reaucracies and would not destroy those institutions which have proved useful in the past. This study should be considered as one of the many pilot programs that should be initiated in order to determine the type of program that would best solve the problem of health care in rural Mexico. Other programs already being considered at the National Autonomous University of Mexico include the A36 plan of the Faculty of Medicine, now in operation; the work of C. Biro carried out in Netzahualcoyotl City (both focused on providing medical care to the urban poor); and the Open University program.

Unless an efficient program designed to meet the needs of rural communities is quickly put into operation, Mexico will, in the near future, be facing the same problems now confronting Southeast Asia.

References and Notes

1. In most cases the information sources vary among themselves, therefore, the average data expressed should be considered approximate.
2. Dirección General de Estadística, *IX Censo General de Población, México* (Secretaría de Industria y Comercio, México, 1970).
3. Population aged 5 years and up speaking an Indian dialect instead of, or as well as, Spanish.
4. Dirección General de Estadística, *Anuario Estadístico de los Estados Unidos Mexicanos, 1968–1969* (Secretaría de Industria y Comercio, México, 1971).
5. L. Cañedo and L. Estrada, *La Ciencia en Mexico* (Siglo XXI, Mexico, in press).
6. P. D. Martínez, *Gac. Med. Méx.* **102**, 4 (1971).
7. Boletín Epidemiológico Anual de 1971, *Salud Pública Méx.* **14**, 879 (1972); P. D. Martínez, *ibid.* **12**, 669 (1970); C. Garrocho, M. L. Nuñez, F. A. Rodríguez, *ibid.* **11**, 217 (1969).
7. A. Cañedo, L. Cañedo, J. Negrete, G. Yankelevich, in *La Reforma Educativa en la Enseñanza Superior* (Academia de la Investigación Científica, México, 1972), p. 9.
8. L. Cañedo, L. Chavez, G. Deffis, in preparation.
9. F. F. Biagi, M. R. López, C. González, M. Gutierrez, *Gac. Med. Méx.* **96**, 183 (1966).
10. C. N. Myers, *Demografía y Economica* **5**, 193 (1971); *ibid.* **6**, 99 (1972).
11. Secretaría de Salubridad y Asistencia, *Memoria de la Primera Convención Nacional de Salud* (Secretaría de Salubridad y Asistencia, México, 1973).
12. L. A. Vargas, *Gac. Med. Méx.*, in press.
13. A. I. Lagarriga, *Rev. Sanid. Mil. Méx.* **26**, 2 (1972).
14. J. Brown, *América Indígena* **23**, 93 (1963).
15. Sociedad Mexicana de Radio, S.A., México (October 1972).
16. Departmento de Medicina Preventiva, *Algunos Datos Estadísticos de la República Mexicana* (Instituto Mexicano del Seguro Social, México, 1969).
17. Dirección General de Servicios Coordinados de Salud Pública en Estados y Territorios, *Memoria, 1965–1970* (Secretaría de Salubridad y Asistencia, México, 1970).
18. Second report of the Experts Committee on Public Health Administration, *Methodology of Planning and Integrated Health Program for Rural Areas* (Tech. Rep. Ser. No. 83, World Health Organization, Geneva, Switzerland, 1954).
19. M. King, *Medical Care in Developing Countries: Nairobi* (Oxford Univ. Press, London, 1966).
20. Secretaría de Salubridad y Asistencia, *Boletín Informativo Interno* **1** (No. 1), 25 (México, 1972).
21. P. A. Alsberg, *Natural Resource Information System* (Center for Advanced Computation, University of Illinois at Urbana–Champaign, 1972); G. Duenas and L. Cañedo, in preparation.
22. G. N. Yankelevich, *Gac. Med. Méx.*, in press.
23. Grupo de Asesoría Técnica, *Sobre el Trabajo de Promoción en las Comunidades Rurales* (Instituto de Ingeniería, Universidad Nacional Autónoma de México, 1973); D. H. Reader, "Models in social change with special reference to southern Africa," *Afr. Stud.* **33**, (1964); J. C. Mitchell, *Social Networks in Urban Studies* (Manchester Univ. Press, London, 1969).
24. J. Navarro, *N. Engl. J. Med.* **287**, 954 (1972).
25. V. W. Sidel, *ibid.* **286**, 1292 (1972); M. R. Martínez, *Salud Pública Méx.* **11**, 138 (1969).
26. J. Limón-Lason, H. del Castillo, M. Romero, H. Sierra, L. Cañedo, *Memoria IX Reunión Anual* (Sociedad Mexicana de Bioquímica, México, 1972); J. L. Pérez-Silva, J. F. Sierra, *Naturaleza* **3**, 274 (Universidad Nacional Autónoma de México, 1972).
27. J. M. Ifeyinwa, thesis, Harvard Graduate School of Education (1972).

