Holst Lecture 1977

The Role of the Engineer and the Engineering Sciences in future Society

by Alexander King

Technische Hogeschool Eindhoven

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Holst memorial lectures

In 1976 on the occasion of the twentieth anniversary of the inauguration of the Eindhoven University of Technology, it was decided to commemorate future anniversaries with a Holst Memorial Lecture. The organisation of these lectures has been made possible thanks to the financial support of N.V. Philips' Gloeilampenfabrieken, Eindhoven. The Holst family approved the association of the name of professor Holst with the lectures. The first of the Holst Memorial Lectures was held in 1977.

The choice of 'Holst Memorial Lectures' as the title emphasizes the importance of prof. Holst in the fields of education and research in the Netherlands. His great interest in the application of the physical sciences to technology is expressed in the central theme of the lectures, namely 'the development of the technical sciences and their interaction, on the one hand, with the physical sciences and mathematics, and on the other, with industrial applications, and the consequent impact on society'.

Prof. Holst was chairman of both the committees which played a vital role in setting up the second university of technology in this country, that of Eindhoven. Indeed, he was closely concerned with it and made essential contributions to the philosophy on which the curricula of the various degree courses are based.
The remarkable thing is that, for the year 1956 when the Eindhoven University of Technology was inaugurated, the emphasis laid on the social sciences was very great.

Holst exerted a profound influence on scientific research in the Netherlands. He was Kamerlingh Onnes' assistant in Leiden and carried out the tests which led to the latter's discovery of superconductivity. Prof. Holst's most important contribution to scientific development was that, in the period from 1914 to 1946, he set up the Philips' Research Laboratories, whose first director he was. In a unique atmosphere which not only encouraged the untrammelled interchange of ideas but avoided rivalries and provided opportunities for international contacts, bringing specialists from discrete fields together, the research work carried out in those laboratories attained a high level of excellence in a relatively short space of time, developing forward-looking techniques in the process.

That the levels of knowledge and technology were highly esteemed in the Netherlands is evident, among other things, from the fact that, apart from Holst himself, many members of the staff of the Research Laboratories were appointed to ordinary or extraordinary professorships at Dutch universities, in fact, they still are.

The Holst Memorial Lectures are to be held annually preferably in December. A lecturer of international fame will in each case be invited to deliver an address on the chosen central theme from the viewpoint of his own discipline to an audience made up of interested people from industry, the lecturer's own field, students as well as members of the Eindhoven public.

The Holst Memorial Lectures
Organising Committee,

Prof.dr. H.B.G. Casimir

Prof.dr.ir. J.H. Hagedoorn

Prof.dr. P. van der Leeden (chairman)

Dr.ir. A.E. Pannenborg

Prof.dr. G.C.A. Schuit

Prof.dr. J. de Vries

Ladies and gentlemen,

It is both a great honour and a pleasure to have been invited to deliver the first Holst Memorial Lecture and to be amongst you in Eindhoven. To my great regret, I never had the privelege of meeting Dr. Holst, but from all that I have heard and read of his work, it is clear to me that he was a pioneer of the new generation of really science-based technology, in that he had a profound conviction of the importance of ensuring that engineering development was continuously interacting with the most advanced discoveries of the physical sciences. As an assistant of the great Kamerlingh Onnes, Dr. Holst participated at Leyden, in the discovery of the phenomenon of superconductivity and he was thus exposed to the creative excitement of fundamental scientific discovery, while, at the same time, impressed by their potentiality for practical application. It was the marriage of these two approaches which transformed the engineering industries gradually, from the empirical invention of earlier times to the sophisticated technology of today. Dr. Holst was well aware of the need to attract first class fundamental scientists to participate in the work of the Philips Research Laboratories of which he was the first director, much as people such as Langmuir and Cooledge had been enticed to the laboratories of the General Electric company at Schenectady and revolutionized its production. At the time, this was a rather radical approach, since so much of the new physics seemed so distant from the realities of engineering production and so theoretical, but Dr. Holst had the foresight to appreciate the general significance of the new research trends and made sure that their inputs would be available at Eindhoven. Teh inclusion of fundamental research scientists in his team also ensured the best of possible contacts with the scientific community and helped to maintain the continuing vitality of more applied research.

The same appreciation played a great part in the conceptual development and interdisciplinary philosophy of this university. Indeed, one of the most important functions of a university is to provide the point of contact and interaction between advanced thinking and the best practice in fields such as engineering, medicine and social development.

