Technology in the Waning Century

BY WILLIAM H. PICKERING

After the technological bonanza of the 1960's, science and technology changed almost overnight from hero to antihero. What are the prospects now?

Science, no less than other fields of human endeavor, has always had its germinal periods that have left indelible bench marks along the paths of history.

We like to look at Newtonian physics as such a landmark in establishing the concept of law and order in the universe, leading to the emergence of modern science and the application of the experimental method in research. The industrial revolution of the last century, by harnessing power to the production of goods, became another dynamic force in the evolution of our modern technological civilization. Today, we are experiencing what has been called the cybernetic revolution, in which we are adapting automatic control and electronic computing devices to simulate some of the complex switching network functions of the human brain and nervous system.

These years since World War II are in many ways

remarkable decades. The advent of the Atomic Age in the late 1940's unleashed the dream of science, promising to remake the world in a new image. Technology would find a solution to the postwar problems that followed the troubled peace after Hiroshima. All mankind would co-exist without war, without want, without fear.

But first, it was necessary to achieve security if we were to follow the men of science along the path to lasting peace. And that meant developing an intercontinental missile capability to counter the Russians, who by now also had the Bomb.

During the 1950's, we entered a period of frantic technological growth, an era largely dominated by the rocket engine makers, who were attempting to adapt the visionary experiments of Goddard and Malina to the harsh realities of the launch pad at Cape Canaveral.

Then, as we seemed to be approaching a kind of missile and warhead parity, the Soviets orbited Sputnik in October of 1957. An emotional trauma shook the land. For the first time, we realized that American science and tech-

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nology were not supreme in the world, and that what we had regarded as a land of lumbering peasants could beat us into Earth orbit.

Our confidence was deeply disturbed. We searched in desperation for ways to revamp our scientific, industrial, and educational establishments. Because we had never shunned a challenge and our honor was presumably at stake, in 1961 President John Kennedy set as a national goal the landing of American astronauts on the Moon before the end of the decade.

What followed in the 1960's was a technological bonanza unique in all history. The thrust of the space program was felt in almost all areas of science and technology. Researchers who had spent most of their careers cloistered in isolated laboratories suddenly found themselves in great demand. Technological innovation spawned projects of unprecedented complexity. It seemed as if any conceivable technical undertaking could be developed and demonstrated. The difficult took a year or so; the impossible—men on the Moon—took eight years.

The obvious way to erase the bitter memory of Sputnik was to beat the Russians with men for lunar exploration and with instruments to probe the planets. We unveiled Apollo—possibly the most ambitious peaceful, technical undertaking in the history of the race. NASA became much more than an agency largely confined by its aerodynamic research mission. Now it would launch tons of rockets, spacecraft, and men into the Florida sky, looking toward a Moon landing a quarter of a million miles away.

This was a time when it seemed as though engineers and scientists were almost given blank checks on the federal treasury. There was no apparent limit to the promises of science and technology. The only constraint to be reckoned with was imagination. The laws of Newton and Maxwell governed an enormous variety of hardware projects, and the government was a ready customer.

Then, and quite without warning, something began to happen as the 1960's reached their midpoint. Vietnam began to develop into something more than a gunboat incident. Riots wracked our major cities; the campuses became hotbeds of demonstration and destruction. Ethnic groups found power they had never before exercised. Climactically, a new word was dredged out of the dictionary—ecology became the battle cry. Science and technology became the villains.

Suddenly, the glamor of space declined. Even Congress became less enthusiastic. The federal bounty, which had seemed endless during the glory years, began to dry up. We realized that the public had turned against the fountainhead; science and technology changed almost overnight from hero to antihero.

What had happened? Had technology been too successful? Had the public recoiled from the prospect of the Orwell syndrome coming to term before 1984? Had the New People, the uninhibited young, revolted against the computerized society, the era of solid-state electronics?

Perhaps the concern most loudly articulated was over the expenditure of billions of dollars to explore the solar system while millions of Americans were underprivileged and even on the fringes of starvation. Congressman and constituency alike wanted the money spent "here on Earth" where it could be immediately beneficial.

Among many intellectuals, there was a concern that space projects were really of interest only to the technicians, who worried over how their systems would perform in the vacuum beyond Earth's atmosphere while thousands died in Vietnam. They suspected that scientists were merely carrying on an esoteric dialogue with other scientists.

It was plain as the 1960's wore on that the era of technological *laissez-faire* had come to an end. Research could no longer be based only on the search for pure knowledge. There had to be an immediate fallout that could be measured in dollars and cents in the marketplace, that could be equated with the betterment of society.

What is the prospect for the scientific and technological establishment as we enter the last quarter of the century? Perhaps we should attempt to make a sober assessment of what seems to lie ahead beyond the Bicentennial of 1976.

We must recognize that we have lived in a time of rapid change and that change will continue. In the recent past, to a very considerable degree, change was largely dependent on science and technology for its motive power. In the future the driving force may be different, but we as engineers and scientists should not regret this fact, nor regard it as catastrophic.

Ours is the most advanced nation in the world, and most of our material progress stems from a steady flow of innovative technology as the fallout of a free and intellectually untrammeled science. Yet, isn't it ironic that ours is the only country in which a considerable portion of the liberal intellectual community would scuttle the technological base from which most of the nation's affluence and a major part of its power for good in the world have come!