28. I thank L. Chávez, R. Calderon, J. Chávez, and S. Chávez for their help in the recollection of information; M. Szekely, for allowing his data on community promotion to be used prior to publication; and A. Cañedo, D. Slotnick, R. Iturriaga, and T. Garza for their valuable suggestions and continuous encouragement.

NEWS AND COMMENT

Safeguard: Disputed Weapon Nears Readiness on Plains of North Dakota

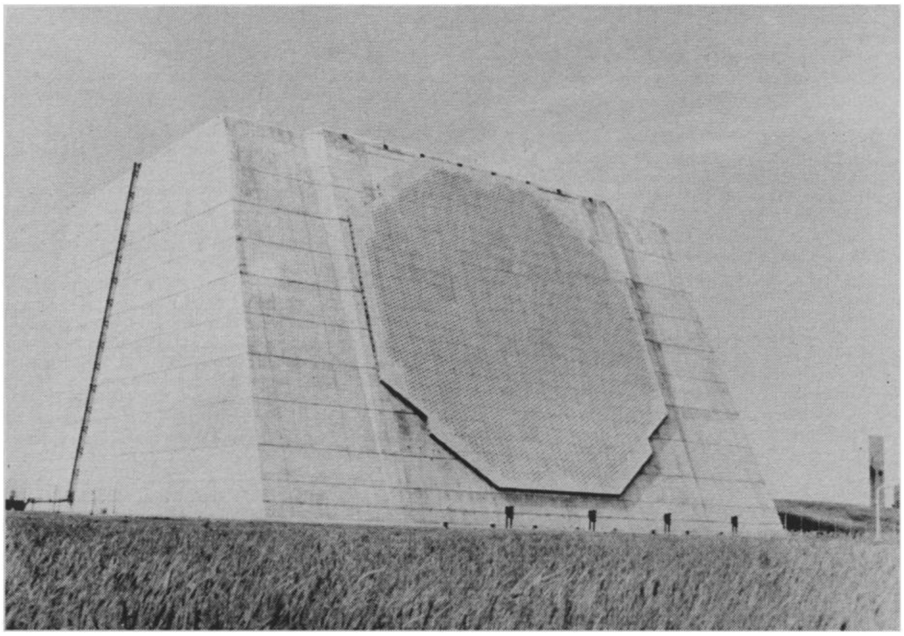
Nekoma, North Dakota. The distinctive black earth of North Dakota is the sediment left by a vanished lake that covered the region in the wane of the last ice age. From the fertile, dark deposits grows much of the country's durum wheat, used to make spaghetti and other pastas. The ancient lake bed is also the site of one of the wonders of the modern world, a flat-topped pyramid only 75 feet tall but housing the most complex electronic system in existence. Poking up amid the wheat fields of Cavalier County, midway between Devil's Lake and Walhalla, stands the Missile Site Radar, heart of the Safeguard antiballistic missile system.

Across Route 1 from the Missile Site Radar is the one street hamlet of Nekoma. Anyone staying at the Nekoma Wigwam on the day nuclear war broke out would be witness to a remarkable aerial battle, although he would see only a small part of it. He would not see the Russian missiles en route to attack the 15 pockets of Minuteman missiles defended by Safeguard. But 25 miles to the northeast, the gigantic eye of the Perimeter Acquisition Radar, its beam ranging far across Canada, will catch the salvo as it comes over the North Pole.

The radar plots the trajectory of each missile and passes the information to Central Logic and Control, the Safeguard computer housed on the second floor of the Missile Site Radar pyramid. With about 5 to 10 minutes to calculate and act, the computer plans out the battle ahead, arranging that its interceptors engage the incoming salvo at points where their warheads will not destroy each other or black out the radars' vision.