Before daring to approach the speculative topic of the influence of engineering on future society, it may be useful to make some remarks on engineering-societal contacts in the past. In classical times the engineer was greatly appreciated for his military assistence, both in the perfection of weapons and in the design of roads and bridges. This emphacis persisted up to and beyond the Renaissance when universalist genius as in the case of Leanardo da Vinci was sought by princes and tended to embrace art and the humanities as well as the mechanical arts. Indeed, until about a century ago, the total information bank available to humanity was sufficiently small that some comprehension in depth of a whole range of subjects was possible for all scholars and it was not uncommon that a learned theologian, for example, should be versed in physics, or natural philosophy as it was called at the time, in hellenic literature and engineering. Science was then understood as equivalent to knowledge as a whole and it was only much later that the Anglo-Saxon heresy arose, whereby science was taught in terms of chemistry, physics and the like and the rest of learning as the humanities.

By the end of the eighteenth century the natural sciences had begun to emerge in their present form, the phlogiston theory was dead and combustion was understood at last. It is not surprising that thinking men of that time should begin to speculate on how the new and rapidly increasing understanding of nature might be applied to the industrial arts. It is interesting in the context of our theme tonight, to recall the interdisciplinary discussions of the too little remembered Lunar Society of Birmingham, whose members were the fathers of the industrial revolution. This curious Society derived its name from the habit of its members who met regularly in Birmingham and who having dined and wined well and were replete with new and bewildering ideas, had to drive home, late at night to various towns in the English Midlands. They therefore chose to meet, for safety, on evenings when the moon was full. Of course they soon became known as 'the Lunatics' and enjoyed the conotation. William Blake wrote a lampoon on the subject. The group included scientists such as Joseph Priestly, the discoverer of oxygen, engineers such as James Watt, the inventor of the improved steam engine, and a number of industrialists such as Boulton and Wedgewood, who were amongst the wealthiest manufacturers of the time. Their discussions - the proceedings have survived - of course concerned the new findings of science as well as the problems of industry, but they also overflowed to politics, philosophy and religion.

This was a period when fears were expressed that there were limits to growth, a decade or so before Malthus' famous 'essay on population' and a couple of centuries before Meadows. A large part of the forests of England had been felled and burnt to supply charcoal for the metallurgical industries. It was known that coal existed in plenty, but it was difficult to mine because the pits were quickly flooded with water. The Lunatics with their multidisciplinary approach saw in Watt's engine a solution to the pumping dry of the mines and hence a plentiful supply of metals which would lead to further engineering improvements including the mechanization of the textile industry. Their records indicate moreover, a deep appreciation of the social consequences and envisaged a great upsurge of industry and wealth which could eventually abolish poverty.

The members of the Lunar Society, despite their relative affluence were quite radical. They held a dinner to celebrate the first anniversary of the fall of the Bastille and the rich merchants of Birmingham affronted by this, incited the mob to burn down poor Priestly's house. Fortunately, the dinner was taking place quietly in a hotel nearby.

This early realization of the possible marriage of the new science with industrial development turned out to be premature. The industrial revolution exploded brutally, although its inception saw many interesting social experiments such as those of Robert Owen and gave rise to much social theory, but it was in general a revolution of invention in which science played little part. It was only much later, after the discovery of the laws of thermodynamics, understanding of electricity and the development of organic chemistry that the content of the sciences filled up sufficiently to explain the phenomena of industry and to provide the basis for the arising of the science-based industries of today. During this period science and engineering were very far apart. Pure science retreated into the ivory tower and protected itself in academic snobbery. It is only necessary to recall the contemptuous comments of Clark Maxwell when he learned of Bell's invention of the telephone, that this was a mere commercial gadget devoid of any intellectual interest.

Nevertheless it was during this period that the basic characteristics of engineerings began to be formulated. Sadi Carnot, who enunciated the second law of thermodynamics expressed clearly the qualities to be expected of the engineer.*
'To know how to appreciate in each case at their true value, the considerations of convenience and economy which may present themselves; know how to discern the more important from those which are only accessories; to balance them properly against each other in order to obtain the best results by the simplest means; such should be the leading characteristics'.

