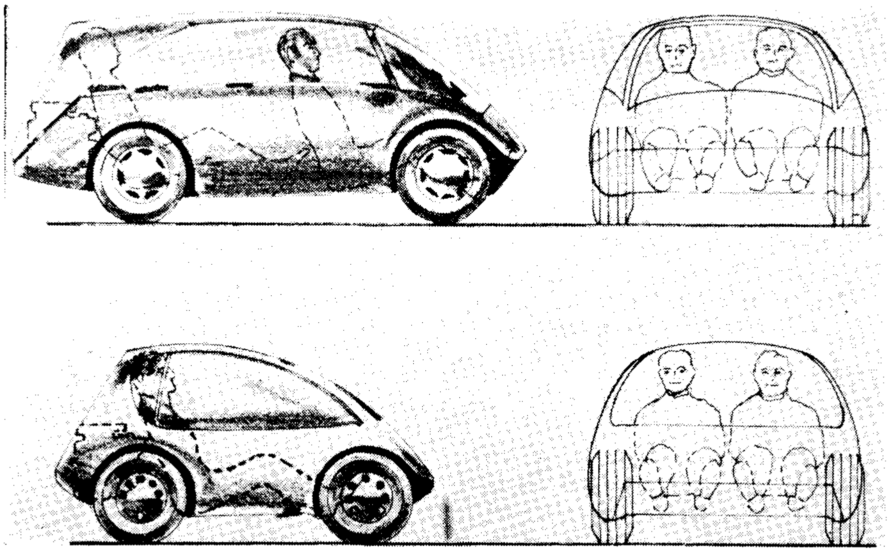


—*Courtesy of General Motors.*

Sketches above are artist's conception of limited-emission vehicles now being designed for diminution of air pollution and easing of urban traffic jams. In experiment planned for Philadelphia by University of Pennsylvania under subsidy from U.S. Department of Housing and Urban Development, small light-weight cars would operate by coin or punched card as pay telephones now do; parking lots at railroad stations would hold vehicles for commuters, who would drive into town, debark, and leave the empties for recovery by a community pickup service.

by social, political, and economic forces—the organizational structure of a company, the attitudes of people. So I urge that the engineer, if he is to be effective in a modern world, has to be literate. He must have some concept of the society in which he operates—its economics, its politics, its art, its esthetics, its laws. The society of engineers must encompass people who are deeply wedded to the value systems of our society—men who concern themselves with whether or not engineering is worth doing at all. It is a travesty, in my view, that engineers are responsible for the design of vehicles in which so many people are killed or maimed. It is a travesty that engineers are responsible for the design of industrial plants that pollute our atmosphere and our streams. Engineers must feel a sense of moral values through which they weigh the consequences for evil as well as the consequences for good of their work and make some judgments between them.

J. Herbert Hollomon was the first assistant *secretary for science and technology in any* Cabinet department in Washington. Now deputy secretary of the Department of Commerce, he will soon become president of the University of Oklahoma.

WHAT LIES BEYOND VIETNAM?

3. Planetary Engineering

—*U. of Miami.*

By S. F. SINGER

DURING our lifetimes, and especially in the past few years, we have witnessed a sudden extension in the scale of exploration of our physical environment away from the surface of the earth: down into the oceans, and into the earth's crust towards the mantle boundary, as well as upward into the atmosphere, and even beyond the atmosphere toward the moon and earth's neighbor planets. Coupled with this explosion in our capabilities to *explore* has come a more modest extension of our *understanding* of the natural environment, especially of the relationships between different parts of the physical environment. In addition, important ecological relationships to the biosphere are gradually being unraveled.

The next step must surely be modification and management of the environment. Actually, this phase has been underway for quite some time. In his fight with the natural environment, man for thousands of years has been forced into the position of finding or constructing protective shelters, principally against the weather. Through agriculture and irrigation, man entered the stage of transforming to some extent the external physical environment. This has been a haphazard process, largely unplanned, and conducted on a small enough scale so that its consequences have not been felt on a world-wide basis. But as the industrial revolution has amplified the energy management capability of man, major projects of environmental modification have been carried out: e.g., the digging of the Panama Canal, the filling of the Zuyder Zee in Holland, and, quite recently, the Snowy Mountain Project in Australia which resulted in reversing the course of several rivers for purposes of irrigation and generation of electric power.

