transmission of Spacelab's data to earth. Without one or both satellites, much of the scientific data will be lost. "The bytes will just fall off the end of the table and onto the floor," says Richard Chappell, a Spacelab mission scientist.

NASA and ESA have several options if both satellites are not up and running by 30 September. One is to delay Spacelab's flight by as much as a month, a choice that ESA likes because it might result in only minor data loss. But NASA is concerned that such a delay will crowd the tenth flight of the shuttle, now scheduled for November, which has a payload constructed by the Defense Department. National security comes before science under the Reagan Administration space policy.

A second option is to fly in September with only one satellite available. Chappell says that under this option "a majority of the 77 experiments on Spacelab will lose some data." No one yet knows which ones and how much. But certain experiments require more live data transmission than others to ensure their success. Included in this category are experiments in x-ray spectroscopy, measurements of deuterium and of the solar constant, microwave remote sensing, an investigation of motion sickness, and a $30-million experiment involving active generation of charged particle beams. "If the experimental time line is redone and extra recording tapes are stored on board, perhaps 90 percent of the data could be retained," Mellors says.

A third option is to delay the flight until February, when the winter solstice has ended and there is sufficient light for the experiments requiring earth observations. The chief disadvantages are the added expense, and the need to revise the schedule of experiments so as to take into account intervening celestial movement.

Mellors says that if the delay winds up costing a lot of money, ESA might have to pull back from its contractual commitment for engineering support during the second Spacelab flight sometime later next year. "We want to avoid this if possible," he says. "But if we do have another hiccup, we may well have to invoke the contract clause that says 'subject to the availability of funds.' "

NASA is earnestly attempting to avoid any delay. Recently, for example, it decided not to test-fire all the shuttle engines together after repairs are completed, because it would require 3 weeks of preparation. Abrahamson says that four shifts are now working around the clock and on weekends to smooth out the troubles at the launch site. No one at the agency seems certain how much this will cost, but most estimates are in the tens of millions of dollars.

Unlike some previous shuttle program managers, Abrahamson is candid about the agency's role in the present mess. For years, the agency cut back on testing and the production of spare parts in an attempt to control costs and give the program as low a political profile as possible. The agency's technical problems were manipulated, not solved. Difficult work was put off until the first shuttle was so far along that Congress could not scrap it. The object, Abrahamson says, was to get the first flight off quickly, and to do it without exceeding the tight fiscal constraints. "We just didn't have much spare hardware," which meant that if something went wrong unexpectedly, it required a long time to fix. "We didn't catch the problems we would like to have caught earlier," Abrahamson says.

The existing engine problems are the legacy of this management style. Few engine parts are available for repairs. The first shuttle must now be cannibalized so that the second can fly. Abrahamson is trying to improve the situation, but spare parts ordered today will not be available for several years. The agency, meanwhile, finds itself under increasing pressure to meet its commitments, from the White House, the Congress, the Pentagon, and its commercial clients. Consequently, it continues to exude optimism.

—R. JEFFREY SMITH

Vietnam's Herbicide Legacy

Recent studies in Vietnam have found long-term environmental damage and a possible rise in birth defects from U.S. spraying

A major epidemiological study conducted by Vietnamese scientists has turned up evidence of an increase in the incidence of congenital abnormalities among children whose fathers were exposed to herbicides during the Vietnam War. Several Western scientists who examined reports of the research at a recent conference in Ho Chi Minh City called the study "impressive," but cautioned that the findings are suggestive rather than conclusive.

Nevertheless, the study is likely to influence debate in the United States over the long-term impact of the spraying on American troops who served in Vietnam. Some veterans have claimed that exposure to Agent Orange—the most widely used herbicide—caused birth defects in their children. But the evidence is anecdotal and comes from a self-selected group. The Vietnamese study "is the first reported scientific investigation. . . . We have to pay attention to it," says Maureen Hatch, a reproductive epidemiologist from Columbia University who attended the conference.

The conference provided the first opportunity for scientists from outside Vietnam to review research on the long-term environmental and health effects of Operation Ranch Hand, the U.S. military operation that dumped some 72 million liters of herbicides and defoliants on southern Vietnam between 1961 and 1971. In addition to the preliminary findings on birth defects, several reports indicated that the spraying inflicted some lasting scars on Vietnam's environment.

The most striking evidence linking exposure to herbicides with reproductive problems comes from a survey of some 40,000 families in northern Vietnam. Because all the spraying took place in the south, women in the northern villages were not exposed to herbicides or defoliants. The survey found that women whose husbands fought in the south—and who were therefore potentially exposed to the spraying—had a higher incidence of pregnancies resulting in stillbirths and congenitally abnormal offspring than women whose husbands had remained in the north. An independent follow-up study indicated that the risk factor was about 3.5.

The survey and the statistical analysis were apparently well conducted, according to those who examined the methodology. "We had no control over whether

the study was done in the way they said they did it, but we had no reason to believe that it wasn't," says John Constable, a surgeon from Massachusetts General Hospital who attended the conference.

Constable and others point out that more studies are needed to confirm the results. "You cannot consider one paper absolute proof," he says. Caution is particularly warranted because this is apparently the first epidemiological study to detect an increase in birth defects following paternal exposure to a chemical.