Engineering has been defined as the art of applying mathematics and science to the economic use of materials and the forces of nature with judgement based on study and experience. The term economic should be interpreted broadly in terms of the optimum use of capital, materials, energy and human

* S. Carnot. Reflexions sur la puissance matrice du feu et sur les machines propes à developer cette puissance. Gautier Villars, Paris 1824.

skills, but with appreciation of moral, ethical and aesthetic values in the satisfaction of human needs.

What then of the future? Before considering the role of engineering and the engineer, it is logical to ask questions as to the nature of the society of the next decades as far as can be deduced from present trends. At present there is much confusion in the public mind as a consequence of the very different conclusions of different groups looking at the future. These are, erroniously to my thinking, generally classified as the optimists and the pessimists. I would prefer to regard these two schools as the wishful thinkers and the 'doom-breakers'. At the one extreme is the Hudson Institute of Hermann Kahn who, in his book, 'The next three hundred years' propounds the thesis that by the full and wise use of technology, it will be possible by then to provide an average income of twenty thousand dollars per capita to a world population, then of twelve billion.
At the other extreme are the warnings of the Club of Rome and other groups, that unless we have a radical change of policies, structures, attitudes and values, the future will be bleak indeed. The latter approach is not one of doom-saying, but rather a propylactic approach to the future. In 'the Limits to Growth' for example Meadows stated repeatedly that this work was not one of prophesy, but merely a warning that unpleasant things would happen in the future *if* existing trends and their interactions, existing policies and attitudes were to continue, *in order that* changes would be made to ensure that they did not happen. This was, of course generally disregarded by the critics. Adherents of this approach, to which I belong, are essentially optimists in that we are convinced that the situation can be modified for the better and hence that it is necessary to scan the world situation consistently, identifying both threats and lines prompting for meeting them. The real pessimists are silent and impotent.

The Present Trends

In a seminar here yesterday we discussed the 'State of the Planet' and many of the major problems facing our civilization. There is no possibility in the scope of this short lecture to repete these in detail, but in groping our way towards an understanding of the needs of future society it is necessary to summarize some of the trends.
Most of the mounting difficulties of society are not new; they have existed since the time of Malthus and of the machine breakers. What is new is the present scale of human activity. Everything today is big and becoming still bigger - the world population, the size of the cities, the populations of automo-

biles and the size of the bureaucracy. Many of the growth functions appear to be exponential, but, as with all such curves in nature, a flattening out appears and eventually this must inevitably be so in many of todays trends such as the population explosion. The real question is as to whether the levelling off will come through restraint and wise management in, for example, the world population explosion, or through catastrophy and intolerable extents of human suffering.

The problem areas of contemporary society, the resolution of which will determine the nature of that of the future, range over a wide spectrum from those of affluence to those of poverty. Above everything hangs the spectre of the early doubling of the world population - an extra million people are being added to the population of the planet about every four and a half days - with its needs for vastly increased food production and inevitable increase in the demands for capital, materials and energy. Owing to the very low average age in many parts of the world today consequent to recent demographic growth, the prospective doubling of the population will entail a threefold increase in the work force, mostly in places where there is already widespread unemployment and underemployment. Associated with this is the cluster of problems concerning inequity in the distribution of wealth between the rich and the poor nations, aggravated by a generalization of expectations to the third world, now aware of the dependence of the industrialized countries on natural resources from the less developed areas of the world. In the developed countries also height per capita income has not eliminated pockets of poverty, while generally people, accustomed to a steady increase in the material standard of living over recent decades of high economic growth, demand still further material and social benefits. Many basic issues are raised as to the future of energy supply, with the prospect of petroleum becoming scarce and inevitably costly by the end of the century and the question as to whether humanity is sufficiently wise to accept an essentially nuclear economy in the absence of any real prospect of de-coupling military uses from the peaceful production of nuclear energy and the possibility that the enforcement of the necessary safeguards would be impossible in a free society. Other problems include stagnation, balance of payments disequilibria and monetary difficulties, unemployment, race tensions, deterioration of urban conditions with increased crime delinquency and rising violence, alienation of many individuals from the society which nurtured them and general indifference, with cynicism towards the political system. Recent incidents of violence warn us how vulnerable the technologically based society is with its dependence on electricity, computers and communications nerve centres.
Environmental problems are of various types; direct pollution of air and water

from industrial, agricultural and human effluents increase with increasing numbers in the world, but can be minimized to a reasonable level at a cost which is high but bearable. More menacing perhaps, because insufficiently understood are the threats of irreversible and possibly fatal changes in the climate and the ecosphere as a whole, as the result of excessive emmissions of carbon dioxide to the atmosphere through the so-called greenhouse effect, or the destruction of the ozone layer above the earth, which protects us from ultraviolet radiation. It is ironic, for example that the advocates of a total nuclear solution to the energy problem dismiss the use of coal on a large scale as too dangerous.

