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Opening Lecture

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PREFACE

I appreciate the invitation to give the opening lecture not merely because I am honored by it. The subject of responsibility has preoccupied me for a long time and, in a officially way of course. At present global peace depends on an equilibrium of fear; fear based on fifty thousand atom bombs in the arsenals of the superpowers. This fragile equilibrium could be disturbed by the appearance of new atom powers. Against such a proliferation there is the well-known treaty to which 114 countries belong and whose ten years of operation is being reviewed in Geneva at the moment. It is the job of my office to check by independent international in situ inspections whether the treaty obligations are being fulfilled by these countries. Roughly seven hundred atomic plants in 50 countries are subjected to this inspection which covers among other things a total of 68 000 kg of plutonium. Last year roughly ten thousand inspections were carried out in these countries. In the period between the inspections automatic cameras are in operation which have taken four million pictures in critical areas of these installations. The inspection system and its development require the most modern scientific and technical means; systems analysis, precision instruments, large computers, and many other things.

Due to this treaty and inspection system no additional atomic weapons power has been added to the list of those existing in 1964. On the shoulders of the statesmen and participating scientists and technicians rests the extraordinary responsibility maintaining this success and producing for the future a basic climate for a general nuclear disarmament. Although I address you out of a sense of personal duty and responsibility, I also feel obliged, out of a sense of scientific honesty, to admit that I am no expert on the subject of responsibility, if indeed there can be such an expert. All I can do is report to you how the problem appears in the mind of a physicist, and of course I will have to limit myself to a few points which seem important to me.

RESPONSIBILITY IN SCIENCE AND RESEARCH

If we are not severely mistaken mankind has reached a crucial turning point in this second half of the Twentieth Century. Such a conclusion can hardly be merely an error of viewing the past in present-day terms. The turning point has been heralded by a series of development-leaps that have followed one another in quick succession: the splitting of the atom, the conquest of space, microelectronics. It is also indicated by sudden new developments of knowledge in behavioural science and in molecular biology. It can even be read from the very "destiny curve of mankind", i.e. the increasing rate of the population growth which has leaped to seventy million per year and may reach a reversal in this decade. Another turning point should be mentioned: the exhaustion of fossil fuels as a cheap source of energy for the unparalleled expansion in production and consumption in the developed world.

Ahead of us, between the reversal of the population growth rate and the actual stabilization of the population of the earth in the next century, perhaps at a total of eight to ten billion people, there are going to be many decades of unbelievably difficult humanitarian tasks: There is not only the almost insoluble job to improve the lot of the two billion poor of today. Before we reach a world population equilibrium, many more billions of human beings will grow up in the poor countries and there will be no peace for the world until a reasonable existence has been assured for them too. To those who cannot live without bread the well-fed will first have to prove that man does not live from bread alone.

One would think that science, research, technology and economic power should be able to provide the material means to create a tolerable world for eight to ten billion people. After all, even the Club of Rome had to postpone for the time being the dramatically announced end of the world through the exhaustion of raw materials. None the less the enthusiastic acceptance of this premature announcement by many intellectuals of the western world has brought to light new limits to growth, limits that lie outside the material realm. There has been in the last few years in the western world, as another symptom of a turning point, a radical change in the attitude towards science and technology, thus towards the very foundation of our prosperity.

Nineteen years ago, when J.F. Kennedy challenged the American space industry to put a man on the moon within a decade and bring him back alive, the world of science and technology seemed alive and well. These vehicles of progress brought us not only almost unbelievable revelations about space, the structure of materials and the basis of life, but also effective means of combating hunger, poverty and illness and, at least in the West, provided for the first time in history a higher expectation of life in prosperity and freedom for the majority of the population. Futurologists and the media raised the public's expectations beyond measure. Everything seemed possible as long as science and technology could be used. The prestige of science was uncontested. Ambitious young people studied nuclear physics, and on television screens a doctor in a white lab coat told us that toothpaste X was scientifically proven to be effective.

This picture of a world completely governed by reason could not remain intact very long. It could not hide the fact that science depended on society and that its realization through political action was lagging far behind science and technology. We found out that the real world of man, even in our enlightened century, depended far more on emotions, interests, and irrationality than on reason and the desire to cooperate. With each new triumph of science and technology there-

fore the possibilities of abuse of their discoveries and products increased. And so we have the electric light and the electric chair, atom power and the atom bomb. As a result of this cleavage of technical and social development, we live in a world today which washes the laundry whiter than white and at the same time produces the blackest air; in a world in which people can be brought back alive from the moon while 300 000 people are killed in automobile accidents every year; in a world in which millions commit suicide with knife and fork while millions die of hunger.

