FAITH OR GOOD WORKS

the justification of science and technology

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A local businessman asked me recently how long I had been in the Los Angeles area. Learning that it had been about a year and a half, he asked what I had done before that. I told him that I had been Secretary of the Air Force. He scowled and muttered something about the military-industrial complex. Then he asked me what I was doing now. When I said I was at a university, his expression became still less friendly. I could almost see his vision of of students bent on revolution, with their professors handing out matches in front of the ROTC building. Finally, I confessed that I was president of Caltech. He said, "What a mess you scientists have got us into! How are you going to get us out of it?"

The conversation made it clear that three of the least popular activities that a person can pursue in the United States today are those of the military, the university administrator, and the scientist and technologist. Although the combination of all three of these in my own history may leave me with a good deal to explain, I'll do that on some other occasion and confine these comments principally to a discussion of science and technology.

Why are science and technology the subject of special controversy today? Why do so many react to them and their practitioners with fear, anger, or—more mildly—merely disdain?

The first reason, I think, is that people tend to look at new problems which science and technology have not solved, or may even have helped to create, rather than looking also at the old and sometimes overwhelming problems which they *have* solved. It is the old attitude of "What have you done for me *lately*?" And I suppose that attitude is not entirely amiss. Professionals in any area ought to be prepared to answer it. But the question, of course, is prompted by people's forgetting that, for example, biologists and doctors are faced now with the problem of solving the degenerative diseases of the old, mostly because they have done so much in the past to reduce and nearly eliminate the acute physical diseases of the young. Those diseases are now the exception rather than the principal causes of suffering and death that they used to be.

People worry about the concentration of DDT throughout the biological cycle, and the poisoning of fish, small animals, and perhaps even man, that this concentration of DDT produces. And they *should* worry about this. On the other hand, the insect-carried diseases of man and of food crops have been virtually wiped out in many parts of the world because DDT has controlled those insects. Thus malaria, which until recently was the most common cause of death in the world (more people died of malaria than of heart disease or cancer or anything else) has been eliminated in many areas of the world. Now that's not necessarily a good reason to keep using DDT instead of finding new non-persistent insecticides, but it does show that DDT, like most technological advances, was introduced and developed for a humane purpose.

This case illustrates a major difficulty of technological advance. What solves the problem of one segment of the population does not necessarily help everyone. Indeed, we are well aware that it may create new problems. This situation is the more acute because we have not yet found a social and political mechanism to weigh and balance the positive against the negative effects of technological advance on the population as a whole, or on its segments. Nor have we found a way to balance off the positive effects on one segment against the negative effects on another segment and come to some over-all conclusion that is politically and socially acceptable.

Let me take another example. Our big cities, and sometimes our small cities, are plagued with air pollution. This is certainly a condition that must be changed, or life in them will become unlivable. But the technological advances that have helped create that problem are the same advances that gave us a mobility contrasting sharply with earlier times, when few men traveled as much as 50 miles from their birthplace during their entire lives. Today we know virtually no limits to travel—which may not be an unmixed blessing, but in any event it is one we are unlikely to forego—and the problems that have been created by this travel go with the benefits and can't easily be disentangled.

by Harold Brown

A second reason, I think, for the decline of science and technology in public esteem is that they have been oversold as a cure for all the ills of society and individual human beings. It is clear that scientific discovery and its applications in technology are limited in what they can do —limited by the resources of this planet, for example, and limited also by the nature of man. The scientific method solves by simplifying. But the simple truths one discovers through the scientific method can seldom be applied in any straightforward way to the complex ethical problems that face us all every day. And it is equally clear that the practical fruits of scientific discovery must be implemented by economic and political action.

In trying to explain current attitudes toward science we must also face a third factor. This is the fact that there is a strain of irrationality in man, a strain with a dark as well as a bright side. According to some modern anthropological theories, one can describe the dark side as the heritage of the aggressive instincts that were bred into our ancestors by the environment ten million years ago. Unfortunately, there has not been time for evolution to breed into us the changed behavior patterns so necessary now that we have come to possess enormously greater powers to destroy. And I suppose that a theologian might call this aggressive ancestral heritage original sin, Whatever you call it, this quality of man clearly does not welcome rational thought, let alone its embodiment in science and technology.

A fourth cause of the troubles of the engineer and scientist today—the current leveling out of support from government and private sources for science and for research and development—was inevitable for economic reasons, too. Expenditures, both the total for research and development and for basic scientific research in the universities, grew in the late 1950's at the rate of about 15 percent per year. This growth was triggered to a substantial extent by the launching of the Soviet Sputnik, which was only 13 years ago but seems so much longer ago than that. That event conveyed a correct signal to us but probably one that we saw in too simplistic terms. The signal was that no country that lags in scientific training and its technological applications is going to be in the forefront of wherever it is that our civilization is taking us.

