ZAHEER SCIENCE FOUNDATION LECTURE 1980

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Reflections on Science and Technology

Professor Abdus Salam, N.L.,

Address by Professor S. Nurul Hasan

Distinguished members of the audience

I have great pleasure and deem it an honour to extend a very hearty welcome to Professor Ahmad Abdus Salam, Nobel Laureate, who has kindly agreed to deliver the Sixth Zaheer Foundation Lecture.

There were certain matters totally in common between Dr. Zaheer and Professor Salam and one of them was their dedication to science and the desire to build the temper of science. I am, by no means, competent to speak on Professor Salam's scientific eminence. Most of the members of the audience here would understand the significance of his work much better than I do, but I have had the opportunity to hold many useful discussions with him and I am sure that not only because of his scientific eminence but also because of his human qualities, we all take pride in the recognition that he has received. He is deeply devoted also to the cause of the developing nations and peoples and is convinced that the present unequal relationship can be ended only if the developing countries adopt the method of science and the temper of science. I don't want to stand any longer between you and Professor Salam. I would only take one more minute to thank him profoundly on behalf of not only the Zaheer Science Foundation but also on behalf of CSIR, for having accepted our hospitality.

At the end of his lecture, a very pleasant but brief ceremony will take place. As you are all aware, the Banaras Hindu University admitted Professor Salam to the degree of Doctor of Science, *Honoris Causa*. The Vice-Chancellor is here in person to present the diploma of this degree to Professor Salam. Thank you.

Reflections on Science and Technology

Professor Abdus Salam

Professor Nurul Hasan, Ladies and Gentlemen

I had the privilege of meeting Husain Zaheer in 1966, when both of us attended the Rockefeller University New York symposium on Science and Human Conditions in India and Pakistan. The symposium was attended by a galaxy of scientists from India - Husain Zaheer, Vikram Sarabhai, M.G.K. Menon, A. Rahman and others. In his forceful way, Husain Zaheer talked on the subject of the development of scientific research in India and the role of the Council of Scientific & Industrial Research in it. He told us of the phenomenal growth of the Council, which, starting with a budget of $ 100,000 in 1941, had by 1966, grown to an operating budget of $ 51 million annually. Zaheer spoke of the steps he had taken to secure the involvement of scientific community in the decisionmaking machinery of the Council and the direct involvement of universities in its work. But quite clearly what gave him great happiness was the success in abolishing hierarchical gradation in the organization and the decentralization of powers which he had brought about within it. He told us the story of the laboratory for which he considers himself primarily responsible - the Regional Research Laboratory of Hyderabad - where for 15 years all the staff, from the Director up to the Janitor, had their meals

together in the canteen. No seats or tables were reserved, but one side of the bench was vacated for the Director as soon as he appeared. I can still recall the beatific smile on his face when he made these remarks. I shall return to the talks which he and I gave at that conference but before I do that, I would like to speak for a short while about the problems of physics on which we have been engaged in recent days. Since this meeting is taking place at the National Physical Laboratory, which is so deeply concerned with the problems of energy and since physics is synonymous with energy, I shall try to make my remarks about the physics of recent days in the context of whether we, the particle physicists, have anything to contribute towards the problems of energy. Of course, all the solutions which one could have from the recent work are absolutely fanciful but I would like to go over them with you, just to see what the scientist on the frontier is concerned with at the present time.

In the first transparency*, you will see the magnitude of the energy problem, as in 1980 and the projection in 2030 - 50 years from today. The population of the world will have grown from 4 billions to 8 billions. At present, the energy requirements of the world are 8 Terrawatts - 1 Terrawatt is equal to 10^{12} watts. It is expected from the projections (which Dr. Haeffle from IAASA in Vienna has made and from which I took these figures) that the energy demands will have gone up to 26 Terrawatts. The developing countries, at the present time, are consuming 1,3 Terrawatts, that is, about 7 per cent. They will be consuming, hopefully, 30 per cent of the total energy demands in 50 years. At present, oil and gas account for 5 Terrawatts; it may be expected then that in 2030 A.D. 7

*shown by Prof. Salam during his lecture.