As the Russian missiles close in, the computer launches Spartan missiles from the silos near the base of the pyramid. The Spartan is a long range interceptor which flies out to meet its target above the atmosphere and destroys it in a burst of x-rays. But the Spartan's target may be concealed among decoys, rocket fragments, and a cloud of other debris, all moving in at about 4 miles a second. If the Spartan misses, or if no interception is attempted at this stage, the computer waits for the cloud to hit the atmosphere so that with the Missile Site Radar it can sort out the real warheads. With seconds remaining, the computer launches its close-in interceptors. The cone-shaped Sprint missiles are flung out of their cells at the radar's base, ignite, and race toward their target faster than bullets. Under the computer's guidance they reach it in seconds and, at the computer's command, detonate their warheads in a burst of neutrons.

Safeguard might or might not survive such a battle, depending largely on how many missiles the Russians could spare to throw at it. But the antiballistic missile system already has won an equally ferocious battle for survival, a 20-year odyssey which included scenes of high melodrama such as then Vice President Agnew breaking a tie Senate vote in favor of continuing work on the system, and former AEC chairman James R. Schlesinger flying his

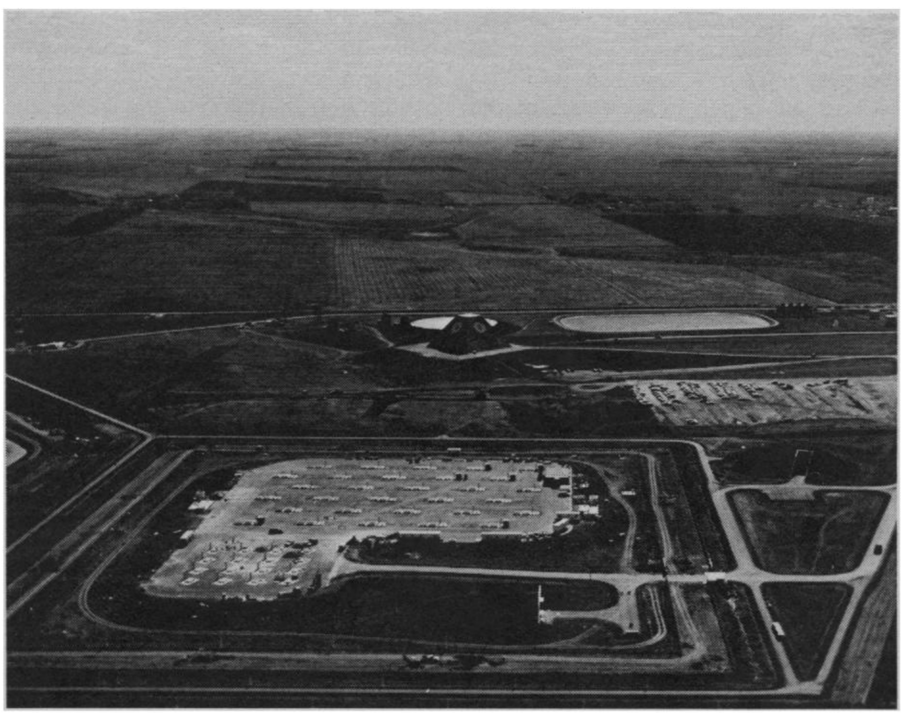


Perimeter Acquisition Radar, 25 miles northeast of the Missile Site Radar, faces north to detect missiles launched from the U.S.S.R. The radar's field of vision is about 120 degrees. Missiles arriving from other directions, such as submarine launched missiles, would be detected by the Missile Site Radar.

family out to Amchitka Island, site of an underground test of the Spartan's warhead. The system has progressed by cancellation, the number of sites having been cut from the 17 originally envisaged to 12, to two and now one. Its political guardians have repeatedly changed its name, picking aliases first from Greek mythology (Nike-Zeus, Nike-X), then from deodorant soap brands (Sentinel, Safeguard). It gathered a large, distinguished, and devoted body of critics who argued with devastating effectiveness that it would probably never work, and even if it did, the Russians could overwhelm the defenses simply by sending in more missiles. Safeguard, as the system came to be known in its final metamorphosis, not only survived but performed before even being completed what may be its most useful achievement—that of serving as a trading counter in the strategic arms limitation talks. The Russians evidently had more confidence in Safeguard's reliability than did its enemies at home, for according to the most authoritative account of the SALT negotiations (John Newhouse's *Cold Dawn*), it was in return for confining Safeguard to two, and later a single site, that the Soviet Union agreed to limit its fast growing arsenal of offensive missiles.

