month to cover expenses and to start a mail-order, discount bookstore as a source of income. They pledged themselves to the project for a minimum of 2 years past their Ph.D.'s (a naive estimate of the time required, it turned out).

In March 1972, MIRA was incorporated as a nonprofit institution in California. The group dipped into their savings to make a down payment on 80 acres of land for auxiliary buildings near their intended observatory site in the Los Padres National Forest. The advance guard of the group—Weaver and Albert Merville and their families—moved to Monterey and found part-time jobs. By this time word of their intentions had begun to circulate through the astronomical community, and they were invited to give a presentation at the 1972 meeting of the American Astronomical Society. Through the auspices of Martin Schwarzschild of Princeton, they were able to borrow for an indefinite period an unusually high-quality 36-inch mirror, intended as a backup for a National Aeronautics and Space Administration (NASA) project but never used. The loan of the mirror propelled the group to upgrade their ambitions still further and aim for an observatory capable of making full use of the reflector's potential. It also set the style for many of their subsequent acquisitions, from electronic detectors to computers to the design of the telescope itself, all of which MIRA has obtained as gifts or for nominal sums. By the end of 1974, when all nine members had arrived in California, MIRA had landed a $76,000 grant to cover construction of the telescope from a private foundation, the Research Corporation, and had accumulated through donations new and used equipment worth more than $100,000. Monterey had become the scene of an experiment in finding new sources of support for basic science.

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The beauty of the Monterey area is justly famed. The spectacular coastline has long been a magnet for visitors and wealthy residents. Hunters and backpackers have known the nearby Los Padres National Forest and Ventana wilderness, now largely blackened by last month's huge fire, as one of the most rugged and untouched in California. There is another scarce natural resource, less widely appreciated, to be found here in more pristine form than anywhere else in North America, and that is the sky. More precisely, it is what astronomers call the "seeing," a measure of the clarity and lack of turbulent distortion of the atmosphere. The prevailing winds blow in off the Pacific, where there are no mountains to cause turbulence in the upper air and where the cold California Current flows along the coast, contributing to an arid, even climate. With no major cities or heavy industry, the dry, stable air above the inversion layer remains largely undisturbed by plumes of smoke and smog. At an altitude of 5000 feet on the summits of the coastal range, nighttime clouds are rare and the seeing is so good that distortions of less than 1 second of arc are frequently obtained. On the basis of detailed measurements, astronomers from the University of California's Lick Observatory describe the

Carcinogens in the Workplace: Where to Start Cleaning Up

The most hazardous industry in the United States, in terms of exposure of workers to carcinogens, may well be the manufacture of scientific and industrial instruments, according to a study prepared by John Hickey, James Kearney, and their associates at Research Triangle Institute for the National Institute for Occupational Safety and Health (NIOSH). The fabricated metal products industry was rated second most hazardous, and the manufacture of electrical equipment and supplies third. The chemical industry, which many people would consider an odds-on choice to head the list, was ranked a lowly 12th.

The study* was designed as a first step for controlling exposure of workers to carcinogens. But because of NIOSH's limited resources, it was first necessary to identify those industries where the potential hazard is the greatest, and therefore where the maximum effort should first be exerted.

The rankings in the study are based on two separate sets of data: the total amount of exposure to carcinogens, and the relative potencies of the carcinogens. The relative potencies of the carcinogens were estimated as accurately as possible from a comprehensive search of the available literature. The ranking for carcinogenic potential took into account the time required for tumors to appear after exposure to the carcinogen, the minimum amount of carcinogen required, and the method of administration. Some of the available data about individual carcinogens are contradictory and some are incomplete; most of the information, furthermore, is based on studies with animals. Each of these areas represents a potential pitfall of the study, particularly the need to extrapolate animal data to human exposures. But the data used, the report emphasizes, are the best now available.

The investigators ranked some 86 industrial chemicals according to their carcinogenic potential. The ten most potent chemicals, the report concludes, are *N*-nitrosodiethylamine, thallium, chromium, asbestos, nickel, coal tar pitch volatiles, methyl methane sulfonate, acetamide, yellow OB, and ethylenimine.

Information about the exposure of workers to carcinogens was obtained primarily from NIOSH's National Occupational Hazards Survey (NOHS). For this $6-million, 3-year study—which has not yet been completely published—a group of engineers went to manufacturing facili-

Table 1. The most hazardous industries and some of the carcinogens used in them.

Industrial and scientific instruments (solder, asbestos, thallium)
Fabricated metal products (nickel, lead, solvents, chromic acid, asbestos)
Electrical equipment and supplies (lead, mercury, solvents, chlorohydrocarbons, solders)
Machinery except electrical (cutting oils, quench oils, lube oils)
Transportation equipment (constituents of polymers or plastics, including formaldehyde, phenol, isocyanates, amines)
Petroleum and products (benzene, naphthalene, polycyclic aromatics)
Leather products (chrome salts, other organics used in tanning)
Pipeline transportation (petroleum derivatives, metals used in welding)

The Development of an Engineering Control Research and Development Plan for Carcinogenic Materials (Government Printing Office, Washington, D.C., in press).

mountains in northern Monterey County as the best remaining astronomical site in the United States, excepting possibly Hawaii.