Terrawatts may come from gas and oil. So, we have a deficiency here of something like 19 Terrawatts, which has to be filled up, with other ways of energy production. Coal is at present contributing 2 Terrawatts; hopefully, it may contribute 10 Terrawatts by 2030; that is a question mark. At the present time, the share of nuclear energy is half of a Terrawatt, hydro, one-fourth, solar zero and other forms of energy, wind and others one-fourth, of a Terrawatt. Nuclear energy share may go upto 7 Terrawatts, with perhaps fusion energy already available. The hydro potential will probably not increase beyond 1 Terrawatt, the solar may increase to one Terrawatt - a very small increase, and other forms of energy may go up to half a Terrawatt. Can the new advances due to particle physicists have any relevance to this energy-problem ? My conclusion will be - No; but I am sure you will wish to hear what these advances are.

For my purposes, it will suffice to consider 1935 as a bench-mark for the elementary entities of which matter is made. There are the protons and the neutrons, the so-called heavy particles (baryons), plus two light particles, neutrinos and electrons (leptons). The picture has changed now but for purposes of this talk, this enumeration of elementary particles will be adequate. The basic forms of forces which exist between these particles are four; these are the gravitational force, the electromegnetic force, and two types of nuclear forces - weak nuclear and strong nuclear.

Let us take gravitational force; the mention of terrestrial gravity as the cause of falling of the apple towards the earth, was already known to Aryabhatta and Brahmagupta in the 5th century A.D. However, we owe to Newton the tremendous generalization around the year 1680 that terrestrial gravity is the same force as celestial gravity, the

force which keeps the earth moving in its orbit around the sun.

The emergence of the concept of an electro-magnetic force started with the ideas of Faraday and Ampere who showed that electricity and magnetism are not two independent forces but magnetism is nothing but a force produced by a moving charge. This is a tremendous unification between these two distinct forces. Maxwell, about a 100 years ago, showed that accelerating electric charges give rise to radio waves, heat waves, light waves, x-rays, gamma rays and so on. This was verified in the laboratory by 1890, ten years after the death of Maxwell. It was the first time that these waves were actually demonstrated in the laboratory. Then came the realisation that the electro-magnetic force is responsible for all chemical attraction and for all physiological processes. But before this work was done, had come Einstein. In two remarkable papers written in the year 1905, Einstein unified further these concepts - of space and time and energy and matter with his famous equation $E = mc^2$.

For the purposes of NPL, the more important equation came in the same year by Einstein. This is $E = \hbar\nu$ which tells us that the energy carried by a photon - a particle of light - is proportional to the Plank constant $\hbar$ times the frequency. This is important because it states that dilute sun light gives the same photo-chemical reaction as concentrated sun light; only the rate is smaller. The quality of diluted sun light and the concentrated sun light is identical.

Whereas the Bhabha Atomic Research Centre should have $E = mc^2$ as its doorpiece, the National Physical Laboratory should have $E = \hbar\nu$.

The next advance made by Einstein in the year 1917 was to go back to Newton's gravity and to postulate that space and

time are curved, an idea which he actually took from the work of Riemann and Gauss. However, they were considering the curvature of space alone; Einstein considered curvature of space and time. In his view, it was this curvature which was responsible for the force of gravity. This then was one of the greatest ideas with which mankind has lived. It gave us the concept of expanding universe, of the Big Bang with which the world started, of the radiation which now has a temperature of 3 degrees Kelvin and finally the concept of black holes. Einstein at this point started to have a dream of which I shall be speaking about. That dream was to combine the force of gravity and the force of electro-magnetism. So far, I have talked of only these two forces. Einstein thought that since gravity, in his formulation, was a property of space and time which corresponded to the curvature of space and time, perhaps in electro-magnetism, the electric "charge" carried by an electron or a proton may also correspond to yet another property of space and time. And perhaps that property of space and time together with curvature may form one single whole. In that sense both these forces may be reduced to one and the same property of space and time. That was Einstein's dream with which he lived 35 years and on which he consistently worked. There is a poignant story told by Abraham Pais, a Professor at the Rockefeller University. Pais tells the following story: He and Einstein were together at the Institute for Advanced Study in Princeton for a number of years. They were friends, taking their walk together and one day Pais got an invitation to go back to his country - Holland. Einstein was in very poor health and Pais thought that he would go and say goodbye to Einstein. It was quite clear to him that Einstein was sinking so fast that this would probably be their

last meeting. So, he went to see Einstein. They had tea together, and then Pais said goodbye and tip-toed out to the door. He looked back from the door to have perhaps a last glimpse of his friend and hero. He saw that by then Einstein had gone back to his work for the unification of gravity and electro-magnetism. After a few days, Einstein, in fact, died.

