"A safe and effective antiviral agent is not likely to be in use for the next several years."

This PHS projection is based on the assumption that the average cost per patient will be about $46,000, a figure derived largely from health care costs for AIDS patients in the San Francisco area. Some participants at the Coolfont meeting called this estimate unrealistically low because the gay community in San Francisco provides support and home care assistance for AIDS patients, making their average cost much lower than the national average. However, Walter Dowdle, acting AIDS coordinator for PHS, thinks the $46,000 figure is realistic because "it has been shown to be achievable and we hope that by 1991 there will be better treatments for AIDS."

The AIDS virus is transmitted in three major ways—by sexual contact, through contaminated blood or blood products, and to children born to infected mothers. The virus is present in blood, semen, vaginal secretions, saliva, sweat, tears, and various body tissues including brain and skin. It is most commonly associated with cells, such as infected T lymphocytes or macrophages, and the role of cell-free transmission of virus is unclear at present.

The predominant method of transmission of the AIDS virus is through sexual contact with someone who is infected, either a man or a woman. At the Coolfont meeting, Thomas Zuck, of the Food and Drug Administration (FDA) said, "We need to tell people what behaviors put them at high risk for the disease." It is not only having multiple sexual partners that puts an individual at risk, it is also having sex with someone who has multiple sexual partners that is risky.

People who become infected with the AIDS virus make antibodies to different parts of the virus, its outer envelope and inner core, for example. Screening a person for viral infection means testing for seropositivity, or having these antibodies in the blood. Researchers think that individuals are probably most contagious early in the course of their infection before they develop the full disease. Thus, most people probably become infected with the AIDS virus by having sex with seemingly healthy partners.

Scientists are working to develop vaccines to prevent infection by the AIDS virus and antiviral drugs to treat persons already infected. The new PHS report indicates that a vaccine will probably not be available for general use in this decade, but that "limited clinical testing for some [vaccines] could begin within 2 years." The report also indicates that "a safe and effective antiviral agent is not likely to be in use for the next several years."

The PHS report reflects the opinions of Coolfont participants in its approach to health care policy. Both stress the importance of massive educational programs targeted at special populations, including children and teenagers, women, and minority groups, as well as the general population. In addition, AIDS screening and counseling centers should be established throughout the country. Use of these centers would be voluntary and information would be confidential. Anyone found to be infected with the virus would be strongly encouraged to notify his or her sexual contacts and refer them to a center for screening.

At present, state and local health services are largely unequipped to cope with sharply rising numbers of persons infected with the AIDS virus or sick with the full disease. The magnitude of the problem calls for a coordinated response from federal, state, and local agencies; greatly expanded educational and training programs for health care workers; and careful assessment of the appropriate care and costs for care required at various stages of the disease. ■

DEBORAH M. BARNES

Mobile Missile Design Generates Controversy

The Pentagon and Congress are skirmishing over the number of warheads needed for a new strategic missile

At industrial plants scattered throughout the West, military contractors are hard at work on an unusual new intercontinental ballistic missile. A marvel of high-tech engineering, it will stand only 4 feet across and 15 yards high, yet have the capability to deliver a powerful nuclear warhead with unerring accuracy virtually anywhere in the Soviet Union. To be hauled around the desert on the flatbed of a low, blast-resistant truck, it will be capable of quick launch by remote control.

The Air Force calls it the "Small Missile," eschewing the popular name "Midgetman." During the past 3 years, a number of engineering challenges have been overcome, including the need for powerful new rocket propellants; strong and lightweight motor cases; thin yet highly effective insulation; and advanced materials for the rocket nozzles. Today, its managers assert, the Small Missile is one defense program with no cost growth, no technical snafus, and no delays.

Some of those with their fingers on the military purse strings do not seem impressed, however. Donald Hicks, the Pentagon's under secretary of defense for research and engineering, for example, does not like the Midgetman, and wants it redesigned. He has found some backers in Congress and the White House, and won vigorous support from the influential contractors who have so far failed to win a piece of the missile's $50-billion pie.

Hicks's chief complaint about the Midgetman's present design is that it lacks efficiency. At the express instructions of the Congress in 1983, it will carry only a single warhead. Hicks and his supporters want more bang for the buck. They prefer the new ten-warhead MX missile, which Hicks calls "the cheapest way, the lowest cost way that we can produce hard-target killers for our deterrence." If the Midgetman must be purchased, as Congress will probably insist, Hicks wants it to be a bit more like the MX, with at least two and perhaps three nuclear warheads.