The Safeguard site at Nekoma, 75 miles from Grand Forks and a few miles below the Canadian border, is thus the lone realization of a grand design. When Secretary of State Henry Kissinger visited it for the first time this July, the system was essentially complete except for installation of its 100 nuclear missiles—30 Spartans and 70 Sprints—which are allowed by treaty. When the site is completed this October, the total cost of creating Safeguard will amount to $5.5 billion—about a quarter the price of putting men on the moon. The structures alone of the two radars, the missile silos, and other buildings cost $327 million, and the equipment comes at similarly steep prices. (The system's computer costs $20 million; development and production of the Sprint missile will amount to nearly $800 million.) The intellectual effort invested in Safeguard has been equally substantial. During 1970 to 1973, the years of peak activity, about 10,000 professionals were involved in the design of the system, including some 2,000 computer programmers whose labors are said to represent the most complex software package ever devised.

From the outside the most impressive part of the Safeguard system is the great eye of the Perimeter Acquisition Radar, its 6,200 antenna elements resembling the compound eye of an insect. Occupying one face of a 110-foot-high box, more spectacular in its way than the farsighted devices of myth such as Jamshyd's bowl or the palantirs of Middle Earth, the eye looks northward across Canada, its 1,800-mile beam being steered electronically to



The 75-foot-high pyramid in the center is the Missile Site Radar, the heart of the Safeguard antiballistic missile system. Beneath the pyramid is a 230-foot-square building containing the Central Logic and Control computer. Next to the building, also underground, is the power plant housing six generators. In the foreground are two adjoining missile fields, the nearer having silos for 16 Sprints and the further holding 30 Spartans. Silos for 54 additional Sprints are distributed in four fields located within a 15-mile radius.

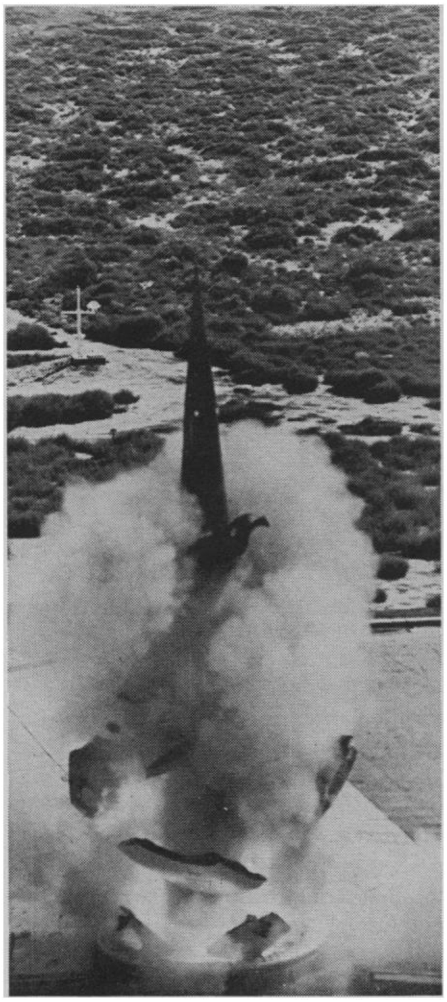
afford a 120 degree angle of vision. Behind the eye are five stories of equipment including the radar's computer, a smaller version of the Central Logic and Control, and the electronics supplying power to the antenna elements.

The Missile Site Radar has a shorter range, 300 miles or more, but can see in all directions, the power output being switchable at a moment's notice to any of the four radar faces. Within the pyramid, half of which is underground, are four floors of heavy electrical equipment and thousands of miles of cabling, waveguide tubes, cooling pipes, and fire detection wires. The platforms carrying the equipment are either mounted on springs or suspended by shock absorbers, enabling them to withstand the building moving up to 9 inches during an attack.