Now the next advance which is of concern for purpose of this talk was the nunification of the Quantum Theory and Einstein's special theory of relativity made around 1928 by Dirac. This unification led them to the principle that every particle - proton, neutron, neutrino, electron - has an anti-particle. What happened was that Dirac wrote down a remarkable equation for the electron. This equation was exceedingly successful in describing all the phenomena in which the electron was concerned. It had only one flaw; it described particles of positive as well as negative energy. A negative energy particle would behave like a mule; you would push it and it would come towards you. No one had seen such a particle. Dirac and everybody else were perturbed by this set of solutions till Dirac himself hit upon an idea that this was a representation of an anti-particle which had the same mass, but opposite electric charge. In an electric field such a particle would go in a direction opposite to the normal electron. These negative energy solutions then provided the concept of anti-particles. For my purpose, the important remark is that when a particle and anti-particle come together, they both annihilate into light, into photons, into electro-magnetism and into gamma rays. This is pure energy and is the most exothermic reaction, one would think of. If you could have a packet of anti-protons all your problems of energy conversion will be completely solved. For, this packet brought together with normal matter would yield pure

energy. This is the type of fanciful idea which I will go on speaking about in the rest of my lecture

Perhaps here I will just tell one more story about Dirac's discovery of the anti-particles. As I said, he found this as a consequence of thinking about the negative energy particles and the concept of negative energy apparently came to him when he was a student and participated in a problem's drive at the Cambridge University in St. John's College. Dirac had the following problem:

There are three fishermen who go out fishing and they make a haul of fish. It is a stormy and dark night and they bring the haul to an island and go to sleep. In the middle of the night, one of them says, I will go home; so he takes the fish, divides it into three parts and takes his 1/3rd; he finds that one fish is outstanding, he throws it into the sea and departs. Then the second man gets up and he too not knowing that the other one had departed, divides the fish into three parts, finds one fish outstanding, throws it into the sea, takes his 1/3rd and goes away. And likewise does the third man. The question is, what is the minimum number of fish with which you could do this. Dirac's answer was minus two fish! If you take minus two fish and divide by three, you get minus one fish as your share plus one fish as outstanding; you throw that plus one into the sea, you take away minus one, you have minus two again and you can carry on.

Next we come to Einstein's dream of unification of fundamental forces. The great advance which Einstein ignored in particle physics was the advance concerned with nuclear forces. Einstein did not take them into account and that made his task hard. What you will hear from me is that our generation having been born with nuclear forces very much established and well-known, we decided to strive to

find a unification of electro-magnetism not with gravity but with the nuclear forces. Now, as I said there are two types of nuclear forces - the strong nuclear force which is responsible for the phenomena of fission and fusion, and the weak nuclear force which is a force between doublets of proton and neutron and the neutrino and the electron. It leads to neutron decay, - another exothermic reaction. If you had a packet of free neutrons, each neutron would go into a proton plus a neutrino plus an electron in about 10 minutes. This could be another fanciful source of energy.

Let me give you a flavour of what I was taught, in Jhang, 1934, when I was a student, of the fundamental forces. I still remember, when we had our first lesson concerning fundamental forces, our teacher spoke of gravity, of course, and then of magnetism; magnets were everywhere. And then he said "electricity - ah! that is another type of force; but it lives in Lahore - 100 miles east from the town of Jhang". Then he came to nuclear forces and he said these forces lived in Europe only. But he mentioned the capillary force as a fundamental force. I now realise this was a fall back on the teachings of Ibn Sina. You may recall Ibn Sina was both a physicist and a physician and therefore, for him the capillary force was the most important force in the whole of nature.

