*This insensitivity becomes more understandable when the basic dynamic properties that lead to the unstable overshoot mode are considered. These basic properties are:*

*1. Relatively rapid physical growth.*
*2. Physical limits to that growth.*
*3. Possible erosion of those limits by overuse or misuse.*
*4. Delays in the feedback signals that limit growth.*

*Physical growth is generated in the model by the balance between the positive and negative feedback loops that control population and industrial capital. Physical limits are represented in the three other sectors: the stocks of nonrenewable resources and arable land, the maximum value of land yield, and the pollution assimilation half-life. Erosion of those physical limits can occur through the mechanisms of nonrenewable resource depletion, land loss from urban-industrial use and erosion, land yield decrease from air pollution or loss of soil fertility, or a decrease in the effectiveness of the pollution absorption process from the accumulation of pollution itself. Delays in feedback loops occur throughout the model. Every level, or state variable, represents an implicit delay in a feedback process. Other delays are explicitly represented, for example, the pollution appearance delay, the social adjustment delay, and the delay inherent in the population age structure.*

*The combination of these four basic properties causes the World3 system to grow beyond its sustainable carrying capacity and to erode that carrying capacity before the delayed feedback mechanisms that stop growth can take effect. It follows that small numerical changes (such as the change in the fraction of industrial output allocated to agriculture FIOAA) that do not alter any of the four basic properties will not affect the model's overshoot behavior mode. Numerical changes that do alter the exact specification of these properties (the change in initial nonrenewable resources NRI that moves one limit upward, or the change in the average lifetime of industrial capital ALIC that increases the rate of physical growth) will not affect the general behavior mode, since the basic properties still exist even though the timing or strength of their effects may be altered.*

*These sensitivity tests are helpful in designing effective policies: any policy designed to avoid the overshoot mode of behavior will be effective only if it influences one or more of the four basic properties of the model. The rest of this chapter is devoted to tests of technological and social policies designed to affect these basic properties.*

## 7.5 TECHNOLOGICAL POLICIES

In the preceding simulations we have demonstrated that the parameters and relationships of World3 produce a global behavior similar to that of the real world for the period 1900–1970. When projected into the future they exhibit a fundamental behavior mode of overshoot and decline. Of the three possible behavior modes of the world system—continued growth, a smooth transition to equilibrium, or overshoot and decline—overshoot and decline appears to be by far the least desirable. This section presents a number of simulations to illustrate the response of the model to technological policy changes designed to avoid this behavior by raising the physical limits to growth. Since all the technological policies tested in this section assume advances beyond those that can be reasonably expected as further developments of present trends, they were modeled as modifications of the parameters and structures employed in the reference run.

In the first part of this section, discrete technological advances are assumed to be implemented within one year, 1975, and at no cost. This is an unrealistic approximation that was relaxed in later technological runs, for, in reality, any global technological change will take place gradually over a number of years in response to a perceived need for the technology and at a cost dependent on the nature of the technology. Furthermore, such discrete changes, if actually implemented in the real world, would undoubtedly cause a certain amount of political and social disruption not represented in the model. It is shown that discrete improvements in technology do not alleviate the model's instability in the long run but simply move the limiting factor that stops growth from sector to sector.

The second part of this section tests the sensitivity of the model to exponentially increasing improvements in technology, again ignoring the delays and costs that would be an inherent part of real-world policy changes. The third part consists of a group of technological runs simulating the effects of adaptive technological policies on the behavior of the model. An adaptive policy is one that is formulated in response to a perceived system need, such as the development of pollution abatement technologies in response to a perceived discrepancy between the existing level of pollution and the desired level of pollution. The improvements resulting from these technologies were modeled as exponentially increasing functions whose rate of growth, measured in percentage improvements per year, is variable but limited by a postulated upper bound. Additional simulations illustrate the effects of delays and costs of technological development and implementation on system behavior. The conclusion drawn from the series of simulations of technological policies presented here is that, when realistic assumptions concerning the nature of technological development are included in the model, technological policies *alone* are not sufficient to avoid the standard model behavior mode of overshoot and decline.

### Discrete Changes in Technologies

As a first approximation, all technological changes in this series are assumed to be implemented within one year, 1975, and at no cost. Each successive run represents the effects of an additional policy that is designed to relieve the limitation to growth evidenced in the previous run. These simulations illustrate the fact that discrete technological changes designed to relieve the negative pressures limiting growth are successful only in moving those pressures to a different sector of the model.