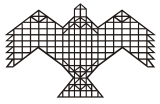
First Annual

Dr. Raja Ramanna
Memorial Lecture

C. V. Sundaram

NIAS Lecture LI-06



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First Annual Dr. Raja Ramanna Memorial Lecture*

Much is known about Dr. Raja Ramanna. Much has been written about him, more since his passing away in September 2004, remembering him, recalling his many outstanding contributions and paying tributes. The writers include scientists, a few, his contemporaries and many who admired him greatly and some, whose careers he shaped. There were also numerous public persons from several walks of life who had known and admired him in one context or another. Prof. M. G. K. Menon who had known him personally for over 50 years and whose professional career ran parallel to his called him a "Towering Personality". Dr. R. Chidambaram called him a "nuclear pioneer" and an "institution builder". Prof. Sreekantan recalling his many associations and contributions felt it appropriate to

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* Prof C V Sundaram prepared this lecture in collaboration with his former colleague Dr. T S Radhakrishnan.

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remember the words of the poet Longfellow that 'great men leave behind their footprints on the sands of time'.

Dr. Ramanna's biographical sketch is a sketch of magnificent proportions and a condensed version for a quick reading is as follows:

- An outstanding Scientist and Scientific Administrator, Founder of several scientific institutions, Musician and Musicologist, Philosopher
- Born on January 28, 1925 to Shri. B. Ramanna and Smt. Rukminiamma at Tumkur, Karnataka
- Schooling: Bishop Cotton Boys School, Bangalore; Madras Christian College, Tambaram; King's college, London (Ph.D).
- Career: Joined TIFR as scientist in the year 1949; Inducted into the Atomic Energy Programme in 1954; Director BARC, 1972-78 & 1981-83; Chairman Atomic Energy Commission, 1983-87; Director General, Defence Research and Development Organisation, New Delhi and Secretary, Department of Defence Research, 1978-81; Scientific Advisor to Raksha Mantri, 1978-81; Director, National Institute of Advanced Studies, Bangalore, 1987-89 & 1990-97; Minister of State for Defence, 1990; Member, Rajya Sabha, 1990 & 1997-2003.

- Honorary Positions held: President, Indian National Science Academy; President, 30th General Conference, International Atomic Energy Agency, Vienna; Vice-President, Indian Academy of Sciences; Chairman, Governing Council, Indian Institute of Science, Bangalore; Chairman, Council of Management Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore; Chairman, Board of Governors, Indian Institute of Technology, Mumbai; Chairman, Indian Vaccine Corporation, New Delhi; Chairman, Council of Management, NIAS, Bangalore.
- Musician: Piano player; given many solo recitals including at the Music Academy, Chennai and the National Centre for Performing Arts, Mumbai.
- Author of Books: "Structure of Music in Raga and Western Systems"; Autobiography - "Years of Pilgrimage"
- Awards: Shanti Swarup Bhatnagar Award; Padma Vibhushan; Nehru Award for Engineering and Technology of the Madya Pradesh Govt.; Meghnad Saha Medal; INSA Gold Medal; Asutosh Mukherjee Memorial Gold Medal; Om Prakash Bhasin Award; R. D. Birla Memorial Award of the Indian Physics Association; Desikottama (Doctor of Letters), Viswa

Bharathi University; D.Sc (Honoris Causa) of several Universities.

- Passed away on September 25, 2004

Rather than elaborating on the information explicitly known, it may be more meaningful to enquire, "What made Dr. Ramanna so unique?" In other words, how was it possible for this individual to have so many very diverse interests, how was he able to discharge so many responsibilities with distinction and how was he able to have so many accomplishments and embellishments to his credit. And as Prof. Sreekantan remarks that in all this, he managed to keep himself so cool, so collected, so calm, so easily approachable, always with a positive attitude, straightforward and transparent in his thoughts and doings. An analysis of his career and personality might perhaps help us nurture the right talent in the right ways that the system might grow a few tall persons for the glory of the nation.