Now I come to the problem of unification - the realisation of Einstein's dream as we have tried to achieve it. As I said we have tried to combine weak nuclear, strong nuclear and electro-magnetic forces first and *then* combine them with the gravitational force. This is where we have partially succeeded and I will deal with some of the steps that we undertook in order to show that this type of unification indeed happens. The clue to the unification lay in the similarity of the forces of electromagnetism and the weak nuclear forces. This

similarity was first postulated in 1957. At that time, one recognised that both these types of forces are mediated by certain particles, the photons, the quantum of light, the quantum of radiation, in the case of electro-magnetism; in the case of the weak nuclear forces, the quantum of radiation which mediates the force was postulated to be a set of particles called 'W^+' and 'W^-' particles. The indirect existence of these particles was shown by certain experiments which were done in 1957. These experiments showed that these mediators W^+ and W^- would have exactly the same spin as the photon. So, these three particles had a similarity - asymmetry - in their spin. Those of us who were looking for clues to the unification of weak nuclear and electromagnetic forces were heartened by the fact that these three particles; one pertaining to electromagnetism and two pertaining to the weak forces had exactly the same spin. There was, about the same time, made another conjecture.

This states that you do not have a unification but you have a new type of weak nuclear force mediated just as the weak nuclear force is mediated by W^+ and W^- but with a new type of heavy photon - which we call F°. So, we have two conjectures; one which spoke of the unification of the forces and one which told you of a new type of weak nuclear force. Now, from experience we have found that whenever we have two beautiful ideas, Nature usually makes use of both of them; Nature is not parsimonious. We soon found that a beautiful synthesis could be made of these two ideas. We have both the unification of weak nuclear force with electromagnetism as well as a new type of weak nuclear force predicted, which is mediated by the so-called heavy photon Z°. There could then be situations where the new heavy photon Z° and the "old" well-known photon could interfere.

Evidence for this interference was obtained in June, 1978, at the Slac (Stanford Linear Accelerator Laboratory) which clinched the existence of this interference between the light and the heavy photons. I will show you the theoretically predicted curve and the experimental points which fall on the predicted curve. The experiment took three years of preparation and cost $ 1 million. It showed for the first time the unification of electro-magnetism with the weak nuclear force thereby reducing the four forces to just three.

I will tell you the story of how I learnt about this experimental result. In June 1978, having made these predictions, one was very desirous of knowing how the experiment had gone, particularly as a year before, some experiments (which had now been shown to be wrong) had caused doubts on the prediction of the theory. I remember ringing up Slac. It was 10 at night at Trieste; I rang up Professor Taylor who was the head of the team which did this experiment. Taylor said there were forty physicists who had collaborated in doing this experiment. He said, "we are being besieged by a battery of reporters and we have taken an oath, all of us, not to reveal the results of the experiment till tomorrow when we give a seminar on the result of the experiment." He added, "I am very sorry, I know how much you are interested and I should be telling you what the results are, but there is our oath." I agreed with him that he could not perjure himself. I proceeded to put down the phone; when he heard the disappointment in my voice, he said, "what time is it in Trieste?" I replied, "It is 10 O'clock at night". He asked, "Is this your bed time?" I said, "Yes". He said, "All I can say to you is, go to bed and sleep well." Remember, all this is indirect evidence. Let me show you what the accelerator needed will look like before the Z°

particle is produced. The first accelerator which you will see in the slide is a proton, anti-proton collider. It is a 6.8 m circumference accelerator at CERN which will produce the Z° at the end of this year. Another one is proposed at a cost of half a billion dollars and it will have a circumference of 30 m.

This is a view of Geneva, the lake and this red circle marked is a 6.8 m circumference accelerator and the 30 m accelerator will have to go under these mountains, at the end of Jura mountains.

This is a bubble chamber, one of the chambers in which the first set of experiments, were done to show the indirect existence of the Z°. This was donated by the French Government to the CERN Laboratory in Geneva. This has now been discarded and is lying as scrap in the same laboratory.

Now, having got to this stage and having this unification, how can one use Z° for energy conversion. Of course, one can use Z° just like the photon for making electron, positron pairs. This is a very exothermal reaction and could be used for energy generation. Do not forget, of course, we need to spend about half a billion dollars to produce a few hundred Z° in a day!

