

years. Understanding that the dust wouldn't just pile up to be observed amid the clutter of geological events, creationists have looked for evidence of the dust in concentrations of nickel in deep-sea sediments, whose major source of nickel is the dust, they say. From the concentrations of nickel reported they calculate an age of Earth of only around 9000 years, even including other sources of nickel.

However, Edward Anders (professor of chemistry at the Enrico Fermi Institute of the University of Chicago) told us that Gish must be using an old, discredited value for the meteoritic influx that is several orders of magnitude too high. A reliable value, determined in 1968 by Anders and John Barker from the iridium and osmium contents of deep sea sediments, is $(9 \pm 4) \times 10^{-9}$ g/cm² year, which gives a layer of 5 cm, not 50–150 feet, over 4.5 billion years. Very similar values have since been obtained by analyses of Antarctic ice and lunar soils and interpretations of photographic meteors and interplanetary dust measured by satellites.

Anders notes that Gish must be making another error by a factor of 10^5 , probably by neglecting the thickness of the sediment column, in deriving an Earth age of only 9000 years. Gish's assertion that most of the nickel in deep-sea sediments (about 5 g/cm²) is meteoritic, implies a total deposit of about 500 g/cm². The accretion of this amount in only 9000 years would entail a meteoritic influx rate of 6×10^{-2} g/cm² year, about 10^7 higher than the current values.

Is it science? A great deal of the evidence creationists gave us for a young and created Universe in fact only disputed the theories most scientists find convincing in these matters. Gish says there are only two models on origins; so any evidence against evolution is evidence for creation. Ralph Alpher (General Electric Research Center), a contributor to big-bang cosmology, has pointed out that creationists, lacking coherent and consistent theories, instead supply *ad hoc* arguments against their opponents' theories. Brush points out in *The Science Teacher* that creationists fail to see how theories are used by scientists to organize information and stimulate new research.

At the core of many critics' objections to creationist arguments is one that Helfand expressed to us: While theories in science are falsifiable, creationist beliefs are not. When the empirical data don't offer the desired result, God can be understood to be as inventive as any creationist imagination: He has been understood by them to vary the speed of light and the decay rate of radioactive materials and to create anything else needed to bring the *Gene-*

sis account into apparent accord with present-day reality.

Bouw, pressed for positive evidence after he mentioned problems he says disenchanted him with evolution, told

us with more honesty and humility than his critics usually find in creationists' arguments: "If I had to point to one positive aspect, one that convinced me most, it was the Bible." —DG

Physicists contribute to MX debate

President Reagan announced on 2 October his five-point program to "revitalize our strategic deterrent." A pivotal part of this program is the decision to modernize land-based missiles by developing the MX. In this plan the "shell game" concept for deceptive deployment of 200 missiles in 4600 silos advocated by the Carter administration has been cancelled. Instead, Reagan has recommended placing from 18 to 40 MX missiles in existing Titan or Minuteman silos that have been superhardened with concrete and steel to withstand overpressures of up to 5000 psi. Meanwhile, further research would be conducted about other basing options for the balance of the 100 missiles scheduled to be purchased. Funds would also be invested to upgrade command, control and communication systems.

As they have in the past, a number of physicists have assisted the executive and legislative branches in evaluating technical and strategic aspects of the MX. Both the Townes Commission (composed of scientists and technical and military experts selected in the spring of 1981 by the Secretary of Defense to advise him on strategic missile applications) and the Jason group were given access to classified data to use in formulating their advice. The report of the Townes Commission (which included physicists Solomon J. Buchsbaum of Bell Labs, Michael May of Livermore, William Nierenberg of Scripps Oceanographic Institution and Albert Whelan of Hughes Aircraft) remains classified. The Congressional Office of Technology Assessment was asked by Congress in May 1980 to conduct a study of basing modes for the MX. The OTA, which included on its advisory panel Sidney Drell (SLAC), Henry Foley (Columbia) and Jerome Wiesner (MIT), had access to much of the same material, and their report was released in September.