In addition to planned projects, some unplanned changes have also taken place, including the severe water and air pollution produced by all kinds of human activities. Some changes were not only unplanned but also unnoticed until recently. For example, the burning of large amounts of coal and oil during the past 100 years has led to a large increase in the concentration of carbon dioxide in the atmosphere with consequences for the earth's climate that are not yet known with any certainty.

Powerful technical means are now at hand that can revolutionize the future of environmental control:

► Observational techniques based on earth satellites, which can give us detailed information on environmental changes over the whole globe on a nearly simultaneous and continuous basis. We can then trace changes in climate, and relate these to the behavior of the oceans, to the ice and snow cover and other properties of the surface, and to space radiation.

► Data-processing methods based on electronic computers, which can convert this mass of data into meaningful quantities that the brain can grasp.

► Cheap and controlled energy based on nuclear fission reactors and even nuclear explosives. Controlled hydrogen fusion is still eluding us; but eventually, the availability of energy from hydrogen atoms will change the energy dimension again by orders of magnitude.

► Development of systems analysis concepts and methods, and of people who are trained to deal with incredibly complicated technological problems.

With these tools at our command, we can think of tackling not only the immediately pressing problems of air pollution and water pollution, but we can look ahead to the needs of a growing population in coming decades. We can visualize the modification of the weather to eliminate damaging storms and hurricanes, or to utilize and direct rainfall into areas where it can be useful. We can look to giant projects of water management: converting Long Island Sound into a fresh water reservoir; or even the $100 billion North American Water and Power Alliance proposal to redirect some major Canadian rivers (now flowing into the Arctic Ocean) southward into the United States and Mexico at the rate of 160 billion gallons of water per day.

Inevitably, such major engineering projects will change not only the hydrology but also the climate of the North American continent, and will certainly produce world-wide influences. Various schemes, some fanciful, some more realistic, have been suggested specifically in order to modify world climate: e.g., removing the reflecting snow cover and increasing absorption of solar energy by spreading soot over large snow areas, changing the ice cover of the Arctic Ocean, or deflecting the course of certain ocean currents.

THE real problem is not so much the technical one of carrying out such projects but rather the precise forecasting of the resulting change in climate to make sure that the modification will be stable and will not result in any appreciable overshoot. As an example, consider the geophysical consequences which are introduced by a warming trend in the earth's climate. The warming affects the surface temperature of the oceans and causes melting of glaciers and icecaps and, therefore, an increase in the sea level. As the sea level rises, low-lying land will be covered with water. Ice and land appear to be relatively white as viewed from space, while the oceans appear to be black. With less solar radiation being reflected back out into space, this results in greater absorption of solar radiation, which results in increased heating of the earth, which results in increased melting of the icecaps, increased sea levels, etc.

Is this effect, once started, a cumulative one or are there factors which will limit its propagation, e.g., atmospheric circulation effects leading to changes in cloudiness? What we are really asking is the following question: Are changes in climate taking place which are irreversible and might even accelerate, or is the climate of the earth so stable that whenever some influence upsets it, other factors enter to bring back the original equilibrium state?

Here we see immediately the close connection between applied environmental sciences—planetary engineering, if you wish—and basic scientific understanding. We need to understand, for example, the origin and cause of climatic changes, both of the major ice ages and of the smaller fluctuations. We need to know whether the transitions between these different states are inherent in the earth's atmosphere-ocean environment or are produced by external causes: fluctuations in solar activity, variations in volcanic activity, changes in the inclination of the earth's axis, or geophysical redistribution of the continents, the oceans, and the mountain chains.

It seems possible (and this is a conclusion reached from geological evidence) that a reasonably wide range of climatic conditions can occur without drastic changes of an astronomical or geophysical character. Perhaps then the equilibrium of the climate is not very strong; we may find that it can be influenced if we can only find the sensitive point at which we should apply our limited human influence.

As a matter of fact, many human activities are already producing influences on the atmosphere and on the hydrosphere. The increase in carbon dioxide due to industrial effluents, the introduction of new ingredients because of pollution, the change in the moisture circulation due to land use, and, finally, important changes in the composition of the stratosphere and higher layers of the atmosphere. All of these, and others, may already be exerting some kind of influence on world climate. For example, we have realized that high-flying jet planes produce contrails which are really artificial cirrus clouds, tiny ice crystals that can remain in the atmosphere for long periods of time. Now Roscoe Braham of the University of Chicago has found that cirrus clouds can act as triggers for storm development and, therefore, could affect the weather at lower altitudes.