Today, only eleven years after man's landing on the moon, science, research and technology are regarded more and more critically in the prosperous industrial countries (and not only in those) and we detect an increasing tendency to make them responsible for all sorts of ills, damages, and threats of our modern life. We fear that their progress creates more new problems rather than solutions for old problems. The media which just a few years ago rivalled with each other in the admiration of science and technology and created vastly exaggerated expectations are now devoted to attacking the authority of science, research and technology, now they have already undermined the authority of the family, the church, the state and the economy. To fill the resulting gaps they fuel and fan trends of irrationality. Weird and strange things are reported - and believed: e.g. archangels landing in spaceships, UFO's streaking through the sky, whole fleets of ships disappearing in the Bermuda Triangle. The morning newspaper tells you your fate in the horoscope and reports of alchemists succeeding with wondrous new drugs. The only thing missing is the engineer who is guided in the choice of a construction site by the flight of a bird or by the study of entrails! Even man's fascination and "longing for the end of the world" can be satisfied perfectly and in the most modern way: no longer by pitch, sulfur, pestilence and meteorites, but by computer predictions of growth catastrophies and exploding nuclear powerplants.

The pessimistic picture I have painted is intentionally exaggerated; we do not yet have to agree with Schelsky that in the western industrial countries the age of enlightenment is finished and that the second Middle Age has begun, nor with Oswald Spengler's view of the End of the Western World. None the less the symptoms described have caused scientists and engineers to think about their work and the effects of their work on society and its development. One thing seems to be clear: mankind will need to master the new critical phase which it faces, not with less but with more science and research. At the beginning of the industrial revolution when at least one billion people could be fed on this globe, Rousseau was applauded enthusiastically by intellectuals when he advocated the return to the innocence of nature. In our world with its five to 10 billion people, a romantic return to an idyllic preindustrial existence on a global scale would be completely inhuman. Only the wealthy in the affluent countries can enjoy this idyllic concept in a second home in the country, like Marie-Antoinette in Hameau.

The loss of confidence in science, research and technology is not only the work of a radical new generation which has, however, made tremendous strides in its march through the institutions and especially the media. The modern gloom and doom prophets would remain a small ridiculed sect if it were not for large sections of the population who see their own fears articulated in the exaggerated warnings of the prophets. Science, research and technology do appear to many pepple as a threat. Perhaps this is caused by "future shock" triggered by the incredibly fast rate of change of technical means. Another cause of the fear can be found in the side effects and waste products produced by our own increasing consumption. An understanding of these fears and a better appreciation of our

own role and responsibility as scientists and researchers, must be considered as a condition for the desirable restoration of mutual understanding and confidence.

With some imagination we may consider science and technology as the continuation of natural biological evolution by other means. Man's body and brain has changed very little in the last few thousand years. Man's behaviour, his moral and political insights, appear to change only slowly and from recorded history would appear to move within a few basic concepts only. In the last few centuries, however, there has been a dramatic and accelerated development in the picture of nature that man has been able to form in his own head and in the technical means he has been able to derive from this, for example in the means with which we have been able to "extend" our own limited organs or the artificial environments which have permitted our own weak body to exist in the ice of the Arctic, in the heat of the desert, and in outer space. If we admire natural evolution and regret the alienation of man and nature we should also remember that nature itself in the form of the human brain produced the possibility and "necessity" of this artificial evolution. Nature has, however, at the same time, given us the power to comprehend the damaging consequences of this development and has therefore confronted us with the obligation to accept the responsibility for our own actions.

One thing, however, is characteristic for the products of scientific thinking and technical creation: it is their neutrality towards good and bad and towards the inability of society to renounce its destructive tendencies. One can in fact view the changes brought about by science and technology as mutations in our world picture and in our artificial environment. The sign of these mutations, that is the plus or the minus, is determined by the selection process. In nature the elimination or adoption of new variants is determined by the altered chance of survival. In science it is the criterion of truth that decides, in technology the functional and economic success of the new creation. The critical difference, however, lies in the fact that nature itself eliminates or "forgets" the unusable mutants, whereas society does not forget even the most dreadful mutant. Even worse, in today's world the survival and promotion of a technical mutant is indeed assured when such a mutant is viewed as a useful means of destruction.