There is no second opinion that the atmosphere at home while growing up and the guidance and encouragement got as a child helped the young Raja Ramanna stand out in self-confidence. It is no mean task to excel in music to the level of being able to give a public performance at the tender age of eleven. Even so, we do hear of child prodigies, although sporadic. That he chose to acquire such prowess on a western instrument viz. the piano, not so common in Indian homes

even at that time of the British Raj, indicates the unique path he wanted to tread even at that very early stage in his life. He was also in a sense lucky to be appreciated and patronized by no less than the then Maharaja of Mysore, His Highness Sri.Krishnaraja Wadiyar, so known for encouraging and supporting arts and artists, in whose court he was often called upon to perform. It has been mentioned that he could easily have taken to music as a career. The circumstances contrived in such a way that he embarked on a career in physics and as we know he distinguished himself as a scientist and a leader.

There are many accounts including his own that he enjoyed studying physics, that he had affinity for his teachers and that he excelled in his studies. With his many talents, he could win a scholarship to UK to King's College, London, to carry out research in physics leading to a PhD degree. Here, he chose to work in experimental low energy nuclear physics, very different from what he himself has termed as the fashionable area of high-energy physics. As a research scholar, it was suggested to him by his supervisor Dr. Alan Nunn May that he should develop a new type of ion chamber to detect ionizing particles emitted in nuclear reactions. It was unfortunate for the young Ramanna to lose the guidance of his supervisor as Dr. May became discredited and arrested, charged with espionage. Nevertheless he combined

effectively in his work with other specialists and scientists in his laboratory and succeeded in his task. This detector unlike the conventional detectors was also capable of measuring the direction of emission of a particle with respect to a given direction. As a result of this, Dr. Ramanna was credited with a short publication in the prestigious Journal, 'Nature', coauthored by the head of his Department, F. C. Champion. It must be pointed out that the authors cared to acknowledge that Dr. May suggested the idea behind the development in spite of the fact that he was discredited. This is indeed noteworthy as human nature generally is to disregard the persons no longer in position of authority. Such honesty has been the characteristic trait of Dr. Ramanna throughout his life. Dr. Ramanna also tried to use his new detector for the measurement of the angular distribution of fission fragments emitted in the fission of Uranium 235. This could not be completed at that time, as he did not have the adequate experimental infrastructure. He was awarded his Ph.D. soon in 1948 and the problem (of his investigation) remained with him to be taken up subsequently. This phase of work, accomplishing the development of the new device must have given him a tremendous self-confidence and belief in self-reliance, which had also remained the hallmarks of his personality throughout his life. While in England, he also came in contact with other great scientists like D. H. Wilkinson and James Chadwick, the latter the

discoverer of neutrons. All these must have served as precursors to stimulate him in the many developments he propelled in later years.

This is the point at which Dr. Bhabha asked him to join TIFR. In fact Dr. Bhabha allowed him to spend one further year in England to familiarize himself with the then current developments in Atomic Energy and Nuclear Physics. It is often said that Dr. Bhabha chose his people well. Indeed Dr. Bhabha had earlier been impressed by Dr. Ramanna's personality in the context of the latter's prowess in western music of which it is well known that Dr. Bhabha was a connoisseur. As Prof. Sreekantan recounts, 'Dr. Bhabha who had known Ramanna's interests and abilities in music allotted him two adjacent rooms in the TIFR hostel, one for him and the other for his piano!'

At TIFR, then functioning as a make shift arrangement in the servant's quarters building of the Old yacht Club, Dr. Ramanna began an experimental programme in nuclear physics in right earnest. One of the first tasks was the in-house development of the necessary instrumentation such as particle detectors and pulse electronics. Unlike now, those days India was industrially quite backward and this was a daunting task. He had put up this essential infrastructure in a short time and was initiating some studies in nuclear physics. Dr. Bhabha in the meanwhile was carving out the cradle for

the Atomic energy Programme in India and sent the first team of Indian scientists, for a yearlong visit to Paris to get familiar with the French work in reactor building and associated control instrumentation. Dr. Ramanna, who had by then been inducted into the Atomic Energy Programme, was a key member of this team. As of this time, it is clearly discernible from his work and research priorities that he fully recognized the import of this vastly greater role envisioned for him. Coupled with the deep admiration and loyalty he had for Dr. Bhabha, he saw this vision of establishing the Atomic Energy programme in India as his mandate. On his return from France, he was fully involved with the work of the development of the laboratories at the new site of the Atomic Energy Establishment at Trombay.

