grasses and wetlands. (For the past two years Odum and his colleagues have had a contract from the Environmental Protection Agency to probe every possible aspect of erosion.) The Southeast must also start conserving water, their most precious natural commodity. For instance, water off the eastern coast of Georgia is deteriorating in quality, as is water up and down the entire East Coast of the United States. The Southeast must start keeping track of how much ground water it has. Industry currently has to report how much water it uses, but farmers do not. If too much water is drawn off the Chattahoochee River before it reaches Atlanta, the river will not have enough water for Atlanta by the year 2010. The river is the city's sole source of water.

Finally, "we have to get ecology and economics together," Odum advises. Southeast residents must learn to draw up ratios between the advantages of jobs and environmental devastation, in order to achieve the best for both people and environment. For instance, Georgia does not need oil processing since it provides few jobs for the poor and less-educated, yet creates a lot of pollution. In contrast, the textile and food processing industries now provide most jobs in Georgia, yet do not use all that much water, thus providing a good example of the marriage between economics and ecology. □

Mars contamination looks less likely

The phrase "planetary quarantine" is one of the more pungent bits of jargon in the Space Age lexicon. In science fiction, it has sometimes described the activities of extraterrestrial beings "sealing off" the earth to prevent contamination of other, more civilized worlds by this planet's warlike ways. In fact, however, it has a very real purpose. The Viking spacecraft sent to Mars, for example, were first rigorously sterilized, not only to avoid confusing the biology experiments on the landers, but to keep the planet from being overrun by any earthly microorganisms that might have prospered in the new environment. The sterilization process was both expensive and technologically demanding, often requiring engineers to adopt alternative designs, components or materials that could withstand the many hours at high temperatures required by the sterilization procedures.

Thanks to Viking, however, the designers of some future Mars-bound craft may have it a little easier, judging from the findings of a panel of the National Research Council's Space Science Board. After studying the Viking data, the panel has concluded that conditions on Mars are "considerably harsher to terrestrial life than was heretofore assumed," and that NASA should assume a lower "probability of growth" for transplanted earthly microorganisms when planning future sterilization criteria. In fact, says the group's report to the space agency, "we would object to the elimination of an experiment or the degradation of its performance because of the imposition of unessential sterilization requirements."

The probability of growth, or P_g, is officially "the estimated probability that growth and spreading of terrestrial organisms on the planet surface will occur." The chance, in other words, that a given germ — having survived the clean rooms, the sterilization procedures (if any), the cold and vaccuum and radiations of space, and the heat of entering the other planet's atmosphere — might then survive or even thrive on the alien world, altering it for all time in what would be an ecological disaster of truly interplanetary proportions — particularly if indigenous life-forms are already present.

The odds are thought to be extremely small, but because the consequences could be horrendous, considerable effort is spent on minimizing the possibility. Not surprisingly, NASA uses a formula, in which the probability of contaminating the planet equals the number of microorganisms on the spacecraft at launch multiplied by several other probabilities: that the organisms will survive space and entry conditions, that the spacecraft will reach its destination, that the organisms will get out of the vehicle into the planetary environment, and finally, P_g, that they will grow. For Viking, NASA assumed a P_g of 10^{-6} — a chance in a million.

The Space Science Board's Committee on Planetary Biology and Chemical Evolution, headed in its study by Peter Mazur of Oak Ridge National Laboratory, gives the invading germ a P_g of no more than a chance in ten million, and for most of the planet's surface only one in ten *billion*.

The committee divided the planet into three regions: the nonpolar regions within 6 centimeters of the surface, the nonpolar regions below that depth and the poles themselves. For the nonpolar near-surface, the panel feels that the key factors in its minuscule assigned P_g of 10^{-10} are the extremely active oxidants detected by the Viking biology instruments and the lack (down to parts per billion) of detectable organic molecules, plus the fact that the thermal mapping instruments on the orbiters showed the planet to be generally cold all over. The landers sampled only two sites, but elemental analyses showed them to be very similar, and the oxidants appear derived from atmospheric — and hence essentially global — reactions. The 10^{-10} is derived from a 1 in 10 chance that the deposited microorganism can live without free oxygen (about 10 percent of terrestrial microorganisms are anaerobes, Mazur says), another 1 in 10 that it can survive multiple freezing and thawing, yet another tenth for the avoidance of lethal ultraviolet radiation (a little surface dust would do the trick), a chance in 100 that there will be enough (and useful) organics to eat, another chance in 100 for the presence of liquid water of sufficient "activity" (indicating how hard it would be for the organism to incorporate it) and the big blow — a final chance in 1,000 that the already much-threatened creature would somehow escape the vicious oxidants.

More than 6 cm down, the committee gives the organism a better chance of survival: one in 100 million, still 100 times worse than NASA was willing to count on before the Viking data were in hand. A key factor here is temperature, since the data suggest that the maximum temperature falls rapidly with depth. In the northern hemisphere, even only 4 cm down, says the committee's report, "the maximum temperature is estimated to be 20°C below the minimum confirmed growth temperatures (−15°C) observed for terrestrial organisms. By a depth of 24 cm, the *maximum* temperature is estimated to be −50°C. . . ." In the south, it's nearly as chilly. At greater depths there is the possibility of finding permafrost — water ice — which could conceivably be accompanied by a liquid layer, but water that is liquid below −20°C and is in equilibrium with ice "has an activity below that which will support the growth of any known terrestrial organism capable of growing under the partial pressure of oxygen on Mars." The conclusion is not absolutely certain, the panel points out — there could be warm "oases" too small for the orbiters to detect, or currently unknown organisms that could handle the cold — but the environment is still "exceedingly harsh," and the low P_g is still recommended solely "for the specific purpose of determining quarantine requirements for future Martian missions."

The residual polar caps get only a 1 in 10 million rating. Viking scientists have concluded that at least the northern residual cap appears to consist entirely of water ice, and the atmospheric interactions there are less known, but the cold is still the key. The rating is thus roughly that of the nonpolar subsurface, backed off a bit to allow for the uncertainties.

The committee has never been particularly happy about having to boil all these scientific questions down into a single exponential value, "when nearly nothing is known about the identification and metabolic capabilities of the organism, the size of the initial inoculum, the presence of associated microorganisms, the details of the environment in question, and most important the detailed changes in all of the relevant environmental factors with time." The panel recommended replacing the "probabilistic method" with studies of known organisms most likely to thrive under known planetary conditions. Such a qualitative approach, however, is hard to translate into specific sterilization methods, and it has yet to be done. □