What is the next step in the unification ideas? The next unification which we are contemplating is the unification of the strong nuclear force with the other two forces - the weak nuclear force and the electromagnetic force. It has been proposed by Professor Jogesh Chandra Pati and myself in 1973 and by Georgi and Glashow in 1974 that such a unification is possible; and one of the tests of this unification is the proton decay. At the present time, protons are supposed to live for ever. Our theory says they are not stable. If they decay into, say, positrons or neutrinos, plus pions then

their life time is of the order of 10^{30} years. The lifetime of the universe, according to present ideas, is of the order of 10^{10} years; clearly the proton, according to these ideas, is very very stable, compared to the life of the universe. How does one detect proton decays? If our ideas are right, protons are decaying everywhere, but it is only one in 10^{30} protons which is decaying in one year. Thus these experiments had to be performed with great care, removing all types of background decays. There is a very beautiful experiment, led by professor Menon and professor Rajasekharan of the Tata Institute of Fundamental Research-the Kolar Gold Field Experiment, which I had the privilege of visiting. This experiment involves 150 tonnes of matter, iron plates surrounded by proportional countertubes. This set up is 7000 feet below sea level, cutting down the background radiation of μ mesons. A second experiment on these lines is one being carried out by the Torino group, 5000 feet below sea level in the mont Blanc Tunnel. The mont Blanc experiment has not come on stream yet and there is every good chance that the Kolar Gold Field experiment may detect the proton decay first if the decay life estimate of 10^{30} years is correct. There is a third experiment, which is not situated as deep in the ground as the other two - it is only 1700 feet deep, set up in a salt-mine in Cleveland - with 10,000 tonnes of water surrounded by photomultiplying tubes. In the salt-mine one will persuade a couple of research students to stay for 2 or 3 years. Hopefully they will come up with a signal which correspond to a proton turning itself into a positorn and photons. If these tests are positive and the proton decays as predicted, we shall have unified three of the forces of nature. We shall then have come nearer to the dream of Einstein. The final step will be the unification of the new electro-nuclear force with the gravitational.

How are we going about this? This final unification, as I said before, would probably be of a different type. This unification will be a unification in terms of a generalised property of space and time which describes electro-nuclear force just as gravity represents the curvature of the space and time.

One of the favourite ideas at the present time is the very radical idea that space time may have extra dimensions, and not just the four as Einstein supposed. Supposing space time had five dimensions and the fifth dimension was very very tiny, having the dimensions given by the Planck constant $\approx 10^{-33}$ Cm. We would have no way of apprehending this fifth dimension by direct experiments but indirectly one would apprehend the existence of this extra dimension, through the existence of the electric charge. This has been shown by Klein and Kaluza around 1920 when they showed that if we assume the existence of a fifth dimension then the curvature in the fifth dimension corresponds to electro-magnetism. Likewise, if we now take the nuclear forces, weak and strong, it turns out that we shall need a eleven dimensional space and time - four dimensions of the normal space time and seven of the new variety. These seven are very tiny in size $\sim 10^{-33}$ Cm and they show themselves to us through the existence of electric as well as nuclear charges. You cannot change this number 'eleven'; you could not have some number like 'thirteen' or 'seven' which are favourites of mythology. It is just this number 'eleven' and none other. To my knowledge, this is a number which is devoid of mythological significance. I may be wrong here, but I hope that is the case. So, this then would be a new type of idea and a new type of unification which may come about. What is the signal of such a unification? The important attitude which distinguishes

modern from medieval science is that we have to have experimental confirmation of all our conjectures; otherwise they remain totally valueless. This is the important hall-mark of modern science. It will be sterile to speak of eleven dimensions unless we could produce some experiments which would test this idea. One of the experiments which has been suggested is an experiment which relates to the concept of anti-gravity. Anti-gravity is a force which, all those concerned with the defence establishments, have been looking for, for a long time. Unfortunately, we are now going to give it to them, manifesting itself as a change in the Newtonian Law. Fortunately, it would be a very small change. This force, the change in the Newtonian Law, is predicted to lie between 10 meters and 1000 meters. If you are beyond 1000 meters, it will be far too small to have any significant effect on the motion of planets or anything else. Likewise if the distance is less than 10 meters, it will have no effect. This effect will show itself between 10 and 1000 meters. This then provides the test of the concept of eleven dimensions and the unified theory based on this idea.