Reactions to plans. Commenting to us on the Reagan announcement, Charles Townes (Berkeley), chairman of the Townes Commission, felt that its report had been important in the formulation of the President's program and said "Reagan's program is pretty much in accord with the Commission recommendations. I am particularly pleased with the decision not to deploy the MX in the shell game scheme in Western deserts and the emphasis on improving

command, control and communications for defense."

Not everyone has been equally pleased. General David Jones, Chairman of the Joint Chiefs of Staff, while expressing his overall support for the Reagan program, testified on 5 October at hearings before the Senate Armed Services Committee that he personally preferred the shell game and that missiles in hardened silos might not be able to survive.

Following Reagan's decision, his plans for the MX were subjected to the vicissitudes of the budget process as DOD appropriations were determined. In the House, the Subcommittee on Defense of the Appropriations Committee, led by Joseph Addabbo (D-NY), voted in October to withdraw funds for the MX until Reagan had made a commitment to one basing mode. In the Senate, an amendment sponsored by William Cohen (R-Maine) and Sam Nunn (D-Ga.) to prevent the Pentagon from spending research dollars on the interim plan to put MX missiles in hardened silos, was passed on 2 December by an overwhelming 90 to 4 vote. The two Houses of Congress subsequently passed appropriation bills that included differing amounts of funds for the MX. After conferring, a compromise appropriation bill with an FY 82 defense budget of \$200 billion (the largest in history, up \$28 billion from FY 81) was passed by both Houses on 15 December. The MX was funded with \$1.9 billion and command, control and communication needs were funded at \$20 million.

These actions are the most recent part of a continuing debate about the MX that has centered around the selection of a basing mode and its ability to address the vulnerability of current silo-based ballistic missiles. Specifically, what will the MX contribute to the strategic defense of the United States? How will the means of deployment chosen increase or decrease the MX's effectiveness and survivability?

Defense strategy. The defense posture of the US has evolved to rely on what is known as the "strategic triad," composed of land-based missiles, submarine-launched missiles and bombers. The MX is slated to upgrade the land-based leg of the triad by replacing Minuteman III missiles with a more modern version with more warheads, thus allowing aging Titan missiles to be



"The Soviets have agreed to close their eyes and count to 100 while we hide our missiles!"

retired. The current urgency assigned to deployment of the MX is founded on a perceived widening of what President Reagan has termed the "window of vulnerability."

According to this type of strategic calculation, our silo-based intercontinental ballistic missiles are becoming increasingly vulnerable due to advances in Soviet missile accuracy and their deployment of more missiles, each of which has a greater number of independently targeted reentry vehicles. This improvement is purported to threaten or make vulnerable the ability of US land-based missiles to withstand or survive a first strike by Soviet missiles.

The perceived increase in vulnerability of US missiles is claimed by many to reduce their value as a deterrent and thus to increase the temptation for the Soviets to make a preemptive strike.

The role that land-based missiles play in our strategic defense was clearly articulated in a letter sent by General Lew Allen, Air Force Chief of Staff, in December 1978 to Representative Melvin Price (D-IL), Chairman of the House Armed Services Committee. In this letter, part of voluminous testimony on the MX presented to the Committee, General Allen lists the distinctive attributes of silo-based ICBMs, including: a survival mode different from the rest of the triad; excellent command, control and communication; unique military capability—in its hard target capability, range, short flight time, and retargeting ability; ability to survive in a nuclear attack; low operating cost and personnel needs; ability to survive that does not rely on being concealed; and SALT verification ability.

How will the MX add to this role?

The MX is a 71-foot long, 192 000-pound, four-stage ICBM. The major advances over its predecessor, the Minuteman III, are its ability to carry twelve nuclear warheads instead of three, and a technically superior inertial measuring unit, which is included as part of its guidance and control system and is designed to give the MX greater accuracy. The MX would be limited by SALT II (although not ratified by the Senate, both the Soviets and the US are operating within its tenets) to a maximum of ten independently targeted reentry vehicles, each carrying one warhead. The missile itself, while offering increased military capabilities, does not cure the perceived vulnerability of Minuteman silos. The basing mode was to address this concern.