It was these considerations that weighed heavily with the MIRA group in choosing to settle in Monterey, although they were not unaware of the region's more conventional attractions. Equally important, however, was the proximity to the library and professional stimulation of a major observatory (Lick) and to the technical resources of the burgeoning electronics industry concentrated in what is aptly called Silicon Valley, on the San Francisco Peninsula just an hour's drive to the north. Having settled on an area, the group spent days poring over topographic maps in the Cleveland public library. They came up with three potential sites, but only one seemed to meet all their needs. Chews Ridge, in the northern portion of the Los Padres forest, was potentially accessible, near an existing road. It was not in a wilderness area or near any known Indian ruins. The reach of the national forest, especially to the south and west of the site, guarded against any further development and hence seemed to guarantee a dark sky. And there was what Chester describes as the "comforting presence" of a Forest Service fire tower a half-mile away on the other end of the ridge, a sentinel to ward off unknown dangers. What with hikers of all descriptions prowling the woods and trigger-happy hunters taking advantage of the year-round season on wild pig in the Los Padres, this last would prove to be more than a fanciful concern.

The top of Chews Ridge, at least prior to the fire, was surrounded by dense chaparral, a nearly impenetrable brush that tore at the clothes of a MIRA scouting party sent out from Cleveland in the spring of 1972 to confirm the site choice. They found the site ideal and filed an application with the Forest Service for a use permit. Some 22 months later, and after a careful but persistent campaign by the astronomers to nudge their petition through the bureaucracy, the Forest Service agreed. MIRA was in fact fortunate, because a similar application by Lick for a new observatory has languished for years. The Lick site is in a neighboring portion of the Los Padres forest that has been proposed for inclusion in the Ventana wilderness, and the Sierra Club is opposing the construction of any roads or other facilities that might lessen the chances of obtaining the wilderness designation. A graded dirt road to the MIRA site proved not to be a problem, and in fact appeared gratis—an Army engineering battalion stationed nearby happened to be looking for a training project.

Choosing a site for an observatory that is to operate for many years is a chancy business at best. Observing conditions change, and even the most promising site is generally regarded by astronomers as uncertain until proved by years of use. But omens are not to be disregarded in this business, and Chews Ridge provided one that the MIRA astronomers found very reassuring. The first occasion when they actually saw the night sky from their observatory site was on 30 August

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ties throughout the country to determine, among other things, how many workers in each type of plant are exposed to chemical agents, what those agents are, how the exposure occurs, and the length of the exposure. Data from this survey were then combined with data on carcinogenic potential to produce two new lists, one ranking carcinogens by a combination of exposure and potency and the second ranking industries by the amount of exposure to carcinogens and suspected carcinogens.

In the first case, the investigators combined potency, amount of exposure, and annual production to conclude that the ten most hazardous industrial chemicals are, in order, asbestos, formaldehyde, benzene, lead, kerosene, nickel, chromium, coal tar pitch volatiles, carbon tetrachloride, and sulfuric acid. Similarly, the potency of the materials and the amount of exposure to them was used to rank American industries (Table 1).

The new results differ from the conclusions of previous studies, Hickey tells *Science*, because those previous studies generally considered only the volume of the carcinogens and not the amount of exposure. Previous studies have ranked the chemical industry very high, for example, because it manufactures hazardous materials in lots of tons or more. But the large quantities of materials may actually be manufactured by only a very small number of people, so that consideration only of the volume of carcinogens grossly overestimates the potential hazard.

In contrast, Hickey says, the manufacture of scientific and industrial instruments requires relatively small amounts of carcinogenic materials. But these materials are used in the hand fabrication of devices, so the total exposure—and thus the total risk—is very high. The fabrication of metal and electrical products both rank high for the same reasons. Hickey emphasizes that the total amount of hazard is very similar in the top ten industries, and the actual rankings could be altered by undiscerned factors such as the discovery of previously unrecognized carcinogens. But there seems little doubt, he adds, that these are the industries where research and cleanup efforts should first be directed.

The single most severe problem in many industries, the report says, is the presence of carcinogenic dusts in the workplace. These occur in the dry mixing of paints and pesticides, for example, and in many other processes where solids must be mixed. A major effort is thus needed, according to the report, to develop new ways to enclose the entire system of dry materials production, mixing, and transfer.

Another severe problem that seemingly could be easily solved is better venting of areas where carcinogens are used. In many cases, the report says, the venting system now in place does little good and, in some instances, it even blows carcinogens back in the faces of the workers. More attention apparently also needs to be given to the use of masks and protective gear now used only infrequently.

It must be emphasized that the Research Triangle Institute report is basically a library study. The investigators neither visited factories nor tested potential carcinogens. They also did not use any data about occupational cancer in the studied industries; many of the most potent carcinogens, in fact, have not been in use for the 25 to 30 years that would be required for cancers induced by them to begin showing up. It is also possible that better controls have been established in some industries since the NOHS study was conducted. Nonetheless, the results will give NIOSH a good idea where to begin emphasizing control procedures. The study should also give pause to many executives who now think they run clean industries.

—THOMAS H. MAUGH II