So, let me now summarize:

Before 1978, we thought that there were four types of forces and the corresponding energies - gravity, electromagnetism, weak nuclear, strong nuclear.

From 1979, we have come to believe that this number is not four but three - gravity, electro-weak and strong nuclear.

Maybe, around 1982, we may have evidence of unification of the electro-weak force with strong nuclear. Maybe, in the next 10 or 20 years, we will come to the final concept of electro-nuclear-gravity. This will then be the last unification; it may connote perhaps the idea of the fundamental existence of more than four dimensions of space and time.

Among the exotic processes that I have talked to you about are the proton plus anti-proton, annihilation into photons. The existence of anti protons was shown in the Berkley Laboratory. Unfortunately, to produce a bunch of anti protons, we need a budget of the order of at least $ 10-15 million. The energy output as a result of the annihilation process is of course miniscule, worth a few dollars at most.

Then there is the heavy proton that I have talked to you about and its conversion into electron-positron pairs. Here the initial cost goes up to a few hundred million dollars with the final output of energy still measured in tens of dollars. Then there is proton decay. Due to this mechanism, a hydrogen atom is expected to finish up as two photons - admittedly a highly exothermic reaction. But for one such atom to decay one must wait 10^{30} years.

Then finally, there is this fanciful idea by Penrose & Wheeler of black hole as an energy source where you tap the rotational energy of black hole, by building a civilisation, just outside the rim of the even horizon of the black hole. You do not want to get too close for fear of being sucked in, so just stay outside and feed the black hole with all the garbage of your civilisation. A part of the rotational energy of the black hole will be emitted in the form of radiation which may, of course, be used to sustain the civilisation.

These are some of the fanciful ideas with which we are playing.

Now, I am going to start on the second part of my lecture on Science and Society.

However, perhaps I should remember that I have already taken an hour; perhaps I shall apply closure. Maybe another Husain Zaheer Lecture, for which you may kindly invite me, will be the occasion for this second part of my lecture. I shall

just end with a quotation from Openheimer. This is a quotation from his BBC lectures given in 1953 which summarizes the faith of the Physicist:

"Physics will change. If it is radical and unfamiliar we think it will be only more radical not less more strange and not more familiar and that it will have its own insights of the inquiring spirit."

Vote of thanks by Dr. G.S. Sidhu

I have the most pleasant duty of thanking Professor Salam for accepting the invitation from the Zaheer Science Foundation to give this Foundation Lecture and I have also an equally pleasant duty of thanking all members of the audience for coming here and making this function a success by their participation. I am sure that the President of the Foundation and other members of the Foundation would be more than happy if Professor Salam continued this lecture as the next Foundation Lecture.

Dr. Hari Narain

Professor Nurul Hasan, Professor Salam, Distinguished guests, Members of the Zaheer Science Foundation and Friends,

The Banaras Hindu University has conferred the degree of Doctor of Science *honoris causa* on Professor Abdus Salam in its special Convocation on 4th January, 1981 during the 68th Session of the Indian Science Congress Assocation in Varanasi. I crave your indulgence to read one paragraph of the citation.

"Professor Abdus Salam, Nobel Laureate, an eminent physicist whose investigations have aimed at seeking unity of unseemingly desparate forces of nature, a crusador for stemming the brain drain from developing countries and a person whose constant endeavours stressing that spiritual basis is a prerequisite for the scientific and technological growth have earned recognition of the Academic Council of the Banaras Hindu University for the award of the degree of Doctor of Science. In honouring Professor Salam, the Banaras Hindu University has honoured a renowned physicist and a great spiritualist, a dedicated champion of science in third-world countries and a man who believes that what developing countries really want on a psychological plane is to regain their sense of dignity and self-respect." I am grateful to Professor Nurul Hasan and members of the Zaheer Science Foundation for having given me this

opportunity to personally present the degree, the hood and the gown to Professor Salam.

Professor Salam

I have the greatest happiness in accepting this very great honour which you have done me, Sir.

I would like to present to you, Sir, for the University museum, a replica of the Nobel Medal which was struck by the Pakistan Government. One is presented to you for the Banaras Hindu University and the other one will be given by me tomorrow to the Aligarh Muslim University.

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