Ambivalent artificial evolution was fine as long as the effective range of the created weapons was limited to a few kilometers, and the concentration of artificially created waste products remained well under the concentration of natural waste products. These thresholds were, however, exceeded in the course of the last few decades by leaps and bounds. The fact that we have become aware of this situation is our problem. Nothing has accelerated this awareness more than the invention of nuclear fission which in a rationally thinking human society could have had only a positive aspect: the unlocking of an immense new source of energy, just at a time when the geological and especially the political limitation of fossil oil reserves became known. In the real world, however, nuclear fission became exploited first as an apocalyptic weapon and today the dichotomy of technical possibilities is represented by its peaceful use in 230 nuclear powerplants which have already produced over 3 billion Kilowatt hours of electricity, and by dozens of military installations stocked with 50 000 nuclear bombs.

Speaking of the dilemma of nuclear fission, we may ask the question whether it would not be possible to ban certain types of research which could have un controllable consequences. It is however clearly impossible to plan and actually carry out such a limitation. We must not forget that in many countries large portions of research expenditures are devoted to military research, a sad fact of life which we have to accept, as long as armed countries and blocs of coun-

tries remain poised as potential enemies.

Nor can we expect that the scientists involved in military research would be willing to enter into a strike against their own research. No matter how qualified and distinguished these people are in their own field of work, in their thinking and acting in society they are not distinguishable from the rest of their fellow countrymen. Naturally scientists are as interested as their fellow countrymen in the maintenance of peace and they are in most cases conscious of their special responsibility. Depending on the circumstances, however, many scientists may see it as their moral and patriotic duty to develop more effective weapons. There is an especially tragic example in Albert Einstein who during his whole life stood in the front row of pacifism. In 1940 he gained the impression, which as we know today was wrong, that his former colleagues in Germany were engaged in an effort to create an atom bomb and could therefore influence Hitler's war in a decisive manner. And thus he pleaded, with all his authority, for a quick development of an American bomb.

Today in an age that depends on a massive nuclear balance of retaliation of the superpowers, we know that the loss of this balance would create an unimaginable risk for mankind. It is therefore the first duty of every scientist, researcher and engineer to do everything in his power to push for the removal of all atom weapons and, as a long-term goal, to push for general disarmament.

In addition there is a basic problem here. In applied research and development it is possible to foresee the positive and negative consequences of a project to some extent in advance. In basic research this is impossible without barring entire research sectors, because the nature of the discoveries cannot be predicted. Early nuclear research, until 1939 for example, was an almost academic and rather unpractical endeavour, and many first class nuclear physicists at the time would have considered the practical value of their work as belonging to the realm of fantasy.

A research embargo would have moreover thrown out the baby with the bathwater and would have prevented very valuable discoveries, quite apart from the fact that, as I said, this would be completely impossible to carry out on a global scale. A few years ago for example some very responsible researchers pointed to the risks of their research because of possible mutations of the genetic material of microorganisms. Frightened citizens of a well-known University city mounted the barricades for a ban on this type of research. Today we know the actually small risks of this research much better. The anger of the population has disappeared and research is producing drugs such as Insulin and Interferon by manipulating certain organisms genetically.

This observation leads us to a further aspect of scientific responsibility. It is exactly the triumphs of medical science which have contributed so much to the fundamental calamity of our times, the population explosion. If this had been recognized a hundred years ago, what should have been done? A ban on medical research? A ban on the transfer of new medical knowledge and procedures to the colonies of the southern hemisphere, that is: should we have left the people of those countries in the hands of the medicine man? The correct humane solution would have consisted in an effective educational program and a prompt improvement in the living standards of those countries. The reason that this did not take place can again not be put on the shoulders of science and technology but rather be attributed to the lamentable dependence of science on man and his behaviour and also to the political inability to transform the positive potential of such a knowledge into a societal reality.

The special responsibility of scientists and engineers stems from the fact that they are the people who discover all these new possibilities in our technical world and make them a reality. It is to them, who sit closest to the origin of all this transformation that we must look for a realization of the consequences of these projects and, if necessary, for a warning of the consequences. The question is whether they will be able to anticipate the consequences of their own actions and also whether they will be listened to. In the case of basic research we have already stated that we cannot expect such anticipation, and that we simply have to accept that some revolutionary discoveries may descend upon an unprepared human society. In applied research, however, and especially in technical projects we can often assess possible impacts. The code of ethics for science, research and technology therefore has to be broadened to include an obligation to assess for each project the possible side effects and long term consequences with the same care as the details of the project itself. In this respect much has already been achieved in many countries, including measures required by law and even the creation of special agencies for the review of the consequences of new technologies.

