that none of the plans "holds much promise beyond the next 10 years" (see "Military Technology and National Security," by Herbert F. York; SCIENTIFIC AMERICAN, August, 1969).

According to York, "one and only one technically viable solution seems to have emerged for the long run: Launch on warning." To most people, including him, he added, "such an approach to the problem is politically and morally unacceptable, and if it really is the only approach, then clearly we have been considering the wrong problem" in attempting to preserve the land-based component of the U.S. strategic deterrent force. For the time being, he concluded, submarine- and aircraft-based strategic weapons would appear to provide a satisfactory alternative to land-based missiles. "I expect, however, that as the continuing national debate subjects the whole matter of strategic arms to further public scrutiny we shall learn that these other alternatives also have dangerous flaws, and we shall see confirmed the idea that there is no technical solution to the dilemma of the steady decrease in our national security that has... accompanied the steady increase in our military power."

The Inflationary Universe

According to the standard big-bang cosmology, the universe began as a point of infinite density and expanded to a volume about the size of a softball by the end of the first 10^{-35} second. At this stage the universe was already far too big and had expanded too quickly to have yet been crossed by a signal moving at the speed of light. Causal connections between events, which are limited to the speed of light, were confined to regions about 10^{-25} centimeter across; some 10^{78} such regions would fit in a universe the size of a softball.

Physical theory now makes it possible to solve several outstanding problems in cosmology by supposing that the universe observable now was once an extraordinarily minute part of such a causally connected region. For a period beginning 10^{-35} second after the big bang and continuing for 10^{-32} second the region may have passed through what is called the inflationary phase. The region blew up by perhaps 100 orders of magnitude, from a trillionth the diameter of a proton to a diameter 10^{47} times that of the current observable universe. (The precise inflation factor is not important as long as it is greater than 10^{25}.) At the end of this titanic expansion the region that was to become the current observable universe must have been the size of a softball, embedded in an unimaginably greater universe that has ever since continued to expand beyond our horizon of cause and effect. At age 10^{-35} plus 10^{-32} second the inflationary phase was replaced by the standard phase, and the softball-size region, as well as the surrounding universe, resumed the rate of expansion that has since governed cosmic evolution.

These striking proposals have been made by a group of physicists and cosmologists who see in the physics of elementary particles a path to a consistent and perhaps even a predictive understanding of what the universe was like only 10^{-35} second after it began. The idea originated in a paper published last year in *Physical Review* by Alan H. Guth of the Massachusetts Institute of Technology. Guth noted certain inconsistencies of the model in his paper, but within a year Andreas Albrecht and Paul Steinhardt of the University of Pennsylvania and, independently, A. D. Linde of the Lebedev Physical Institute in Moscow were able to patch up some of the difficulties. Now these investigators and several others have taken up revisions of the inflationary model and are pursuing its consequences.

Guth's central idea was to apply thermodynamic principles to the interactions of matter and energy in a universe whose temperature is approximately 10^{27} degrees Kelvin. At this enormous temperature a typical particle has an energy at which the distinctions between three of the fundamental forces of nature are thought to break down. At ordinary temperatures there are four such forces: the strong force, which is responsible for nuclear interactions; the weak force, which accounts for the decay of the neutron into a proton; the electromagnetic force, and the gravitational force. One of the most ardent hopes of theoretical physics has been to give a unified account of all four forces, but so far only the first three have been linked by the grand unified theories. Above the critical temperature of 10^{27} degrees K. the theories predict that the strong, the weak and the electromagnetic forces are symmetrical, in the sense that they are indistinguishable from one another. Below the critical temperature the strong force should act differently from the other two forces, and the symmetry is broken. One effect of symmetry breaking, Guth suggests, is that matter and energy enter a new phase.