In most of the phenomena catalogued above, there is a significant element of technology or science. Either the tendencies have been caused or accentuated by technological development, contain important technological ingredients, or else more research is required for their resolution. What is clear is that in attacking the problems of contemporary society, it is no longer realistic to expect the politician alone to provide the solutions. Equally, the economist, the engineer, the natural scientist or the sociologist in isolation can make only fractional contributions. There is a paramount need, therefore, for the cultivation of multidisciplinary approaches and for multidisciplinary research.
These, then, are some of the elements of the untidy tangle of interacting problems which the Club of Rome terms the 'world problematique'. We are facing not a series of separate difficulties which can be clearly formulated and tackled successfully one at a time, but a cluster of interacting problems so tangled the one with the others, that it is increasingly difficult to delineate discrete problems and apply discrete solutions, without disturbing other and apparently remote areas of the tangle. The habitual attempt to solve individual nodes of the problematique in isolation, is to be seen as the removal of external symptoms of a disease that has not been fully diagnosed. Removal of the symptom may initially seem to be an improvement or even a curve, but it can often change the balance of the system as a whole and cause other symptoms to erupt elsewhere in the body, not immediately recognized as related to the original difficulty.

The position of Europe

The different countries of the world are generally considered within three categories, the First World of the industrialized market economy countries, the Second World of the Marxist economies and the Third World of under-development. This political classification is quite unsatisfactory for our present purpose. The third world includes, in fact, a whole array of economic levels and possibilities - countries such as Brazil which approach first world conditions, rich but underdeveloped oil nations and the poorest of the poor, lacking almost everything. In the First World some nations such as the United States are rich still in energy and mineral resources, possess great capital and infrastructural assets and have a great food-producing capacity, while others such as the countries of Europe, East as well as West, while rich in capital and skills have little left in the way of natural resources. Some nations in this category such as Japan have very strong economies despite an almost complete lack of indigenous energy and minerals and are extremely vulnerable to the disruption of supplies from abroad. In reality there is a continuous spectrum of national conditions from the richest to the poorest within a global situation of interdependence, within which each nation has its own characteristics, its own strengths and its own problems.

Thus, the European countries, together with Japan, find themselves in a potentially poor sub-category amongst the industrialized nations, in contrast to the United States, Canada, Australia and the Soviet Union which are more richly endowed by nature. True, North Sea oil and gas may provide some alleviation for a few decades, but the resource poverty of the European countries will necessitate foreign policy and behaviour which will encourage their access to minerals and energy as well, to some extent, of food from the rest of the world.

A further characteristic, derived from demographic structures will mark, not only Europe, but the whole of the affluent world in the decades to come. While the population of the Third World is exploding, fertility levels in the industrialized countries is low and in some cases even below replacement level. This means that in the early years of the next century, the proportion of the world's population in the presently industrialized countries will have fallen to below 25% of the world's total. Furthermore the population average of the developed countries will be middle aged by the early years of the next century, while that of many of the less developed nations will be not much over fifteen. The worst that could happen would be the existence of an enclave of rich, elderly countries, heavily armed with sophisticated weapons and surrounded by the great majority of the world's citizens, poor, unemployed and extremely young. Such a situation could not persist for long, but the shadow of such a possibility should be sufficient to make possible some sort of New Economic Order, within which each nation would strive towards some sort of self-reliance but not self-sufficiency in a world of interdependence and mutual respect.

What has all this to do with the role of the engineer in the future society. A great deal, I think. Firstly, the demographic structure will mean a shrinking of the work force in the countries of Western Europe, while at the same time welfare systems. This will demand the production of greater resources by smaller numbers, a result which could only be achieved through technological innovation and the production of goods for the world market of high added value type. Thus the demand for engineers and research scientists, for modern trained managers and indeed skills of all kinds should be very great.