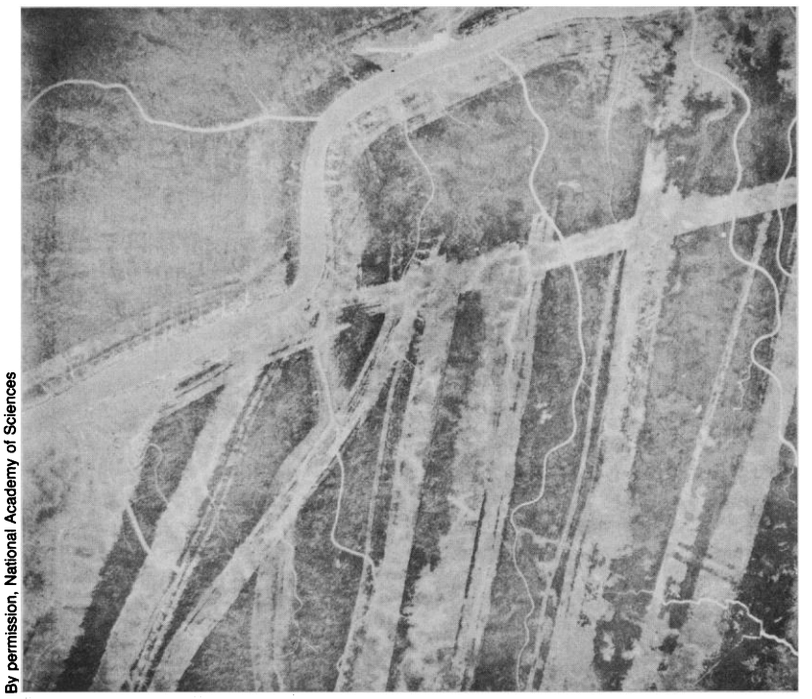
Studies of women in South Vietnam who had themselves been directly exposed to the spraying also showed an increase in birth defects apparently related to herbicides and defoliants. In particular, there was an increase in the incidence of neural tube defects, deformities of the sensory organs, deformities of the limbs, Siamese twins, and cleft lip among the offspring of exposed women. These are the same congenital anomalies noted in the study of northern villagers. A report of the conference notes, however, that although "we are much impressed by the large numbers of reported cases" of these anomalies, the link with spraying is far from proven.

The suspicion is that dioxin, a long-lived contaminant of Agent Orange, is to blame for any health effects resulting from the spraying. At least 170 kilograms of the chemical were present in the herbicide sprayed over South Vietnam, according to U.S. military records. An extremely toxic chemical, dioxin has been found to be a potent teratogen, mutagen, and carcinogen in animal studies. "If you accept the figures [from the North Vietnam study] then you would be hard pressed to say that it wasn't caused by the spraying," says Constable.

If the evidence linking exposure to birth defects is tenuous, the links to other health problems are even more difficult to pin down. Several studies have indicated a possible increase in the incidence of liver cancer and neurological disorders following herbicide exposure, but the evidence is "no more than suggestive," says Samuel Epstein, an epidemiologist from the University of Illinois School of Public Health who reviewed the studies at the conference.

Environmental impacts of the spraying are more obvious. "The combined ecological, economic, and social consequences of the wartime defoliation operation have been vast and will take several generations to reverse," states the conference report.

The effect on the inland forests is patchy. In areas that were heavily and repeatedly sprayed, most of the trees died. But in lightly sprayed areas, the bulk of the trees survived, according to Peter Ashton, director of the Arnold Arboretum at Harvard University. Ashton spent 3 weeks in Vietnam and visited many of the heavily sprayed areas.



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Destruction of mangrove forests

More than 40 percent of southern Vietnam's mangrove forests were defoliated. Heavily sprayed areas are not being regenerated naturally. This photograph, taken during the war, shows strips of defoliaton.

The chief barrier to reforestation of the damaged areas is uncontrolled burning by villagers who moved in after the spraying, according to Ashton. Although agriculture has been established in a few previously forested areas, in most places the soil is unsuitable for growing crops and the land has become covered with a coarse, deep-rooting grass.

The destruction of strips of forest seems to have had a major impact on some animal populations. A survey in one heavily sprayed forest, for example, found only 24 species of birds and 5 species of mammals, but in two nearby control forests, 145 and 170 bird species and 30 and 55 mammal species were counted. Ashton speculates that the spraying may have created islands of forest too small to support some animal populations, and the defoliation may also have reduced food supplies during the time it took damaged trees to recover.

The impact on the country's mangrove forests is more severe. "The effects of spraying are widespread, long-lasting, and severe within the affected areas," the conference report states. A 1973 study by the U.S. National Academy of Sciences concluded that natural recovery of heavily defoliated mangrove forests would take at least a century, largely because destruction was so complete that few seed sources remained. Recent surveys have indicated that some minor "weed" species of mangrove are starting to recolonize damaged areas, but there has been no natural regeneration of the major commercial species.

"In essence, a substantial proportion of the mangrove ecosystem, including its associated estuarine flora and fauna, experienced a significant productive loss," the conference report states. Timber, firewood, and tannin resources were lost, and there has apparently been a decrease in estuarine and nearshore fisheries. An estimated 40 percent of the coastal mangrove forests were sprayed at least once.

One bright spot is an area on the Saigon River where mangrove forests were completely destroyed by repeated heavy spraying. According to Ashton, more than 80 percent of the area—some 1500 hectares—have been replanted with commercial species, a feat that Ashton calls "astonishing."

While Operation Ranch Hand was under way, successive U.S. administrations argued that the spraying should not be considered chemical warfare because the chemicals were nonlethal and the impact would be short-lived. But some 12 years after the spraying ended, some effects are still being felt.

—COLIN NORMAN