During the early 1960's, government planners for science and engineering could identify continuing future requests for large and expensive programs that called for many more thousands of scientists and engineers each year than were then being trained. These planners also noted that expenditures for research and development were less than 2 percent of the gross national product, and that basic science consumed less than one-half percent of the GNP. What we forgot (and I say "we" because I was among those who made those projections) was that such technological projects, however much sense they made to their sponsors, would not automatically be funded in the face of competition from the needs and desires of other segments of the population.

Federal research and development expenditures amount to something between $17 and $18 billion per year. Total research and development expenditures in the United States are about $24 or $25 billion per year. The fact that such a figure is only about 2 percent of the current gross national product does not make it seem a small amount to the taxpayers and stockholders who have to provide that money. Neither does it seem small to the government officials and industrial managers who have to decide whether to spend funds on science and technology or on capital investment or, instead, on social welfare or on the solution of other urgent problems. And during the early 1960's—that period of hopeful planning—there was a failure on the part of the planners to communicate to the public either the long-term nature of the practical benefits that flow from science or of the benefits to the human spirit which accrue from knowing how nature functions.

The results of these public attitudes toward science and technology created a severe crisis as government funding began to lose momentum. In the mid-1960's the rate of annual increase dropped from about 15 percent to about 5 percent, and in the late 1960's, at about $18 billion per year, the annual federal funding for research and development leveled out. Meanwhile, price levels have continued to increase. This has resulted in a net shrinkage, by as much as 5 percent per year, of the actual program being carried out. In other words, the work being done goes down at the rate of about 5 percent per year even if the funding stays the same because prices

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go up by about 5 percent per year. This happens both in technological development and in the basic research carried on in the universities. To be more specific about basic research, the federal obligations for academic science, which is another word for the same thing, increased by less than 2 percent from 1967 to 1969, standing in 1969 at about $2.3 billion.

I believe that the future public funding of academic science can be fully justified at a level which is at least a constant percentage of the GNP. This would mean, over an extended period an increase of something like 4 percent per year in constant dollars. In current dollars that would mean perhaps 7 or 8 percent depending upon what inflation rate you think will have to be added to the 4 percent. In other words, if the economy levels out so that inflation is reduced to just a few percent per year, then if the real GNP increases by 4 percent per year, it is not unreasonable for the funding of basic science to increase at a rate (in decreasing-value dollars) of 7 percent per year. But whatever the inflation rate, a reasonable projection would be to have the funding of basic science roughly a constant percentage of the gross national product.

In the late 1960's the change in the attitude of the federal government toward funding of basic research was paralleled by a shift in the interest of the large private foundations, which had done so much through their seeding efforts, ranging from support of astronomy and nuclear physics to that of biology and medicine. Those seeding efforts still yield fruit in such diverse areas as the control of thermonuclear power and the creation of the "green revolution" which could double agricultural yields in some parts of Asia. But many of the foundations have turned their interests and their funds to proposals which hold out some hope of rapidly ameliorating urgent situations in such areas as race relations, poverty, and elementary school education—problems which, if we fail to solve them, may indeed destroy us as a society and as a nation. Some industrial organizations have followed the same road to some degree. It is too early to tell how successful these activities will be or even how successful they have been in the past five years. What is clear is that there has been in the past five years a substantial diversion of funds from the support of basic science to such approaches.

The leveling or decrease of support, accompanied by continued cost inflation, has put severe pressure on academic programs—damaging pressure that goes beyond the positive encouragement of greater efficiencies.

Even with increased efficiencies, static or decreased funding and increasing costs have resulted in the deferral or elimination of critically important new programs, and I can give some examples at Caltech. For example, it means for us several years' delay in valuable new research programs, among which is work in behavioral biology to study why organisms, and people, behave as they do for both genetic and environmental reasons. And we are just now in a position to begin to launch an exciting new program to bring together social science and engineering to examine and help find solutions in such problem areas as population growth, the use of technology for economic development, and environmental quality.

There is no doubt that we're going to do these things anyway. But they will be done later because of the difficulty in finding funds. And by delaying their accomplishments we risk a great deal, because the problems to whose long-range solution these will ultimately contribute very substantially are, in fact, becoming more acute all the time.

Also badly hit are the new opportunities in the fundamental studies of the behavior of matter—both in its very largest aspect as represented by radio astronomy which tells us about the distant galaxies, and its smallest aspect as represented by nuclear and particle physics. And the same is true for studies of matter in its medium-size aggregates, studies of things like the catalysis of chemical reactions, which might enable us to control biological and chemical processes.