In addition, if a New Economic Order is achieved and the industrialization of the third world countries proceeds in a spirit of harmony and equity, there should be a very considerable increase in the demand for capital goods from Europe. Undoubtedly such an industrialization in the developing world would mean that the European countries would have tō open their market to textiles and other simpler manufactures from outside, with a consequent shrinkage of their domestic industries in such sectors. These factors and many others point to the need for industrial strategies in our countries which will favour greatly increased levels of industrial productivity, high rates of innovation and the production of highly sophisticated manufactures based on a supremicy of scientific and technological skills. Indeed, lacking as we are in raw materials and energy, the only resource in Europe is the skill and enterprise of our peoples. All this suggests that real efforts must be made to improve our educational systems at all levels, to increase our research and engineering capacities and to evolve the social system on a basis of equality of opportunity, retaining incentives to work and innovation. The prospects for this are by no means dim, but it is imperative that the political leaders are fully aware of the changing needs and plan for industrial transition well in advance.The rode and responsibility of the Trade Unions in such a strategy will be obvious. It will be essential for all to understand that long term stability and prosperity must not be sacrificed for ephemeral short term gains.

The future relations between government and industry require careful construction. An industrial strategy oriented towards automation, high manpower productivity and rapid technological innovation will demand a new level of understanding on both sides and a longer term thinking than is customary to either at present. Much of the technological innovation, with the supporting research will be very costly and possibly beyond the possibilities of all but the largest firms. It is probably only in Japan that this problem is already being faced. In that country leaders of industry have approached the government, pointing out that the next generation of equipment in many fields will entail enormous research development and design costs which can only be achieved through a symbiotic relationship between the two partners in identification of national technological objectives, planning of new innovations, provision of the necessary capital and division of the responsibilities between firms selected to complete the various elements. The establishment of an identity of interest between government and industry is far from common in Europe; too often Governments regard industry as a cow to be milked regularly and fully, while industry thinks of government as rapaciously robbing it of its hard earned rewards. This will have to be changed.

Employment aspects of future development may be difficult. High levels of productivity and an ever increasing extent of electronic control will tend to reduce jobs, so that, unless an ever increasing overseas market can be maintained, technological unemployment is to be expected. Indeed, we may have reached the situation feared by the Luddites at the beginning of the industrial revolution where the replacement of men by machines becomes a reality.

So far, such a situation has been held off by the fact that high levels of economic growth were sustained and new jobs created continuously through the extension of the market for the products of industry. It may be that we are now approaching saturation and that it will be difficult to maintain the growth rates of recent years, which unless deep changes in society are made could lead to endemic unemployment. Certainly, reduction in the proportion of the active population will alleviate this problem eventually and there is likely to be a still further increase in the numbers engaged in the service sector, nevertheless, if Europe is to attain the high levels of innovation and productivity necessary for its competitive survival, the total resources of society will be produced by a relatively small proportion of the potential work force. If a harmonious society is to emerge and individual fulfillment to be achieved, the focus will have to change from employment in the traditional sense to occupation, seen broadly as comprising productive employment together will subsiduary occupations of a craft, artistic and other natures.

Radical changes will have to be made with regard to hours and years of work, the educational system in the sense of life long learning and attitudes with regard to the work ethic, with a new stress on the subjects of how to encourage individual creativity and provide work satisfaction.

The Role of Technology

From its beginnings, technology has been the main agent of homo sapiens in his struggle upwards from subsistence. From the shaping of the first crude tools from bone or flint, the discovery of the wheel, the lever, the plough and the use of fire, until well after the industrial revolution, human ingenuity took the form chiefly of empirical mechanical and chemical invention. With the arising of the natural and engineering sciences, however technological progress began to become more deliberate and systematic in the harnessing of energy and the manufacture of multitudes of substances and products hitherto

the high proportion of elderly people will put great strains on the health and
unknown in nature. Now, a century later, science and technology have transformed society and, incidentally, politics.

Until quite recently, this transformation was regarded by most people as wholly beneficial and seemed to hold out the prospect of universal prosperity. Contemporary man lives longer than his fathers and in a better state of health, better nourished; many of the age-old diseases such as tuberculosis and smallpox have been conquered; infant mortality has been greatly reduced.

Modern communications and transportation have shrunk distance and made information universally available. Economic growth, derived from technology has given a high level of material prosperity to a considerable proportion of the inhabitants of the planet and still holds promise of unprecidented affluence. An apparently ever continuing economic growth is the explicit objective of practically all countries.

