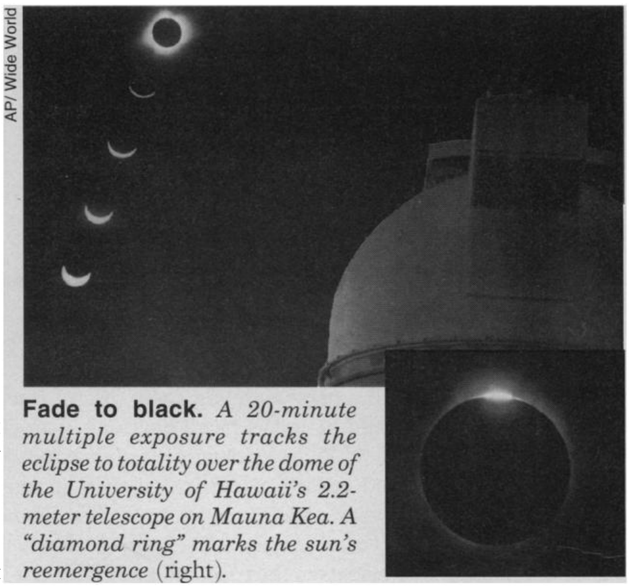
A Mountaintop Cliffhanger of an Eclipse

On Mauna Kea, the most studied eclipse in history was menaced from below by clouds and from above by volcanic haze

Mauna Kea, Hawaii—OUTSIDE THEIR telescope domes near the 4200-meter summit, astronomers groaned as dawn broke on 11 July. It was a beautiful dawn—and it looked like a lousy day for an eclipse.

The sky was dismayingly dramatic and pink at 6:00 a.m., an hour and a half before totality. But that's not what a scientist wants to see on a mountain famous for its clear, dry air. That morning a double curse of thin, infrared-scattering cirrus clouds and a stratospheric haze from the eruption of Mount Pinatubo in the Philippines streaked the sky over the world's largest concentration of optical and infrared telescopes. An hour later, a wave of mist washed over the summit, foreshadowing a potentially greater catastrophe. The tropical inversion, which battens down the rain clouds that throng daily around the dormant volcano, now hung but a few hundred feet below the summit. At risk if the clouds rose any further: years' worth of eclipse preparation.

AP/ Wide World



Fade to black. *A 20-minute multiple exposure tracks the eclipse to totality over the dome of the University of Hawaii's 2.2-meter telescope on Mauna Kea. A "diamond ring" marks the sun's reemergence* (right).

In a way, the excitement atop Mauna Kea was an anachronism. The days of the great eclipse expeditions, such as the 1916 Canary Islands venture during which Arthur Eddington examined stars near the edge of the sun to confirm Einstein's prediction that gravity bends light, are over. To study the region above the sun's visible surface, astronomers no longer have to rely on the moon to blot out the solar disk. Satellite-borne telescopes can peer at the solar corona without being blinded, as can earthbound telescopes called coronagraphs, equipped with special sunshields.

Still, nothing works as well as an eclipse. And this time the eclipse was coming to the astronomers. If the clouds didn't ruin it, the 50 astronomers waiting on Mauna Kea with a clutch of large telescopes and nine experiments would make this the most studied eclipse ever. And, in a nice tit-for-tat, the eclipse would draw world attention to the remarkable astronomical facilities recently collected on the barren summit.

So Donald N. B. Hall tried not to worry about the clouds and dust as he strode the barren summit in the pink morning light, wearing short sleeves in spite of the near-freezing temperatures. Bantering with VIPs including John Waihee, governor of Hawaii, and Akio Morita, president of SONY, having quick chats with astronomers taking a break from their preparations and with journalists and television crews, Hall played the part of landlord of the summit—which is just what the ebullient Australian solar physicist is, having directed the University of Hawaii's (UH) Institute for Astronomy since 1984. Whatever the outcome of the experiments, he knew, the eclipse would mark his university's unofficial initiation into astronomy's top rank.

"To see the focus of national attention on this island will unquestionably make the public aware of what it has here," said John Jefferies of the National Solar Observatory in New Mexico as the eclipse neared. Jefferies, a former UH astronomer, founded the Institute for Astronomy in 1967 and remained its director until 1983, leading the push to build an observatory on Mauna Kea. From the time in the early 1960s when he and astronomer Gerard Kuiper of the University of Arizona first measured the extraordinary smoothness and clarity of the air at the summit, he wanted lots of telescopes on the mountain.