This request that he understand and assess the consequences of his own work is, however, often expecting too much of an individual and isolated specialist or scientist. One of the reasons for the growing uneasiness about modern civilization is that the world has become an indivisible and interdependent whole and that unfortunately the specialist in his painstaking work can only see a part of it. Technical activity based on limited and inaccurate knowledge can lead to unexpected reactions from the whole. Such reactions can become threatening if the changes are widespread and massive. This for example is the case with today's environmental problems. The consideration of the interdisciplinary connections requires a high degree of coordination of knowledge and action and cooperation between specialists. This needed cooperation may have its problems as seen through the eyes of the specialists.

The criticism of those specialists who can only see their own small scientific subject is justified in a world whose interdependence can no longer be ignored. This criticism has however been whipped up in recent years to the false accusation of the "idiocy of the expert" which is often raised by those who know little (but pretend to know everything) against the "expertocracy". The solution of difficult interdisciplinary questions can certainly not be advanced if we replace the expertise of scientific idiots by the impertinence of universal idiots.

Sometimes it seems that a consensus between specialists of different fields is easier to achieve than between experts in the same field. Sometimes it seems that one could almost recognize a specialist by the fact that he disagrees with his colleagues. Nothing undermines however the confidence in science and technology more than a public feud among specialists, more than contradictions between expert opinions given on the same subject.

The complaint of the politicians that they, as non-experts, cannot make any decisions while the experts themselves disagree, is understandable. Politicians should however first satisfy themselves that in a given case it is a controversy between true experts, that is between persons who have been working in their subject for many years, who have planned, calculated, designed and constructed in their field. In many cases one would find that the disagreement is not about factual or technical matters. One party often consists of self-appointed quasi experts who feel attracted as by a magnet, by the opportunity of receiving attention by the media, especially through TV exposure or letters to the editor. It

is strange that often being against something seems sufficient to qualify as an expert. Moreover the inherent selection principles of the media help to emphasize the sensational with the result that politicians find themselves exposed to the characteristic hyperactivity and intolerance of opposing minorities, typical in our modern democracy, while the silent majority of those who really know something about the matter, stand back, stunned.

Unfortunately there are also some real experts, up to Nobel prizewinners, who succumb to the temptations of publicity, especially of television. This situation may lead to impressive but very subjective and almost completely false statements of well-known older men on questions outside their field of knowledge. Good old-fashioned scientific and technical ethics would require of such a person that he clarify his status at the outset, to show that his pronouncements are not "infallible". It requires a great deal of scientific courage from such a person to issue a public correction later if he finds his pronouncement to be in error. A remarkable example of this was given by Professor Eduard Pestel, Lower Saxony Minister for Science and Art. Six years ago Pestel and Mesarovic published a book, "Man at the Turning Point" as a contribution to the Club of Rome. In this book, Pestel, who is a first rate expert on system analysis but not on radiology, declared Plutonium the most poisonous substance in existence and added "the inhalation of one ten millionth of a gram of Plutonium causes with the highest probability, fatal lung cancer. A ball of Plutonium of the size of a grapefruit would be sufficient to kill all people living on this earth if its contents were spread evenly on all mankind." At the end of June this year Pestel noted at a congress in Hanau that he had found out that his statement had not been correct, that chemically Plutonium was no more poisonous than lead or mercury, and that as far as cancer was concerned, the effects of Plutonium as a source of radiation with long term effects had been exaggerated. Pestel quotes an example "Among 25 workers who, towards the end of the war, inhaled 20 times the allowable doses, not a single case of lung cancer has been found, in spite of the fact that 30 years have passed." And he continued, "Today I would consider my statement on the poisonousness of Plutonium, even if it had been correct in the stated form, as irresponsible. When such statements are made, and unfortunately one finds them all too often from the anti-nuclear people and from people against technology, they are usually made with the intention of producing certain emotional reactions. This often produces horror scenarios which are then repeated with real or feigned conviction by anti-nuclear people who claim to be scientifically informed."