Yet technology is today regarded with suspicion by many, if not as an evil. By the late 1960s questions began to be raised both about the desirability of continued increase of economic growth and about the technology on which it is based. The ugly side of the latter had become apparent in the pollution of air and water, loss of satisfaction in work which was seen as inhumanly mechanized, sprawling cities and their faceless suburbs, student unrest, alienation, apathy and violence. These and many other unwanted side effects of technology began to be regarded by many as indicating a draining away of the quality of life. Amongst the young, there is a feeling that technology is an ugly manifestation of a greedy, unthinking exploitation by uncontrolled capitalism, despite the fact that the same symptoms are appearing in the socialist states. In reality it is hardly more sensible to put technology on trial as responsible for the modern ills, than to blame the knife of the assasin.

The real fault lies in the mind and the heart of the man wielding the knife - or of those who misdirect or misuse technology. Today each one of us has at his command many times the mechanical force of the frail human body, but there is little sign that human wisdom to manage and control this force has deepened during the last 2 000 years. The problem is then, not so much one of growth as of the quality of growth, not so much of technology as of its wise selection and management. Ultimately it is the wisdom of man which is in question, his ability to master complexity and change and to use the tools of science and technology for general human betterment rather than let them serve narrow sectoral interests for immediate gain.

This situation as well expressed in the Brooks Report to OECD in 1971*:

* Brooks, D.H. et al. Science, Growth and Society - a New Perspective, OECD Paris, 1971.

'Science is in disarray because society itself is in disarray, partly for the very reason that the power of modern science has enabled society to reach goals which were formerly only vague aspirations, but whose achievement has revealed their shallowness and created expectations which outrun even the possibilities of modern technology'.

If the evolution of the world situation is anything like what we have sketched, the need for still further technological development is beyond argument. Very considerable increase in growth is necessary, for example in the developing countries to produce the basic needs of the increasing populations and to remove existing hunger and poverty. The question is therefore whether the new technology can be oriented more clearly to meet the real needs of humanity as a whole, while respecting environmental and social requirements.

In Japan the government has decreed that in future, all technological development must be accepted only if agreed to be socially acceptable, while more generally there is much concern with the approach of technology assessment, i.e. investigations to forsee the social and cultural as well as the economic consequences of specific developments. In the United States, an Office of Technology Assessment has been set up, significiently, not by the executive arm of the government, but by Congress itself.

The time factor is particularly important in science and technology and is seldom sufficiently appreciated in national planning. The tempo of the world of science is wildly different from that of the world of politics. In economic thinking it is generally implicitely assumed that new technological development is spontaneously conjured up when required, in response to the interaction of economic forces. Much of the economists' hope of solving the longer term problems thus depends on an instinctive reliance on the 'technological fix' - without, however allowing sufficiently for the time constraints.

Research and development are inherently long-term processes. From the first arising of a basic new concept in the mind of the scientist until its generalized application in the form of a new product or process, or a new type of institution may take upwards of thirty years. Of course there are numerous smaller innovations on which the prosperity of industry depends, which can be accomplished much more quickly, while major developments can be greatly speeded up by massive efforts in crash programmes of the type which the United States used in the Manhattan Program to make the first nuclear bombs or to place a man on the moon. But such crash programmes are exceedingly expensive and are bound to remain the exception. In general, therefore, the research-development-production chain is very long and for energy, for example, threatens to be much longer than political and economic exigencies will permit. Even when no fundamentally novel features are involved the process is slow. For example in the French nuclear power programme - not a pacemaker in technological development - a quarter of a century elapsed between the first experimental pile going critical and the first nuclear energy flowing into the grid. When the rate of political, economic and social change is great, i.e. when the interval between successive, distinct sets of circumstances is shorter than the normal lead time of research and development, there is the fear that their results will appear in practice, too late to have a fundamental impact. In periods of slower change, new technological developments did indeed evolve frequently in response to the forces of the market and helped to create the wealth which we have enjoyed. In planned economics likewise are pursued mainly in support of a slowly evolving economic expansion. This question of the long lead time of research and development is seldom sufficiently appreciated at the political level, and much talk, for example, of the contributions which fusion or solar energy will contribute to future demand, is quite unrealistic on the time basis. The harmonious articulation of new technological development with economic policy thus requires considerable planning ahead and cannot always be left to the forces of the market. For instance the development work on the production of high calorific oil and gas from coal was abandoned in the United States and some other countries a decade before the petroleum crisis struck, because the low price of imported oil provided no incentive to either government or industry to prosecute this development. Thus when prices rose suddenly it was realized that ten years of development had been lost. It may well be found necessary in the future to bring a number of contingency processes to the pilot plant or prototype stage as a matter of national insurance policy, possibly by international cooperation to share the costs.