His proposal has ignited a furious debate, which can be desribed as equal parts politics, science, and philosophy. Congressional opponents, including Representative Les Aspin (D–WI) and Senators William Cohen (R–ME) and Albert Gore (D–TE), assert that a redesign will needlessly delay the Midgetman's full-scale development, presently scheduled to begin in fiscal year 1987, and that any postponement may mean certain political death. They also claim that the

extra weight from the new warheads will necessarily render the missile much less mobile, thus presenting an easier target for the Soviet Union.

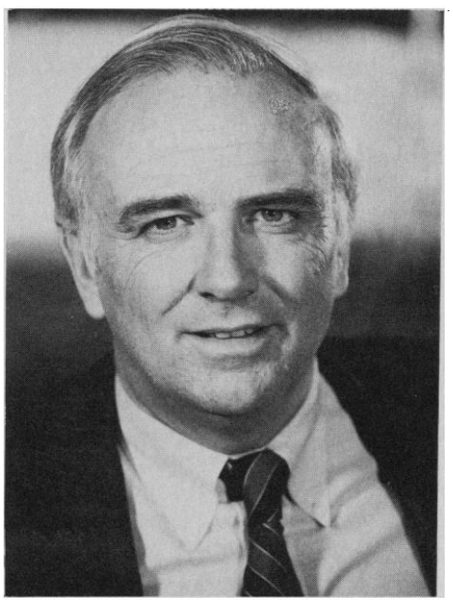
But fundamentally and most important they argue that Hicks's proposal is little more than a traditional attempt to add bells and whistles to a relatively uncomplicated weapons system. According to James Woolsey, a former Pentagon official who recently participated in a Midgetman study for the Defense Science Board, "a good part of what's at issue here is simply the need to hold the line against gigantism." Aspin, who chairs the House Armed Services Committee, told *Science* that Congress "understands this tendency to gunk up a weapons system. If [the Pentagon] tries to do it with Midgetman, they'll quickly learn that this is not what we want."

Thus far in the debate, the Air Force has remained cautiously supportive of the missile's present design. In April, Air Force Secretary Edward Aldridge told the Senate Armed Services Committee that he endorses only a slight modification, which would not impose any delay, to permit the installation of so-called "penetration aids," designed to fool potential Soviet missile defenses (*Science*, 6 June, p. 1186). But others connected with the program have been wary of making firm public statements, partly because of uncertainty about the direction of the prevailing congressional winds. "We can build you pretty much any flavor ballistic missile that you want," said Lieutenant General Bernard Randolph, the Air Force deputy chief of staff for research, development, and acquisition, in recent congressional testimony. "The issue is what the country wants."

The controversy has been intense because Midgetman will probably be the last land-based missile produced before the end of the century, as well as one of the most expensive nuclear weapons systems ever built. According to a recent report by the Congressional Research Service, its "life cycle cost" will be a record $88 million per nuclear warhead in the single-warhead design, compared with $19 million for the MX or $21 million for the B1 bomber. Supporters such as Aspin emphasize that the total cost will be merely 5.3% of the projected $840 billion strategic weapons budget over the next 20 years, but it nonetheless makes many legislators uneasy.

Substantial modification of the missile's design, of the sort contemplated by Hicks, would require congressional amendment of existing legislation that limits its weight to 33,000 pounds. The addition of a second warhead, for example, would boost the overall weight to at least 45,000 pounds, while a third warhead would increase it to at least 65,000 pounds. Both the missile and its mobile launcher would also have to be lengthened by at least 10 feet, causing the combined weight to climb from roughly 160,000 to more than 220,000 pounds. And the design competition between launcher manufacturers, presently narrowed to Boeing Aerospace and Martin Marietta, would have to be reopened to the two losers, General Dynamics and Bell Aerospace/Textron, forcing what the Air Force expects will be a 2-year delay.

Aspin and other supporters worry a lot about the political impact of this delay, noting that the competition for military procurement funds is expected to increase sharply as other new strategic weapons, such as the Stealth bomber and the advanced cruise missile, also near development. They feel that this could in turn unravel the missile's broad bipartisan support. "The danger," Aspin says, "is that if we start screwing around with it we simply may have no missile."