The value of the MX missile itself has been subject to debate. Nierenberg, a member of both the Townes Commission and the Jason group, commented to us "the MX missile should not be built; it is not needed. Other missiles and submarine missiles can be updated. The Trident missiles, for example, will have all the characteristics of the MX and be invulnerable. The guidance system of the Minuteman could be upgraded to provide the same accuracy."

The shell game, chosen by President Carter, employed deception as the key to invulnerability. Hidden among 4600 shelters, 200 missiles would elude detection and thus necessitate that the Soviet Union expend 4600 of its own missiles to destroy 200 of ours. The major objections to the shell game cited in the OTA report were that location uncertainty had to be preserved to ensure that the missile will survive, and that several thousand shelters

needed to be built before even perfect deception would make this possible. In addition, the OTA report pointed out the large impact on the environment of the numbers of shelters needed and that the high cost of building shelters could make the shell game sensitive to future Soviet arms increases. The Soviets can add reentry vehicles at a lower cost than we can add sufficient shelters to keep the ratio of shelters to reentry vehicles effective; thus without further arms limitation agreements the Soviets could acquire enough reentry vehicles to enable them to expend enough missiles to hit all the shelters. Townes commented to us, "In explaining his program, Reagan in fact said that they [the Soviets] can build missiles as fast as we can build shelters at about the same cost to both countries."

OTA report. Along with his intentions to cancel the shell game, Reagan has announced his recommendations to conduct further research on three other basing options: deep underground, continuous air-mobile and anti-ballistic missile defense, one of which Congress has asked him to select by 1983 for the balance of the 100 MX missiles purchased. Another option, proposed by Drell and Richard Garwin (IBM Research Center), for basing MX missiles on small submarines, has been given serious consideration by both the Defense Department and the House Armed Services Committee. These four options were among eleven evaluated by OTA.

Reagan's program for communication improvements includes recommendations to add satellite receivers and very low frequency (3-30 kHz) radios to bombers and air-borne communication posts; to put surveillance radars for submarine launched missile detection in Georgia and another southern state; to put new sensors on satellites to detect nuclear detonations; to harden airborne command posts against the effects of nuclear attack; and to build mobile ground terminals to receive signals from early-warning satellites. Also planned is an extremely low frequency radio system (known as ELF, operating at 20-60 Hz) for communicating with submarines. (ELF is an outgrowth of the original Project Sanguine, which later became known as Seafarer. This project caused considerable concern about environmental effects.) Each of the four basing options has some specific and some general command, control and communications requirements that would enhance its function.

The concept of basing missiles in deep mountain tunnels, buried thousands of feet underground, was found by OTA to have one serious flaw. To protect the missile from nuclear attack

at the surface it would have to be stored behind a tunnel filled with earth. Thus an egress tunnel would have to be dug prior to launch, delaying its flight, thus increasing its time to target and adding difficulty to its operation in a wartime situation. OTA said that reliable means of assuring communications for this basing mode have not been developed. Details about the design for this option were not available in time for OTA to estimate costs.

Another concept for deep underground basing is being considered by DOD, according to Townes. He explained further that "silos in sheltered terrain would be, for example, on the south side of a steep mountain slope. These could not be easily attacked by present Soviet missiles which approach from the north."

Basing the MX missile on wide-bodied aircraft kept in continuous patrol has as its most serious obstacle, according to OTA, a prohibitive cost of between \$80 to \$100 billion for 75 large turboprop planes. Much fuel would also be used, and OTA estimated, using current fuel prices, that it would cost \$3 billion annually to fly 75 planes. The second serious problem is that after a few hours of flight following an attack the aircraft would have to land to refuel, thus making them and the airfields vulnerable to attack to preempt their use. The Soviets could now barrage all airports without significantly increasing the number of warheads they have.

The Pentagon research program is considering the so-called "Big Bird" aircraft, which, according to Townes, would be a relatively slow aircraft and very fuel-efficient, allowing the plane to cruise continuously for several days. This would mean, Townes continued, that only a small fraction of planes would be on airfields at any one time, and Big Bird could reduce the fuel cost from OTA estimates by a factor of five or more, he said.