Some Desiderata concerning the Orientation of Engineering to meet the Needs of future Society

From the above arguments it would seem that more, rather than less technology will be required for the future purposes of society and the economy, especially in Europe. But this development will have to be planned carefully and aimed precisely to meet the needs. Its selection will have to be made in cooperation between government and industry and, for purposes of cost sharing, much of the European effort may have to be internationalized, presumably within the E.E.C., through consortia of companies. It will be essential that the developments are seen as appropriate with relation to the

social and cultural climate, be as pollution free as possible and aimed at giving the maximum of work satisfaction. Profound social and political modifications will be necessary to make this possible.
All this will make big new demands on the engineers of the future and will necessitate considerable reform of engineering education and, indeed of the educational system as a whole. We shall note here, only a few of the more important requirements.

The basic preparations for an engineering career will remain much as at present, with perhaps even greater depth of the scientific ingredients than at present and with early and regular exposure to practice. The growing size of the information base may necessitate a greater degree of specialization than at present. The necessity of relating engineering practice to the realities of social and economic life suggests that young engineers should not be restrained within the somewhat unreal environment of the university and it may be found beneficial to have the initial courses of short duration - a maximum of four years - with return to the university for further periods of a year at a time, after some years of employment.

It will be necessary for engineers to be given instruction in economic social, political, legal and ethical aspects of their work which will increasingly have to evolve in a framework of such considerations.

While engineering practice will have to attain ever higher degrees of professionnal competence than today, it will have to be a much more open profession than now, with diffuse boundaries towards fundamental science, economics, social studies and practice etc.

As seen above, there will be an important need for interdisciplinary attack on many of the problems. Engineers will find themselves increasingly as members of problem-oriented teams, working alongside engineers and scientists with specializations different from their own (for example the mechanical engineer with the electronics expert and the chemist) as well as with economists, sociologists, trades union representatives, etc. They will therefore have to be trained to communicate easily with such people.

There will be a great need for engineering generalists with a wide knowledge of the concepts and practice of their profession and able to assist planners, administrators and decision-makers in government and industry.

All engineers will be encouraged to have some understanding of the rudiments of management, even if only to make them effective as members of mixed teams so that they can appreciate in their work, the social and systems restraints.

Considerable attention will have to be given to the development of methods for the management of complexity, change and uncertainty; for example many alternative scenarios may have to be constructed with regard to solving problems with all the factors (for instance the influence on the environment or climate of a new technological development) before all the facts are known with certainty.

Engineering education will have to accomodate a growing number of people who will not practise in the profession but gravitate to management, government and local administration and politics. It is important that there should be a proportion of people in such occupations who possess a thorough knowledge of engineering concepts and understand the significance of applied research.

There will be a special need for a considerable number of engineers trained to analyse the technological and industrial development needs of the third world countries and capable of devising technologies appropriate to such environments. This will entail, amongst other things, the development of labour intensive technologies of a sophisticated character to meet the need of such countries to create employment.

The engineer of the future will be required to take into consideration the need for minimizing energy and materials requirements, devise recycling processes and to design consumer durables and other products on a modular basis to make replacement or repair of faulty components easy.

In conclusion we may summarize by saying that the role of the engineer in future society is likely to be very great and the tasks facing him will be formidable. It will be necessary for him to work in a social, economic and cultural perspective, to be fully aware of political and societal constraints and to be exceedingly flexible. The ever increasing and varied data base of the profession will inevitably favour a greater degree of specialization, but the temptation must be resisted to cram more and more specialized courses into the curriculum or to lengthen the learning period of formal education unduely.
Young engineers will have to be exposed to the real problems of society as early as possible and hence sandwiches of instruction and practice will be desirable. The creativity and inventiveness of research engineers should be a constant preoccupation of management and, for this purpose the inclusion of fundamental research scientists in applied laboratories is desirable.

The problems facing future society are indeed great and their solutions will depend much on acceptance by the public at large. This in turn demands a much deeper understanding by all of the problems involved, their complexity, interaction and importance for the future The image of the engineering profession will have to be such that their social responsibility is recognized by the public and they are, in fact, given the opportunity to make the major contributions which their knowledge and competence could provide.
For Europe the difficulties will be especially great, and the challenge is enormous.

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