Calif., there were also some accounts (never published in the public record, because the data were classified) of lava flows detected beneath surface deposits. And SIR-B is scheduled to image some of the driest areas on earth, though few may be as parched as the eastern Sahara. At one point, for example, says Breed, the shuttle will pass northeastward over southern Africa, crossing the hyperarid Namib Desert of coastal Namibia and South Africa, then moving on over the somewhat less arid Kalahari in Botswana and so on. Also on the list is China's Taklimakan, although Breed says penetration of the sand is unlikely there except perhaps at the edges.

The "sights" to be "seen" in such locales are largely unknown, another SIR-B researcher notes, and in many cases it is likely to require ground-based studies to be sure of what such apparently subsurface features actually are. The SIR-A Sahara results, he points out, had conspicuous fluvial (flow-caused) shapes, enabling ready comparison with the Landsat photos in which they were conspicuously missing. It is possible that a relatively regular substrate might go undetected.

Other possible finds beneath the sand, however, could be conspicuous indeed.

Los Angeles documentary filmmaker Nicholas Clapp, for example, is not a member of the SIR-B team, but he (like a separate British group) is particularly interested in images of Oman, near the Saudi Arabian border. There he hopes to find evidence of the lost city of Ubar, an ancient center of the frankincense trade described by various names in numerous historical sources — including the Koran — but which has apparently been unoccupied for some 2,000 years. There have been some attempts to find it, and an ancient road that may have led that way has been seen where it disappears beneath the sand. In fact, says Clapp, ruins of another early city referred to "in the same breath" in some accounts are still there. And, he adds, there has been no rainfall there "in memory."

One of the planet's driest spots of all, in places as high on the aridity scale as the eastern Sahara, is the coastal desert of Peru. Numerous signs of pre-Columbian habitations remain, from individual structures to whole towns. Many such ruins, says Maurice Grolier of the USGS, are relatively exposed near the country's Pacific coast, but they are increasingly well buried by the sands near the foothills of the Andes. The tops of walls yield conspicuously bright radar echoes, he says, and SIR-B offers the chance — particularly



SIR-A's radar beam, aimed down at about 50° from vertical, indicates the degree of roughness of a portion of California's Lassen National Park, while Seasat's steeper beam, angled out only about 20°, shows details of topography.

with help from a little sand penetration — to locate them on a single vast map, rather than having to depend on assemblages of miscellaneous small-scale airborne photos and other data. Also to be found are potentially large burial grounds (sometimes major sources of archaeological relics) on the desert flats, and elaborate patterns of irrigation terraces on the Andean slopes.

Identifying those terraces, Grolier says, depends not so much on penetration of the sand as on the characteristic difference between their surface roughness and that of the surrounding terrain. And herein lies an essential example of SIR-B's flexibility compared to its predecessors.

The antenna of Seasat beamed its signals toward the earth at an angle about 20° away from straight down, says Blom, while SIR-A transmitted on a shallower slope of about 50°. The steeper path can provide a better indication of topographic ups and downs such as hills, basins and the like, while the shallower "incidence angle," responding more to the typical sizes of surface grains and chunks, is often a better roughness indicator. And SIR-B is the first in its line to offer a variable incidence angle. Many of its experiments, notes principal investigator Charles Elachi of JPL, will involve scanning the same surface (or subsurface) features at a range of angles, to see which one is best or whether a certain combination in repeated scans can yield the most characteristic "signature" for a given terrain or material.

Much of SIR-B's work, in fact, is concerned not so much with discovering new features on the earth as with learning about the best way to use the SAR as a tool, exploring its capabilities. There are certainly many specific questions about the mission's various targets themselves, acknowledges Elachi — the Leakey Foundation, for example, he says, wants maps of sedimentary basins that might aid searches for the sites of early habitats. And the Saudi Arabian and Egyptian governments would like to identify characteristic natural subsurface structures that might guide searches for water farther down.

But there are also a host of more general topics. Researchers from the Radio Research Laboratories in Tokyo, for instance, would like to know if rice can be distinguished from other crops in radar data, and whether radar is a potential tool for tracking oil spills. For the latter test, they will be dropping quantities of frozen olyl alcohol from aircraft to create "synthetic oil slicks" which should reduce the roughness of the sea surface in a way that, they hope, can be tracked by radar.

In Bangladesh, Mark Imhoff of the NASA Goddard Space Flight Center in Greenbelt, Md., will be spending his time during the mission mapping the varieties, moisture, foliage density and other aspects of two test patches in a vast mangrove forest. Later, working with the Space Research and Remote Sensing Organization of Bangladesh, he will compare these "ground-truth" data with SIR-B's results to learn what spaceborne radar can reveal from its lofty vantage point about the health and other characteristics of such vegetation's vast expanses. At the same time, the head forester of the Idgaon Forest Reserve near the Indian border will be surveying that region for a similar reason.

Imhoff's original involvement with Bangladesh, he says, began as an evaluation of SAR as an aid to monitoring the extent of malaria (by identifying characteristics of moisture, vegetation and other factors that may contribute to its spread), which is rampant in the Idgaon. It would not have been exactly a benign environment for fieldwork, but neither is the present site. With several aides, including armed guards, he expects to be spending the nights of his stay in a well-fenced treehouse high above the floor of the forest — which is one of the largest Bengal tiger preserves in the world.

Apart from the evaluation of SIR-B itself as an instrument, its scientific goals will be divided into five areas: geography (mapping), geology (including delineation of subsurface rock units), hydrology (which will include remote sensing of soil moisture — the opposite extreme from penetration of hyper-arid sands, which may not work if there is even enough moisture to measure from space), oceanography (waves and sea ice are far from forgotten) and vegetation (such as an attempt to identify — with a SAR — the gorse plant that is invading New Zealand grazing land).

But how do you categorize an Australian attempt to measure the relative densities of different eucalyptus forests — which can sometimes indicate the grade of the bauxite on which they grow? □

Sand-covered ruins of pre-Columbian town in the foothills of the Peruvian Andes show faintly in aerial photo. SIR-B may be able to map such settlements in detail.