Representative Les Aspin: *Congress "understands this tendency to gunk up a weapons system" and won't buy it.*

In addition, advocates argue that such an enormous increase in the launcher's size and weight will sharply diminish its ability to roam around on back country roads, a feature considered essential to its survivability (see box). An Air Force report in February 1986, for example, estimated that "vehicle weight must be kept below 200,000 pounds to ensure successful mobile basing without restrictions, e.g., road and bridge vehicular constraints." Similarly, a panel of the Defense Science Board recently concluded that adding two more warheads "could seriously complicate mobility." It recommended immediate full-scale development of the existing missile, in which final, operational prototypes are constructed and both design and basing mode are essentially frozen.

One problem with the mobility argument, as even the missiles' supporters concede, is that there are few data available on larger mobile missiles, due to the Air Force's concerted efforts to comply with congressional demands for a small, single-warhead design. "We are confident that mobility begins to degrade" after the total weight climbs above 225,000 pounds, General Randolph recently testified. "How much and how rapidly, we are not certain."

Hicks makes much hay from this technical uncertainty, arguing that the advocates have simply closed their minds to potential alternatives. He says he has talked to people in industry "that I trust and value in terms of their understanding" who tell him that a large missile with several warheads can indeed scramble over the same territory, and that substantial savings might result from a smaller deployment of such missiles (the total number of warheads expected to survive a Soviet attack would supposedly be the same).

Senator Pete Wilson (R–CA), a member of the Senate Armed Services Committee, agrees. "Devotees of smallness," he says, "are practicing missile anorexia nervosa, clinging desperately to this underweight missile" despite some evidence that its cost could be substantially reduced. Many advocates of the Midgetman say that Wilson's opposition to the present design is motivated in part by the desire of General Dynamics, based in San Diego, to get back in the launcher competition, noting that his first major speech on the subject was made shortly after the company's rejection. But Wilson's aides deny it, and he claims that he is not familiar with the details of the company's launcher design.

Last February in testimony before the House Armed Services Committee, Hicks went so far as to predict that the addition of two more warheads to the Midgetman would reduce production and operational costs by 40 to 50% and manpower by 80% "with little or no loss in employment, flexibility, or survivability." Total savings could be as high as $20 billion, he added, citing the conclusions of a recent classified study by the RAND Corporation.

Several authoritative sources with access to the study challenge this estimate, however, noting that RAND conducted no independent missile mobility assessment, and did not include the potential cost of road and bridge modifications. The study also acknowledged that if the additional weight decreased mobility by more than 25%, the

A Scheme to Attract Missiles and Deter an Attack

The development of a survivable land-based missile force has long been a frustrating objective for the U.S. Air Force. Until recently, its efforts had produced only a thick file of schemes considered too costly, risky, or silly to survive in the political arena. With the new Midgetman missile system, however, the Air Force finally seems to have come up with an idea that enjoys bipartisan support.

The trick was apparently to develop an innovative combination of nuclear hardware and operational tactics. The plan is to transport the new missile on a large number of mobile launchers, capable of traveling at speeds up to 50 miles per hour on paved roads and 15 miles per hour on open terrain. Each will be capable of lowering and anchoring itself to the earth, in order to resist the radiation, heat, dust, and pressure created by a 1-megaton nuclear blast at a distance of at least 1 mile. (This will be verified by two massive explosions of ammonium nitrate fuel oil at the White Sands missile range in New Mexico, simulating the effects of a 500-kiloton nuclear blast. One explosion occurred last June, and the other is scheduled for mid-1987.)

Three different operational schemes are presently under consideration. One calls for deployment of the launchers on up to four government reservations in the Southwest. The primary candidates are military bases in California, Arizona, New Mexico, and Florida, as well as the Department of Energy's Nevada nuclear test site and the reactor complex in Hanford, Washington. In peacetime, the launchers would be dispersed over a total of 4000 square miles at the perimeter of government reservations in the Southwest. In a crisis, some would move inward over a total of 8000 square miles; and on warning of a Soviet attack, they would move both further inward and off the base onto public roads, to disperse over a total of 28,000 square miles.

Under another scheme, the launchers would be deployed at existing Minuteman missile sites in North Dakota, South Dakota, Wyoming, and Montana, perhaps in small garages near each silo. In a superpower crisis or on warning of a Soviet attack, the launchers would dash to predetermined locations over a similar total area. The advantage of this approach is that it will cost about $5 billion less for operation and maintenance, but it will also be more vulnerable to attacks from undetected Soviet submarines near the U.S. coasts.