Now, doubting that science and technology are worthy of the very substantial monetary costs required, government agencies, Congress, and private donors as well are apparently establishing a pattern of reduced support. I believe they should think again. Why? Perhaps the title of this paper, "Faith or Good Works—the Justification of Science and Technology," contains a hint. During the 16th century, and tracing back of course to earlier scriptural writings, theologians argued about how men could achieve salvation. The conflicting doctrines were those of justification (which means salvation) by faith and justification by good works. Science and technology can be compared to these two paths. The pure scientist seeks knowledge for its own sake. And the effort to understand the universe, including the nature of life and of thought, is the essence of the intellectual effort of the past few centuries. In practice, the work of the technologist is often similar, but it is done with a specific goal in mind—the control of nature and the solution of human problems.

One justification of the value of a high level of support for science is the link between it and technology. This link is clearly revealed by a backward look. Every modern comfort (or pleasurable vice, depending upon how you look at it)—television, rapid transportation, all the material benefits which go by the name standard of living, and the very easy access to education, to art, to music, and to literature—all of these depend on the technology which has evolved over the past few hundred years, actually most of it during the past one hundred years.

Each one of these technological advances depends on discoveries in fundamental science. Some of those discoveries took place a few years before their technological application, some 10 years before, some 50 years before. Some of the scientific discoveries (e.g., nuclear fission) were immediately seen by their discoverers to have far-reaching technological potential. Others (e.g., the Mendelian laws of heredity) languished unknown for decades before they were applied. But over time, the use through technology of scientific advances returns an enormous payoff to society.

The second justification of the value of a high level of science and technology—and of equal validity—is the enrichment of the human mind and spirit by science. Scientists and engineers are not often adept at conveying to the public the value of this function. But it is in fact vital to modern man to have a consistent, logical, believable picture of nature. Man evolved and is still evolving from the life process. Life itself grew from the planetary surface by a marvelous, one might almost say miraculous, combination of elements combining in increasingly complex molecular forms. This planet itself was created by the cosmological processes which began when our universe began. Our knowledge of such matters is still fragmentary; it would be a rash man who would say that we would ever know exactly what happened and exactly what laws govern what is and what will be. But even working on these problems conveys a sense of man's belonging in the universe, a sense which modern man seems to have lost—a loss which has resulted in a deep impoverishment of spirit.

The teaching of science, to the technical and non-technical alike, needs to stress these factors. To have such concepts taught from a base of experience and understanding requires that the teachers be researchers as well, in the forefront of research. To teach the engineers, physicians, and other professionals who apply science for the good of society, we need physicists, chemists, biologists, geologists, and other pure scientists who are professionally outstanding, and that means we need to support their research.

The development and continuing growth of science and technology in southern California require special discussion. In a very real way, I think, the difference between southern California in 1920 and southern California in 1970 can be explained by the interaction of two things. The first is sunshine and the attraction it has for people. The second is science and the applications it has in engineering and technology. One may ask whether southern California is better in 1970 than it was in 1920. Certainly it is more crowded and more polluted. For some fraction of those who lived here in 1920 there was a graciousness and spaciousness that modern developments have not been able to reproduce. But it was so for only a small fraction of a very much smaller number of people. Without science and technology, how many of us would be able to live in what is still one of the more pleasant parts of the world?

The aircraft industry was equally a product of good flying weather and of the genius of the applied mathematician and aerodynamicist Theodore von Karman, whose students have spread far and wide as aircraft engineers and managers. The entertainment industry was brought partly by sunshine, but it has grown and flourished through the technological advances of sound and of television. The electronics industry is a product, pure and simple, of basic science converted quickly into technological application. Even tourism, attracted by the climate and scenery, is made feasible by rapid air transport. And the importation of electric power and water into the Los Angeles Basin in the 1920's, which made urban life possible here, was a product of the early flowering of technology. Specifically it was largely based on the work of the early engineers of the institution that was just then changing its name from the Throop Polytechnic Institute to the California Institute of Technology.

What the future holds is hard to say. I doubt that all of it is bright. We must concentrate more on the quality of life, on environment. We may be able, by understanding not only how man came to be but how he thinks—through the study of behavioral biology—to damp down some of his more aggressive and dangerous characteristics. It is foolish to think that science and technology can by themselves solve these problems. But solutions of our social or environmental problems will not and cannot be forthcoming without new technological applications, using science and technology to the utmost to create new things and methods and to increase our productivity. Nor can we solve those problems without a better understanding of man and the universe, an understanding in which basic science plays a fundamental role.

Science and technology have forged the high wire, material and intellectual upon which our society balances. It is hard to predict where we are going or whether we will be happier when we get there. But one thing is sure: This is no time to cut the wire.