The phase transition envisioned by Guth is modeled closely on the conversion of a liquid into a solid. The liquid-to-solid transition is accompanied by a rearrangement of the molecules of the liquid into a regular crystalline array. The rearrangement lowers the total en-

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ergy of the system, and so during the phase transition a certain quantity of energy called latent heat must be removed. It is possible, however, to cool a liquid below its normal freezing point if there are no sites that can serve as nuclei for the formation of crystals. The result is a new phase called a supercooled liquid; on contact with suitable nuclei such a liquid freezes but the release of latent heat can raise the temperature of the resulting solid.

In a similar way, Guth maintains, the symmetrical phase of matter and energy predicted by grand unified theories may have supercooled during the early stages in the evolution of the universe. The symmetrical phase might have been maintained in certain regions of the early universe at temperatures as low as 10^{22} degrees K. In the supercooled symmetrical phase matter and energy expand exponentially until the regions of symmetrical phase are converted into an asymmetrical phase, a relic of which we now perceive throughout the visible universe. During the phase transition the expanded region of symmetrical phase releases a tremendous quantity of latent heat, and the region is reheated to nearly 10^{27} degrees.

Although there remain several theoretical problems for the inflationary model, the model resolves at least three cosmological puzzles. One of them is the homogeneity of the cosmic microwave background radiation, which varies with direction by less than one part in 10,000. If the standard big-bang model is correct, regions of the sky separated by more than two degrees of arc have not been in contact throughout the entire history of the universe. No causal influence would have had time to propagate between them. Because the uniformity of the radiation cannot be accounted for by any physical interaction between distant regions, it must be introduced as an ad hoc hypothesis in the standard model. In the inflationary model such homogeneity is readily explained because the precursor of the present observable universe is much smaller than the one predicted by the standard model. Every part of the observable universe was at one time causally connected to every other part.

The second puzzle is called the flatness problem. A basic question in cosmology is whether the universe is open or closed: will it continue expanding forever, or is the density of matter sufficiently high for gravitational forces to halt the expansion and drag the universe back into a single point? If the density is exactly equal to the critical density that allows the expansion to continue forever, the universe is said to be flat: the geometry of space-time is not curved but instead approaches the Euclidean geometry of a plane.

The actual density of the universe has not been determined precisely, but it is known to be within one or two orders of magnitude of the critical density. For understanding the evolution of the early universe, however, the problem is not whether the present universe is open or closed but rather how the observed density came to be so close to the critical value. In the standard big-bang model the density of the early universe must be equal to the critical density to an accuracy of one part in 10^{49} in order to be consistent with the present range of values. In the inflationary model such precision is not necessary. During the exponential expansion of the universe the region occupied by the observable universe becomes increasingly flat, and the mass density naturally converges to the critical density. The observed universe is flat for much the same reason that the geometry of a small patch on the surface of a balloon approximates the geometry of a plane.

The third puzzle is a rather technical one: How can the production of the exotic particles called magnetic monopoles, which the grand unified theories say ought to exist, be reconciled with the big bang? Monopoles are generated during the phase transition from the symmetrical to the asymmetrical phase, and the number of monopoles generated is proportional to the rate of the phase transition. In the standard big-bang model the transition is so fast that monopoles are produced copiously; indeed, there are enough to imply an unreasonably high density of matter in the universe. In the inflationary model the phase transition is slower and the monopoles are not nearly as abundant.

The most serious difficulty for the inflationary model is accounting for the clumps of matter that are the most salient feature of the observable universe: galaxies, stars and planets. Small fluctuations in the density of the early universe either disappear entirely or collapse far too quickly to account for the observed distribution of matter. Galactic clumping, in the view of several investigators, may have come about later.

Autosplicer

In virtually all organisms genetic information is encoded in the nucleic acid DNA and is transcribed into three species of the similar nucleic acid RNA: messenger RNA, which is translated into protein, and ribosomal RNA and transfer RNA, which have roles in the process of translation. The various steps in transcription and translation are mediated by enzymes, the protein catalysts of biochemical reactions. There are enzymes called nucleases, for example, that cleave a nucleic acid into pieces and ligases that connect the pieces or form a single piece into a circular molecule. It has been taken for granted that for every