Finally, under a third scheme, considered the least popular on Capitol Hill, the missiles would be shuttled among a series of hardened silos constructed so as to complicate a Soviet attack. In essence, this would be a combination of the "Densepack" and "Racetrack" deployment schemes rejected for the MX. The silos may be constructed in Texas, Arizona, California, or Wyoming.

Each of these proposals has the same goal: to create sufficient uncertainty about the exact location of the Midgetman missiles so that the Soviets would have to barrage the entire deployment area, thereby expending a major fraction of their nuclear arsenal. According to calculations by the Air Force, for example, the first scheme would force the Soviets to use between 100 and 800 land- and sea-based missiles, carrying several thousand warheads, to eliminate a potential Midgetman retaliation. (The number required varies according to the degree of warning in the United States.)

The beauty of the first two schemes, according to the Air Force, is that their success is not dependent on missile concealment or deception, at least in the near term. Even if the Soviets can determine the precise location of Midgetman missiles, they will be relatively unable to predict the missiles' locations 10 to 30 minutes later, when their warheads have actually arrived. This problem is not significantly eased by increases in the number or yield of Soviet warheads, because U.S. mobile launchers can be readily dispersed over a wider area, and moved more quickly than the time it takes the Soviets to retarget (presently estimated at more than 24 hours for their most advanced missiles). Ultimately, with substantial growth in the accuracy, sophistication, and number of Soviet nuclear forces, the United States might have to build new roads and decoy launchers or disperse in wooded terrain, but these steps are considered highly feasible and the requirement a long way off. ■ **R.J.S.**

savings disappear. The debate will undoubtedly be sharpened by a series of Air Force studies started recently at Hicks's request; preliminary conclusions are that mobility will indeed be reduced, possibly by as much as 50% for a three-warhead missile and 20 to 25% for a two-warhead missile.

Finally, even if these results prove incorrect, a larger multiple-warhead missile will still encounter some resistance from congressmen who feel that deployment of such missiles is strategically destabilizing. Senator Gore and others argue, for example, that such weapons pose an inherent first strike threat, because they permit an attacker to destroy many targets with a single shot. He essentially wants to return to the period of the 1960's, in which both sides had primarily single-warhead missiles, and thus could not achieve a net gain from preemptive attack. Alternatively, many of those who favor adding warheads feel this concern is overblown.

A final decision on the missile and its basing is not expected until November, when a group of senior Defense Department officials will meet to hear the results of the Air Force studies. Between now and then, a new Pentagon task force created by Hicks will reexamine all of the technical and cost issues considered by the Defense Science Board, as well as the possibility of chucking missile mobility entirely in favor of an active missile defense.

One potential compromise, supported by a number of Midgetman advocates, would allow the missile's weight to grow to 40,000 pounds, thus providing room for the addition of "penetration aids." Meanwhile, a new program would be established to build a pair of compact warheads capable of fitting in the same space presently used by the missile's single warhead, with a target for completion in the late 1990's. Thus some of the Midgetmen could ultimately have multiple warheads, and some would have just one.

Somewhat complicating the Pentagon's final decision is President Reagan's recent decision not to comply with the SALT II treaty. At the behest of senior Defense Department policy-makers, construction of a large multiple-warhead mobile missile was added to a list of potential U.S. measures to be taken in response to alleged Soviet violations of SALT II. Such a missile is seen by assistant secretary of defense Richard Perle and others as a means of responding to a similar multi-warhead mobile missile soon to be deployed by the Soviet Union, the SS24. But Congress's position on the SALT treaty remains highly uncertain.

Another potential complication is the squeeze that Gramm-Rudman is expected to place on all new military research. The Pen-

tagon recently included Midgetman on a list of programs that might be delayed for a year if the President's overall defense budget is not approved, and reductions are needed to constrain the deficit.

Senator John Warner (R–VA), chairman of the Senate Armed Services Committee, predicted recently Congress is likely to authorize most of the $1.37 billion needed to start full-scale development of the Midgetman, but then block the expenditure of some of the funds until it has an opportunity to review the Pentagon's final recommendations early next year. ■ R. JEFFREY SMITH

Second of three articles. Next: The impact of mobile missiles on strategic targeting and future arms control agreements.