Little is known about the effect on aircraft of nearby nuclear detonation. Electromagnetic-pulse effects, for example, could disrupt electronic equipment. For accuracy comparable to the land-based MX, a satellite to provide global positioning data, now being tested, would have to be developed. Reliable sensors for warning of a Soviet attack and management of the air mobile system after or during an attack require complex communications systems.

The anti-ballistic-missile defense of silo-based MXs seeks to protect the MX by destroying attacking reentry vehicles. The two main means of accomplishing this considered by the OTA were:

- ▶ hiding the ABM along with the MX,
- ▶ an interceptor, about the size of an

offensive missile launched into space from a silo, that would use infrared sensors to detect and small homing warheads to destroy reentry vehicles before they enter the atmosphere.

Hiding the ABM and the MX requires that location uncertainty be preserved for both missiles and that the ABM must be able to function near a nuclear detonation. The technology for the interceptor is in the exploratory stage and in addition the system might be vulnerable to decoys. Both methods require tactical warning of an attack and communications to authorize the nuclear-armed interceptor to be used. According to the OTA, "Without adequate warning... [ABM] would be useless." The widespread deployment of ABMs for defense would necessitate the abrogation by the US of the 1972 Limitation Treaty that was passed as part of SALT I and is still in effect.

Encapsulating the MX missile and having it carried horizontally by small submarines stationed off the continental shelf was found by OTA to be technically possible and very likely to survive. (This small-sub basing mode incorporates the essential components

of proposals made by Garwin and Drell.) OTA pointed out, however, that basing MXs on submarines would require a reorientation of our forces. Because it would be necessary to expand shipyard capabilities, construction of subs would proceed slowly, probably putting small subs on line in 1990. The cost of 51 small subs each armed with four MX missiles, and the bases, navigational aids and related equipment to support them was estimated at \$32 billion for acquisition with an additional \$7 billion for 10 years of operation.

To maintain accuracy, OTA considered the joint use of global positioning data from a satellite and a set of acoustic aids. To maintain contact with the National Command Authority to receive information and instructions about an attack, the submarine would need to receive very low or extremely low frequency, radio signals from a fixed-based transmitter, such as ELF. These signals penetrate to great depths in the ocean and thus permit covert operation of submarines. In December Congress decided to spend R&D money on a scaled-down version of ELF. —JC

Optical Society elects Herriott vice-president

The Optical Society of America has elected Donald R. Herriott as 1982 vice-president. Herriott, who is currently senior scientific adviser at the Perkin-Elmer Corporation, Norwalk, Connecticut, will become 1983 president-elect and 1984 president, succeeding Robert Madden of the National Bureau of Standards, who is the 1982 president, and Kenneth Baird of the National Research Council of Canada, who will be the 1983 president.

Herriott studied physics at Duke University as an undergraduate (1945-49) and did graduate work in optics at the University of Rochester in the early 1950s and in electrical engineering in the early 1960s at Brooklyn Polytechnic Institute. From 1949 to 1956 he worked on thin films, interferometry and lens measurement at Bausch and Lomb Optical Company. Beginning in 1956 he was an optical consultant in the research department of Bell Labs, Murray Hill. Working on lasers and interferometry there, he was one of the developers of the helium-neon laser. In 1968 he became head of the lithographic systems development department at Bell and worked on electron, optical and x-ray lithography. He retired from Bell in 1981.

Also elected, to three-year terms as directors at large, were William B.

the physics community



HERRIOTT

Bridges, professor of electrical engineering at Caltech, Frank Cooke, president of the Cooke Optical Company, and Kathryn A. McCarthy, professor of physics at Tufts University. Freeman F. Hall of the wave propagation laboratory of the National Oceanic and Atmospheric Administration was chosen as chair of the publications committee and *ex officio* member of the board for three years. Paul L. Kelley, associate director of the quantum electronic section of the MIT Lincoln Laboratory, was elected chair of the Technical Council and will serve on the board through 1983. □