At the heart of the pyramid are the rooms housing the computer and control consoles. The system was being operated by a group of young computer specialists during this reporter's visit. They were monitoring a nuclear attack from a submarine which had launched five missiles over the United States. The computer determined that two of the missiles were aimed at other targets; against the other three it launched three Sprint missiles. There the exercise stopped, since its purpose was only to test a new piece of software for handling the problem. A man at a twin console reading *Bear Island* didn't even bother to watch the progress of the engagement.

The concept of an antiballistic missile system seems itself to belong to the world of fiction, for the proposition is not just to conduct an isolated duel between one missile and another—the technical feasibility of "hitting a bullet with a bullet" has been known for years—but to engage an undefined number of incoming warheads, sent in an attack pattern of the aggressor's choosing, and perhaps protected by decoys and radar countermeasures. The system's task was the more demanding in that it is designed primarily to defend cities, not hard targets such as Minutemen missile silos.

There was no one day on which the designers of Safeguard declared its mission was possible; rather, the development took place over several years, with the missiles and radars being designed long before it was decided precisely how they would be used together as a system. Most of the hardware was based on state of the art technology at the time it was designed—development of the Sprint began in 1963, that of the Central Logic and Control computer in 1964—but the difficulties encountered have been fairly straightforward engineering challenges, not fundamental problems. According to John J. Shea, the U.S. Army's chief scientist for the Safeguard program, the major intellectual challenge of Safeguard has been to determine the detailed rules of operation that would make the best use of the hardware subsystems to do the system job.



Launch of Sprint missile. The cone-shaped rocket, 27 feet in length, is launched by ignition of a gas generator on the floor of its cell. The cell cover is blown apart by an explosive charge instants before the missile emerges.

Much of the Safeguard hardware uses novel principles. The two phased array radars are among the few of their kind in existence. Conventional dish radars emerged in the early 1960's as a limiting factor because, with their slow response time, essentially one radar was needed to track each incoming missile. Both the Missile Site Radar, designed by Raytheon, and the Perimeter Acquisition Radar, designed by General Electric, possess a fixed grid of antenna elements with no moving parts—a feature which, as the engineers say, greatly enhances their "traffic handling" capability. Also useful in battle conditions is that the radar can be checked and maintained in real time, and even lose hundreds of its antenna elements before the beam becomes degraded.

The computer that steers the beam (essentially by setting up a delay in some antenna elements relative to others, thus maximizing the strength of signal from a particular direction) can follow several targets simultaneously by ordering a sequence of beams in the appropriate directions and can create a wide, low resolution beam when searching for targets, or a sharp pencil-like beam when tracking one. The radar has its own digital logic unit which takes commands in the form of words from the Central Logic and Control computer. Within the unit is a beam steering computer which maintains detailed control over the antenna elements. Information from the receiver goes to an interface computer before being passed on to Central Logic and Control.

Right from the beginning the radar task has been divided between a long range detector and radar for close-in operations. The size and range of the Perimeter Acquisition Radar is determined essentially by the fact that, the earth being round, targets can be detected only when they have come over the horizon.

Spartan, the long range interceptor developed by McDonnell Douglas, is designed to match the characteristics of the Perimeter Acquisition Radar, just as Sprint is designed as a partner for the Missile Site Radar. The detailed division of labor between the two radars and their interceptors was worked out after the respective hardware had been developed.

Sprint is a spectacular example of missile technology even though it was designed and developed during the 1960's. According to Martin Marietta, producers of the missile, a Sprint fired simultaneously with a machine gun will overtake the bullet in three seconds. The missile's acceleration exceeds 100*g*, which puts certain demands on the physical structure of the missile, as well as causing its outer skin to heat with air friction to about 3000°F.

The launch of a Sprint missile, described by observers as a wonder to behold, begins with a shaped charge exploding the fiber glass cell cover. A gas generator in the base of the cell shoots the cone-shaped rocket out through the flying shards of the cell cover and, a few feet clear of the ground, the rocket motor ignites. Almost simultaneously, the missile pitches over on its set course, aimed by a split second injection of Freon into its rocket exhaust, and becomes a distant streak in the sky almost before onlookers realize it has left its cell.

Sprint is controlled at each instant of its flight by Central Logic and Control, a computer designed by Bell Laboratories, the research arm of the Bell telephone system. The unique feature of the machine is that to handle its rather elaborate task in real time it contains not one but a tandem of 10 central processors, with a capacity of performing about 10 million operations a second.