HERE, then, is the real hurdle: In order to reach the stage of environmental control, we must first gain scientific understanding; and this is closely coupled to higher education. A pioneer in the problems of environmental sciences, the late Dr. Lloyd V. Berkner, once remarked to me that in order to deal with the big scientific problems of the environment, such as the origin of the atmosphere, one really needs to have three Ph.D.'s: in astrophysics, in geology, and in biology. Our academic programs, however, are not geared to produce multidisciplinary scientists. Instead, they turn out extremely capable specialists in particular disciplines. As a result, it is unusual for a young scientist to be able to work effectively in more than his one chosen discipline.

A classic example of a multidisciplinary study is Berkner's own pioneering work on the development of the earth's atmosphere [see *SR*, May 7, 1966]. The rise of oxygen in our atmosphere came about because of a complicated interplay between the solar ultraviolet radiation on a primitive reducing atmosphere which was released from the melting of the earth's rocks. Only after life developed on the earth, evolving to organisms capable of photosynthetic reactions, did the highly oxydizing atmosphere that we have today develop. Such an atmosphere appears to be unique, at least in the solar system, and for reasons which we can only dimly perceive at present. In any case, as we begin to understand the evolution of the atmosphere, hydrosphere, and earth's surface features, as well as of the earth's interior, we may be able to tackle with more certainty the problem of explaining climatic changes and ice ages, and the predicting of environmental changes.

IT is clear that beyond this better scientific understanding, the planning and execution of major projects in planetary engineering require organization through appropriate government departments. As the scale of the undertaking increases, international coordination if not international cooperation is required. This point of view has been expressed extremely well by the distinguished Soviet geophysicist, Dr. E. K. Federov, who, as director of the Hydro-Meteorological Service, is directly responsible to the Council of Ministers of the Soviet Union. In a recent address to the Fifth Congress of the World Meteorological Organization, he stated:

> It is not difficult to understand that the problem of transforming the climate on a world or regional scale is, by its very nature, an international one, requiring the united efforts and the coordination of the activities of all countries. Ever more rapidly, humanity is approaching the stage in its symbiosis with nature, when it can turn to practical account all the natural resources of the earth and when, as a result, it will become capable of thinking in terms of natural phenomena on a planetary scale. In other words, man is becoming master of the earth. It is obviously no accident that this period coincides with our penetration of outer space. It is hardly necessary to prove, that in these circumstances, all mankind should regard itself as a single whole in relation to the surrounding world. There is no other way.

Dr. S. Fred Singer, a physicist, is perhaps best known for his prediction that magnetic fields would be found to surround planet earth in precisely the regions where they were found by Dr. James Van Allen of Iowa. Dr. Singer is now chief science adviser to the U.S. Department of the Interior, with deputy assistant secretary rank.

4. Deep Sea Exploration

—*Library of Congress.*

By EDWARD WENK, JR.

I WELL remember the skepticism, some twelve years ago, that greeted the concept of going beneath the thin layer of ocean then accessible to our military submarines. The arguments against running deeper ran as follows: To operate at greater depths required a stronger hull, and a stronger hull was then considered inevitably heavier. If more weight were committed to the pressure hull, other performance characteristics would have to be sacrificed. Thus, at a time when the genie of nuclear power unshackled the submarine from frequent surface refreshment, the opportunity to operate through the entire oceanic medium was deferred because it seemed to carry a price no one wanted to pay.

The feasibility of going deeper was demonstrated ten years ago by the transfer of very simple lessons from aircraft practice—to utilize structural materials with a higher ratio of strength to density, and to design with such high precision that a low factor of safety is tolerable.

An active family of research submarines has been spawned on those principles, and their importance to our nation is dramatically revealed by the increased number of dives by such vehicles. In 1965, about twenty-nine separate research dives were recorded. In 1966, the number exceeded 200. Although the ocean depths today remain as large a mystery as ever—an uncertain terrain under tremendous pressures—the first scouting has been made of the twilight zone of the continental shelf.