In terms of the norm, perhaps the more sedate pace that has so far characterized the 1970's is preferable. There have been serious suggestions from responsible sources that science might take a well-earned holiday while society catches up with the breakneck technological productivity of the last two or three decades. Some even see the cure for our social, political, economic, and environmental ills in a reversal of the flow of time, in an effort to recapture a simpler, more innocent past.

There is something good and something bad in all of these suggestions. The only reality is that the problems are there and they will not vanish, even under the impact of a computer-backed study.

Garrett Hardin has pointed out that the engineer is schooled in a Newtonian world of physical reality, with exact cause-and-effect relationships, and a precise predictability to controlled events. Planck and Einstein modified these concepts, but only slightly. Newton remains the demigod in an ordered universe.

Now, it would seem that, in the future, the technologist will be dealing more with social problems—those of the urban sprawl, transportation, the environment, the troubles of the people. He will be confronting the quality of life more than the reliability of an electronic circuit.

Society will be his customer more than the government. And he will soon find that society is an amorphous assemblage of humans with widely divergent motivations and noncharacteristic reactions to stimuli.

In this world of people, the engineer will find that the responses are not Newtonian, but Darwinian. Cause and effect exist but only in a probabilistic manner. Experiments cannot be isolated in controlled environments; they must always be part of a larger world. The small and remote cannot necessarily be neglected. The inverse square law is replaced by the laws of exponential growth. An item as small as a single germ in a man's throat can change the entire course of history.

We are saying that the engineer and scientist must realize that they are no longer dealing with the immutable laws of Newton and Maxwell, but with the patterns of biological growth, of politics, economics, sociology, and psychology. When the engineer moves into this arena, he must doff his Newtonian cap and adjust to the Darwinian mode. This may be a difficult process indeed but, in the 1970's, the 1980's, and the 1990's, it will become more and more necessary.

Although we recognize that society has many problems that the engineer cannot solve, there is still much to be done in the sense of the high technology of the 1950's and 1960's, but at a materially slower rate of growth. The challenges will still be there: the exploration of the outer planets, the overwhelming question of extraterrestrial life, the solution of the energy crisis, the utilization of the ocean for food and mineral resources. We have succeeded in forcing back the door of our ignorance just a bit, and it is inconceivable that we will completely abandon further pursuit of these fascinating ponderables.

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In dealing with human problems, the engineer of the future will find that the customer is no longer a single autocratic government office with a billion dollar project, but comprises an infinity of humans, whose thought processes are legion, shattering completely his concept of logic. Consensus is a term dear to the poll makers, but it hardly exists in a pragmatic sense outside the political arena. The engineer will find little of the beauty of mathematics or the predictive behavior of the machine.

Patently, the engineer, working from a broader base and dealing with the intangible as well as the tangible, will find the rules of the game dramatically different. The solution to the problem may be software, not the sophisticated hardware of space. Defining the problem and establishing the hierarchy of responsibilities and interface relationships may be impossible, or, at best, imperfectly defined. Most frustrating, the extent of success may be difficult to measure. A social project of 1987 cannot be demonstrated by a test flight landing on target; an extensive statistical analysis of several years of data is required, showing, for example, a reduction in the incidence of sickle cell anemia in the black belt of Detroit.

Tomorrow's scientists and technologists will be needed to assist in solving the most profoundly complex problems facing society. They must, without loss of professional integrity, focus their attack on problem areas with a definite technological component that cannot ordinarily be resolved by social, political, and economic philosophers alone.

There will have to be an early recognition that these projects of the future will be quite different from those NASA/Department of Defense programs of the 1950's and the 1960's. They will involve systems interfaces with nearly all segments of society and many diverse political and ethnic groups. Technical managers will have to structure their teams to include the capabilities of behavioral as well

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as technical experts. They will have to refocus their efforts on social and environmental conditions that are largely open-ended, which cannot be so precisely defined and scheduled as a space project. They must often do this without being able to demonstrate success on a finite time scale. The manager of tomorrow must be a man of *Job-like patience, of great flexibility, highly skilled in the* ordered world of science and in the disorder of human behavior.

We have seen the idea of the mechanized world of Galileo and Descartes developing as a philosophical thesis, finally merging with Newton's rational universe and leading directly to the high technology of today. Now we see the prophets of technocratic doom predicting that the mega-machine will displace man in his own culture, that expanding science and technology are the root causes of most of man's problems.

As scientists and engineers, we do not agree with these pessimistic predictions. We can learn to integrate the sciences with the arts—to cross-pollinate the classical technical disciplines with the humanistic approach to the problems of society. We can learn to better the human condition with technological means. We have achieved a sort of virtuosity in working with hardware. Now we must apply these skills of analysis, synthesis, and management to those elusive factors that dominate human affairs.

The engineer and the scientist freed man from the constraints imposed by the use of human or animal labor and the industrial revolution ensued. No longer was it necessary for the great mass of mankind to work from dawn to sunset to obtain the essentials for survival. The use of cheap energy made possible all of the material advancements we take for granted.

Recently the engineer and the scientist have taken the next step and freed man from the drudgery of simple and repetitive intellectual labor, the cybernetic revolution. Cheap information processing is having just as profound an effect as cheap energy.

Science and technology must now show society that we can join the hardware of the industrial revolution with the software of the cybernetic revolution and bring mankind up still another step toward achieving its ultimate potential. That is the challenge of the closing decades of the century. ☐