Even with the best of intentions regarding professional honesty, some disagreements between experts are probably unavoidable because knowledge is incomplete and not always accurate. One can even say that disagreements between scientists at times of fundamental scientific developments, from the turning point of Copernicus to the relativity theory of Einstein, are indeed an essential vehicle for the advancement of new knowledge. What confuses the public, however, are the collisions between apodictical statements. To improve our credibility it is necessary to say not only the truth but the whole truth. And often the whole truth consists of the fact that scientific and technical statements are valid only under certain given conditions and with certain limitations. If the opponents were to emphasize such conditions and limitations more clearly they would discover themselves that in many cases the contradiction lies in the different assumptions and different limitations.

Disagreements among experts are often exaggerated and distorted by the fact that there are not only unstated assumptions but also divergent conceptual or social positions. Creations of technology and products of an industrial society which

are based on science, such as buildings, vehicles, means of communication, and consumer products, are often inseparable from the structure of society, from human concepts and from moral values. In this respect scientists and engineers are party to them perhaps without even knowing it. The deep change which has taken place in the last few years in the attitudes of many people to consumption, to risks, to our environment, can throw a technologist into a conflict if he does not realize the fact that his creations must also be judged on a human value scale. There may still be engineers, for example, who design automobiles for an outmoded value scale: prestige and comfort at the expense of safety and economy.

One thing that is especially notable is the change in the attitude of many people to damaging side effects that could not be foreseen at the time of the introduction of these new technologies or effects that were tolerated at first and became noticeable only through the multiplication of use. Among these are the damaging side effects of our beloved automobile, of food additives, of air and water pollution, or briefly, the pollution of our environment. It has become fairly common to blame science and technology for all of this. Certainly there is some truth in this. It is essential to recognize, however, that broad masses of the population are able to buy exactly those products from the market economy which they would like to obtain. The population at large therefore cannot be acquitted of the role of being a participant in this. The scientist and the engineer is guilty as a consumer. He, too, is tempted to say, like all the others, that it cannot be his car, his furnace, his swimming pool or his lawn mower that makes the difference.

If we were only dealing with professional abilities in science and technology there would be no environmental problem. Who can doubt that the ingenuity which put a man on the moon and brought him back, would be able to deal with air and water pollution, with noise and with industrial waste. In many cases it is not a question of new discoveries, but of applying simple means such as sewage disposal systems. As an example we only have to think of the saving of many Austrian lakes. The problem lies somewhere else. Of course we can develop durable, safe, pollution-free and efficient automobiles. Who, however, is willing to pay the price for these? We demand a cleaner environment, yet we pollute it ourselves. We consider the consumer goods as our own, and their wastes as the problem of society. If anywhere it is in this field that we shall not get along with less administration or regulation, which we need in order to collect the necessary funds and to divide the load evenly. And the rate of progress will be determined in part by the international market if the individual polluter who wants to produce more cheaply is not to be favoured in the competitive market.

The special responsability of the scientist and the engineer also stems from the fact that they are close to the source of change for the better or the worse. Their example and their warnings will be very important. It is also important that they as experts explain to the public what makes sense and what does not, that they help to separate the weat from the chaff in a market which is dominated by garrish advertisements and promotions of all sorts of solutions. The public must know what the tradeoff are and that, under some circumstances, new side effects have to be accepted. Improved thermal insulation of houses, for example, is clearly important in saving energy and obviously a benefit. But we must accept that because of a reduced air exchange an increased accumulation of radon gases in the rooms will be favoured and that this will lead to an increase in the exposure to radiation of the inhabitants. Thus the end effect will be that millions of people will be exposed to higher doses of radiation day in and day out, to higher doses perhaps than the few ten thousands of people had to suffer in Harrisburg for a few

hours. The damage to health will be insignificant, but the population must know about it.

In conclusion it is necessary to return to some basic ethics which have brought success to science since Galileo and Newton: a passionate desire to find out what the world is really like; rejection of science platitudes and prejudices; conscienciousness in our work and honesty in our statements; advancement in small steps by trial and error; no restatement of old dogmas but rather constant interpersonal and interdisciplinary critical testing of theories in practice. In essence it seems to me that this is also the principle of modern democracy: to be critical of alternative solutions for society put forward by ideologists who always know better; to allow public discussion and free expression of opinion; to permit a reformation of ideas by evolution, by trial and error; to avoid irrevocable decisions.