Oil Industry R&D Takes a Fall

Exxon's corporate research operation cut in half as oil companies "downsize" to adjust to market

CUTBACKS in budget and work force by major U.S. oil companies to compensate for the decline in oil prices have brought sharp reductions in R&D activities. In the case of the Exxon Corporation, the largest oil company in the world, retrenchment includes a recent decision to scale back corporate research by half.

Details are hard to come by. Oil companies are reluctant to discuss budgets, manpower, or research strategy lest they provide clues to their competitors. But industry observers agree that changed conditions dating back to the beginning of the decade have shaped new attitudes toward R&D. Edward E. David, Jr., former president of Exxon Research and Engineering Company, where corporate research is lodged, estimates that the level of effort on research, development, and engineering within the petroleum industry has been cut by at least 30 to 40% in the last 3 years.

At Exxon, the pruning of corporate research ends a boom period for the operation that began in the late 1970's. Corporate research, which, as the name implies, serves the whole company, moved into a new $200-million facility at Clinton, New Jersey, 3 years ago (*Science*, 7 September 1984, p. 1001). Basic research is a principal element of corporate research and the new research center was assumed to mark Exxon's firm commitment to such research.

Exxon officials confirm that staff at Clinton will be reduced on the order of 50%. Peak employment at the center was about 900, including 300-plus Ph.D.'s and a technical support staff of over 200. Lab staff is now apparently down near the levels projected under the cuts. Since April, Exxon has been going through a corporation-wide voluntary separation program aimed at reducing its total U.S. work force by 15%.

While current cuts in corporate research look disproportionately large, Exxon vice president for corporate research Frank B. Sprow notes that the division was insulated from earlier reductions in R&D activities. He says that many of Exxon's other technology units were "downsized" beginning in 1982, but corporate research was protected. Now that major cuts are being imposed across the board, corporate research's turn has come.

Exxon is "reverting to type as a natural resource company," says Edward David.

Exxon's total spending on R&D throughout the corporation declined from $736 million in 1984 to $681 million in 1985. Spending on basic research was put at over $100 million in 1984. Later figures are not available, and it appears that decisions on research budgets for the immediate future are not yet firm.

The expansion and contraction of R&D activities at Exxon generally followed oil industry patterns, although Exxon's investment in corporate research seems to have been relatively greater than its smaller rivals. Sprow says the expansion was fueled by two main factors. Exxon wanted research support for its 1970's diversification into business areas such as office systems and electronics. And the corporation also invested heavily in R&D on synthetic fuels when high energy prices encouraged expectations that synfuels from coal and oil shale would be marketed profitably by the early 1990's.

In the early 1980's, the outlook changed. Exxon's experience with diversification proved disappointing and caused a cooling of corporate ardor on that score. Then trends in oil supplies and prices quashed early prospects for synfuels and negatively affected Exxon's base business. Exxon and other oil companies cut back drastically on expensive synfuels commercialization projects. At that point, Exxon and the other majors also began the downsizing process that still dominates industry strategy.

Sprow says that management personnel at Clinton are being cut with the objective of reducing central direction of research and relying more on researchers to set scientific priorities. Increased contact with other technology units of the company is also planned. Sprow says the aim is to "walk the edge between having the people who use the science produced be more involved, but at the same time not becoming an applied science lab."

Corporate research in the 1970's cultivated increased contact with universities by supporting research there and promoting the interchange of researchers between Exxon and university labs. The biggest program has been a collaboration with MIT that focuses on high-temperature chemistry. Now in the last third of a 10-year agreement, with support running at about $900,000 a year, Exxon says it intends to abide by the terms of that and other cooperative arrangements in academe. Sprow says that for the smaller Exxon research effort to retain its effectiveness it is viewed as necessary to maintain contacts outside. He says that future initiatives are likely to have a "closer fit with internal programs" and be "more tactical, less philanthropic."

The decline in oil prices, particularly the sharp drop that halved prices in a few months earlier this year, is seen as the main cause of recent cutbacks. Chevron on 12 June announced its own 12% reduction in employees. But some observers see expectations of excess capacity and low prices creating a siege mentality in the U.S. oil industry along with a pessimistic view of the value of R&D.

David, who resigned as Exxon's research chief last year before the latest oil price