Small telescopes sprouted on Mauna Kea in the late 1960s, and UH's 2.2-meter instrument opened in 1970. Through the following decade, Jefferies struggled to entice other institutions to the mountaintop, offering sites in return for 10% of the observing time, to be donated to the institute. As a result, UH has gone from being a bit player in astronomy 25 years ago to a position among the top 10 U.S. centers, according to some astronomers. And the summit of Mauna Kea now sports the world's greatest telescope collection, with four large optical telescopes, two infrared instruments, and two millimeter-wave dishes. There's more to come, including a pair of 10-meter telescopes funded by the W.M. Keck Foundation, one of which should be completed within a year, and an 8-meter Japanese telescope.

Most of the existing telescopes were poised for action that morning. (The 3.8-meter United Kingdom Infrared Telescope would have been among them if its designers hadn't made it unable to point low enough to catch the morning eclipse.) If the clouds and the volcanic haze allowed, the array of experiments would scrutinize the sun's exposed atmosphere in three wavelength bands: infrared, optical, and the millimeter-wave band between radio waves and the infrared.

One goal of the infrared experiments was to search for the heat signature of a ring of dust vaporizing a few solar radii from the sun's surface. For decades, astronomers have speculated that debris left over from the formation of the solar system or newly formed from colliding asteroids is continuously falling toward the sun and vaporizing. The infrared signal, if it existed, would be so strong at the altitude of Mauna Kea, above the infrared-absorbing water vapor in the atmosphere, that the light-gathering power of the large infrared telescopes would be overkill. A small lens and an array of infrared detectors would do the trick. One group mounted its setup inside a 24-inch telescope, which did the pointing, but blacked out the telescope's dish.

At millimeter wavelengths, astronomers were less interested in totality than in the buildup to it. Millimeter-wave astronomers can look at the solar atmosphere anytime they want, but their instruments lack the fine focus needed to pin down the altitudes from which specific emissions come. The moon's advancing shadow offered a solution: As it slipped across the corona, its knife edge would block the sun's atmosphere layer by layer. From the progressive changes in the emissions, the researchers hoped to construct a millimeter-wave map of the sun's outer layers. Such a map could yield new information about temperature and density in the photosphere, the thin overlying chromosphere, and the extended corona.

Another experiment, done at NASA's 3-meter infrared telescope, also relied on the moon as a knife edge, in this case to pinpoint an emission line from ionized magnesium. The intensity of the line traces the strength of the sun's magnetic field, and by recording infrared signals during the occultation the investigators hoped to map the emitting magnesium. But before and after totality the telescope's large mirror would also act as a solar collector, cooking the instruments at its focus. So the NASA scientists covered the dish with the white plastic usually used for potato-chip bags, which lets infrared through but blocks sunlight. NASA-Goddard astronomer Donald Jennings called it a great moment for the packaging industry.

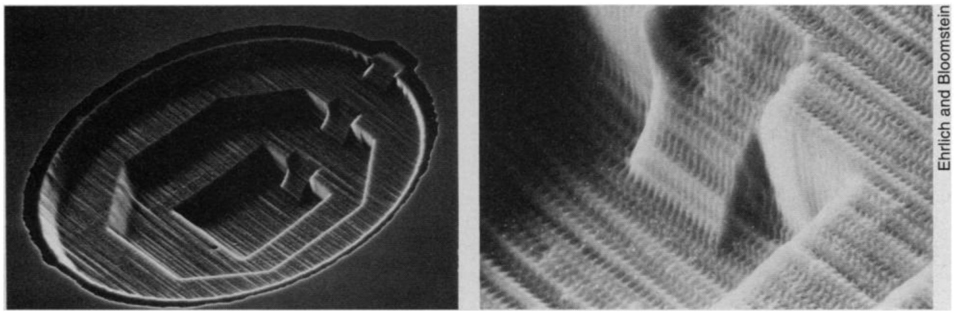
Meanwhile, the optical astronomers planned to use the mountain's big mirrors, the UH 2.2-meter and the Canada-France-Hawaii 3.6-meter telescopes, to make movies of the corona. By snapping many frames per second on video and movie film, they hoped to capture in freeze-frame the mysterious mechanism that heats the corona to a million degrees K just a few hundred kilometers above the sun's visible edge, the photosphere, where the temperature rises no higher than 5800 K.