Besides its 10 central processors, Central Logic and Control consists of 12 program stores, each with a capacity of 16,000 words, 15 variable stores constituting a "scratch-pad memory" for radar data that need only be held a short time, two input/output controls, and two timing and status units. The system can be divided into formally equal "green" and "amber" partitions, which check each other in real time for malfunction. The green partition components are the ones that fight the battle, the amber are for testing and maintenance. If the amber side detects any malfunction in the green, it instantly switches in one of its own corresponding components in place of the faulty green component. As with the radars, redundancy is cultivated to a high degree to ensure the equipment stays on line when needed.

The essence of the Safeguard system is the system design and its embodiment in the software, written by Bell Laboratories with IBM as a subcontractor. According to Shea, Bell has performed the software job in an "exemplary fashion," notably by designing in a significant performance margin.

Bell Laboratories, with its production arm, Western Electric, is the prime contractor for the whole Safeguard system, a job which it undertook at the request of the Army. Unlike other defense contractors, Bell's main business is not dependent on Defense Department contracts, which may make for greater objectivity in rendering advice. "Bell Labs has dealt very candidly with the government and has never overstated what they felt could be accomplished," says Shea. By all accounts the Bell design team has played its part in putting Safeguard together with remarkable efficiency—all performance specifications have been met or exceeded, and the North Dakota site is being completed on schedule. The cost, however, has been greatly exceeded—running some $1.3 billion above the 1969 estimate for Safeguard—but for reasons largely beyond Bell's control, such as inflation and schedule changes. The story of Bell's achievements in designing Safeguard cannot, however, be told, since the company declines to discuss this ultimate service to its subscribers.

When completed the Safeguard site in North Dakota will be operated for a year and a half to gain operational experience and may then be reduced to working a 40-hour week. The critics may be right in doubting its strategic effectiveness—"Technically it's a fine thing, but it's like a train that doesn't go anywhere," says one opponent—yet anyone visiting the pyramid in the North Dakota wheatfields crammed with its powerful and elegant machinery cannot help absorbing a sense that it will work, and that the Soviet Union was well advised to bargain for its limitation. It is, if nothing else, a notable monument to Western technology and preoccupations, one which, like the funerary pyramids of ancient Egypt, will move future generations to marvel equally at the civilization's extraordinary technical skills and at its unswerving devotion to the mortuary arts.

—Nicholas Wade

Plutonium (II): Watching and Waiting for Adverse Effects

If any of you have a pet beagle, guinea pig, or hamster that is involved in a plutonium spill, we can make a fairly accurate prognosis and outline an adequate course of treatment. [*But*] *at best, the practice of extrapolating animal data to man is of questionable validity, and the extent to which this may be done with confidence should be established by human data as soon as possible.*—John A. Norcross, former director of the United States Transuranium Registry, 1972

Almost from the time of its discovery in 1940, and certainly by the late 1940's, radiological health researchers were well aware that plutonium's great potential value was fully matched by its enormous biological hazard. Studies with laboratory animals 25 years ago, for example, quickly established that internal doses of plutonium measured in micrograms were an even more potent carcinogen than radium.

A great deal more has been learned since then about the behavior of plutonium in animals, as the above quotation suggests. But even though plutonium has become an increasingly important and abundant industrial substance, the effects of small internal doses on workers exposed to this strange metal remain uncomfortably uncertain. "The record so far is pretty good," says Walter S. Snyder, an authority on the subject and for many years a leading health physicist at Oak Ridge National Laboratory. But, Snyder adds, "we are still on edge about this."

Faced with this uncertainty—and with the rising prospect that plutonium would begin to spawn a commercial nuclear fuel industry in the mid- or late 1970's—the Atomic Energy Commission (AEC) began in the summer of 1968 to set up a medical data bank to monitor the health of thousands of men occupationally exposed to plutonium. It was hoped that the data bank, which the AEC now calls the United States Transuranium Registry, would serve as a medical trip wire—an early warning system—that would either confirm by its silence that exposure limits adopted in the late 1940's were adequate for workers, or sound an alarm soon enough to head off the kind of occupational health disaster that befell radium workers in the early part of the century, some of whom are still developing malignancies traceable to their jobs.