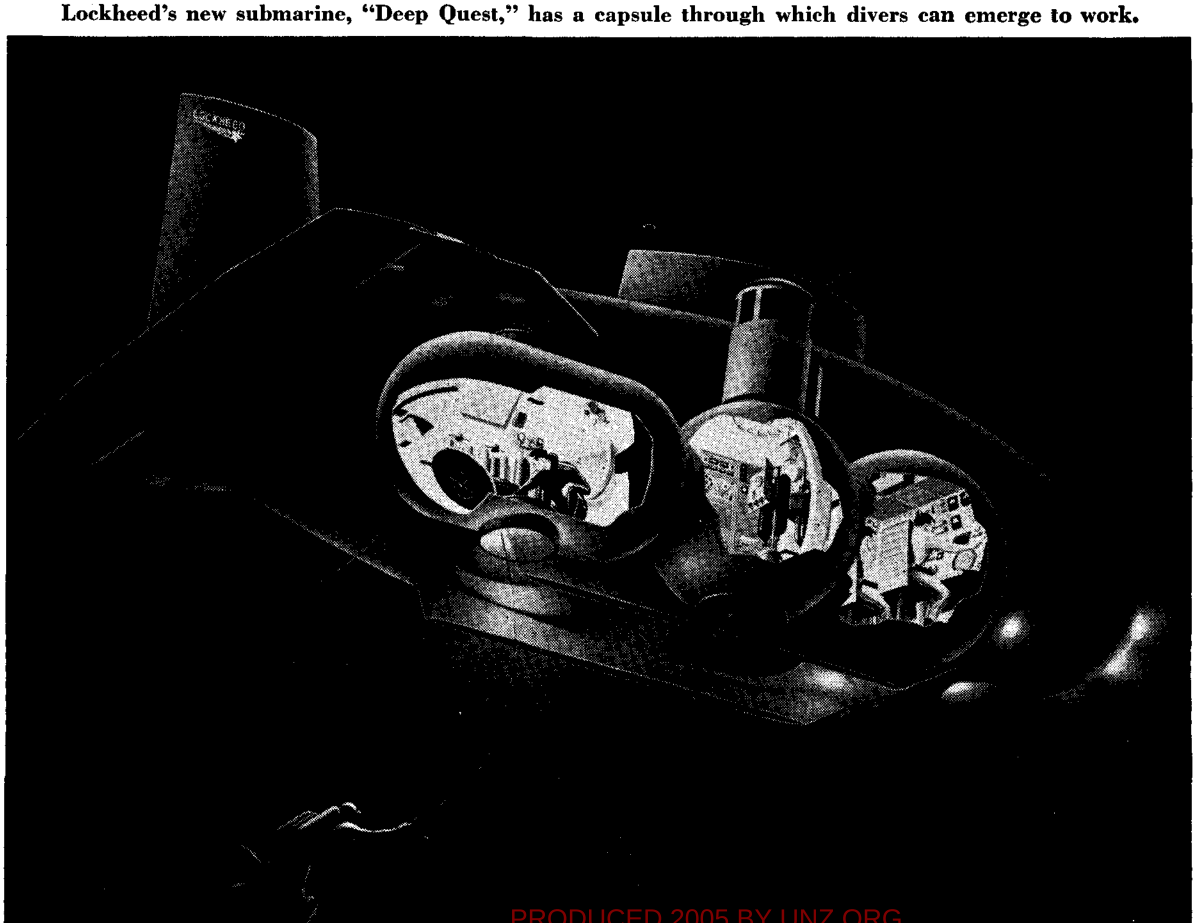
The [Lockheed submarine] *Deep Quest* can operate to a depth of 8,000 feet. Thus it has direct access to 20 per cent of the ocean floor, including all the continental shelves and the water volume above them. *Deep Quest* not only can probe; it can do useful work. Its operating experience will surely prove the design; it will also contribute valuable insights for design of still newer vehicles of the future.

Our knowledge and wisdom in the design of these vehicles must now be matched by judgment and leadership at policy levels. For it is here that initiatives arise as to how these submarines will be employed. No longer can we comfort ourselves with the idea that technological barriers, real or alleged, prevent us from doing the job. We are confronted with new realities of technology and world affairs, and we must be prepared to think through the question of goals for oceanic exploration and development and the priorities for mapping, examining, working on the sea bed.

FEDERAL and state governments, private industry, and universities all must share in setting both the course and the pace of this new venture. We must even project our study beyond our own borders. At a time when threats to world order continue to erupt and remind us how far we are from our goals, we must all the more seek areas where nations may work together. The deep oceans furnish one natural, even unique opportunity for increased international cooperation and increased understanding in an area that has not yet been spoiled by military confrontation.

The recent Treaty on Outer Space continues the precedent of the Antarctic Treaty in promoting peaceful uses of a new environment made accessible by new technology. Nations from both East

Lockheed's new submarine, "Deep Quest," has a capsule through which divers can emerge to work.



—*Lockheed.*