All these projects hung in the balance as the clouds surged around the mountaintop and the moon's shadow raced eastward across the Pacific toward Hawaii. Luckily, the clouds below stayed put through the four minutes and 12 seconds of totality. The sight was sensational; Hall called the corona "ten on a scale of ten" for sheer naked-eye spectacle. A large prominence—a glowing-red streamer of photosphere erupting above the solar limb—wreathed the occluded sun. To the electronic eyes of the telescopes, the eclipse, fuzzed somewhat by the volcanic haze and the cirrus, was less spectacular but satisfactory, astronomers said.

In the case of the infrared search for the dust ring, Hall was able to report within days that "the data were really superb." They don't tell an entirely welcome story, though. "Unfortunately, they don't seem to show any dust rings at all."

Most of the other results will be weeks or months in coming. But outside the telescope domes, eclipse-watchers wasted no time in giving a verdict. As the moon's shadow fled eastward toward Baja California, and the sun's brilliance returned, the crowds burst into applause. ■ CHARLES PETIT

Charles Petit is a science writer at the San Francisco Chronicle.



Ehrlich and Bloomstein

Fine handiwork. *A microscopic pit carved in silicon by Lincoln Laboratory's CAD/CAM system. The contours of the structure were chiseled one "volumetric pixel" at a time* (right).

The Small Wonders of Microengineering

As technoshrinkers get better at miniaturizing sensors and mechanisms, they are pondering where their field is headed

A CHORTLE ECHOED THROUGH A SPACIOUS San Francisco conference hall on 26 June when University of California, Berkeley, graduate student Chang-Jin Kim flashed a slide showing a pair of massive tweezers grasping a huge zucchini-shaped creature. The funny thing about the slide was that it was taken through a scanning electron microscope. Those "giant" tweezer arms spanning the 20-foot screen were actually bits of silicon about 400 microns long, smaller than your average flea. The "huge" creature clasped in the forceps was a one-celled protozoan.

What's the point of embracing a euglena? Kim noted late last month at the Transducers '91 conference (a gathering of microsensor and micromechanical device makers) that tweezers small enough to grasp a protozoan probably could serve well in a minuscule robotic hand. The mini-hand might, say, precisely position a cell under a microscope or simplify the fine handiwork of microsurgical operations. But for Kim and the 800 other technophiles who convened in San Francisco for the world's largest research show-and-tell devoted to the smallest human-made gizmos, just showing what their creations are capable of is enough; most of the researchers are a long way from tailoring their minuscule sensors and manipulators to any very specific use. So far, they have mostly been honing their microfabrication skills and scratching their heads about what place their wares ultimately might have in the world.

Not that the micromachinists have any doubts about the potential importance of their devices. By monitoring pressure, motion, light, magnetic fields, flow rates, and chemistry, tiny sensors could endow larger structures and machines, from vacuum cleaners to space craft, with artificial sensory physiology. Integrating these sensors with microelectronic circuitry on the same piece of silicon real estate could result in devices that are smart as well as sensitive, able to interpret as well as detect environmental cues. And if the system included miniature mechanisms, it could also react to its environment as well.

"The potential impact will exceed anything that has come along since microprocessors," electrical engineer Kensall D. Wise of the University of Michigan said at the meeting during a plenary talk. It might even exceed the impact of microprocessors, added Wise, who heads his university's Center for Integrated Sensors and Circuits. Richard S. Muller, a director of the Berkeley Sensors and Actuators Center (BSAC) and general chairman of the conference, cautions that raising unrealistic expectations in an embryonic endeavor can backfire. But the Japanese government needs no convincing. This year, it approved $160 million for a multiyear national effort in micromachine technology.

To date, only a few micromachined products have actually made it into large-scale commercial settings. The most prominent example is found under the hood of new cars. In the intake manifold is mounted a tiny pressure sensor incorporating a silicon membrane only several microns thick that flexes or relaxes with pressure changes. The membrane transduces that motion into electrical signals that feed into engine-control