It was thus he became interested in the measurement of the diffusion lengths of thermal neutrons in water and Beryllium oxide by way of generating nuclear data used in the design of nuclear reactors, ahead of his other long time basic research interest in the science of nuclear fission. Dr. G. Venkataraman, who had joined him at this time as a young research student recalls the ingenious way in which Dr. Ramanna carried out these measurements. Not having any reactor providing neutrons at that time, he used the just then acquired one million Volts Cockroft – Walton type accelerator at TIFR to produce pulse neutrons using the

standard, D-T reaction. Injecting the pulses of the 14 MeV neutrons into a block of the moderating material at one end, the thermal neutron signal at the far end of the material was studied as a function of time. He was also undaunted by the non-availability of a commercial multichannel analyzer as imports were difficult those days. He came up with the bright idea of building a time analyzer using an oscilloscope, placing several perspex pipes in contact with the screen as light guides, each ending in a photomultiplier tube, the total assembly functioning as a position sensitive detector. And this dilettante approach produced data, which were in agreement with those of other international groups.

In 1956, India's first reactor, a small research reactor known as the swimming pool type, was commissioned as a result of indigenous development in which Dr. Ramanna took a lead role. This was named APSARA by the eminent scientist Dr. K. S. Krishnan, who was a member of the Atomic Energy Commission and who remained an ardent supporter of the Indian Atomic Energy Programme, in the face of indifference, or even hostility, from a few other eminent Indian scientists of the time. With the availability of a steady, though small neutron flux from APSARA, Dr. Ramanna revived his long-term interest of understanding the basic science of the fission process and put together an experimental programme that has grown in stature over the years generating outstanding contributions

and evolving many scientists of international calibre. Simultaneously, true to his early training and research methodology, his research group excelled in the indigenous development of instrumentation and techniques for nuclear physics research.

This is a phase in which he concentrated on basic research, establishing major facilities and carrying out some landmark experiments. A 5.5 MV Van de Graaff accelerator was commissioned in 1962 and through the Canadian Cooperation a 40MW research reactor, presently known as CIRUS was established giving much higher neutron flux compared to APSARA. With CIRUS, he encouraged Dr. P. K. Iyengar, one of his early students, to establish neutron scattering facilities and instrumentation for condensed matter physics research. Dr. Iyengar as is well known had an illustrious career and distinguished himself in his work on neutron scattering and also made several key contributions to the Atomic Energy programme and subsequently rose to the position of the Chairman, AEC.

As was stated earlier, Dr. Ramanna's personal research interest continued to be the study of nuclear fission processes. Here one has to get necessarily technical. Dr. Ramanna and his group studied the emission of prompt neutrons, gamma rays and occasionally emitted light charged particles in the thermal neutron induced fission of

Uranium-235 using an in-house built gridded ionization chamber cum scintillation detector system that could detect fission fragments in the 360 degrees geometry. From these measurements, they showed for the first time that about ten percent of the emitted prompt neutrons are pre-scission neutrons (occurring in the pre-break up stage of the fissioning nucleus). They suggested that these neutrons are emitted during the saddle to scission stage in the fission process. Also around this time, when the understanding of the fission process was still at its infancy, Dr. Ramanna realized that the central problem of fission was the asymmetric fragment mass distribution, a result dictated by the characteristics of the individual fissioning nucleus. To understand this effect, one needed to take into account the nuclear shell structure characteristic of each nucleus (based on the famous nuclear shell model), even when applying the liquid drop model, which was more successful in the phenomenological understanding of nuclear fission. It occurred to Dr. Ramanna that one could do this by using a stochastic model in which the nucleons of a fissioning system move from one fragment to the other in a random way (nucleon exchange model or the theory of random flights of Dr. Ramanna), particularly in the last stage, prior to the breaking up. This idea corroborated well with the experimental measurements of the mass distribution of fission fragments for several fissioning nuclei. However,

there was criticism of this model on the mistaken notion that there was not sufficient time for this statistical distribution to take place in nuclei before the fission. Although, he and his colleagues had other powerful arguments in support, the idea could not be validated experimentally at that time because of lack of the required facilities anywhere. It got eventually validated when more facilities became available internationally much later, but Dr. Ramanna observes philosophically and perhaps even a little sadly that the practitioners of the field did not care to make a reference to his idea, published much earlier. Ironically, as was mentioned earlier in this article, he himself was very meticulous in making due acknowledgements of the contributions of others.

Going by the velocity and content of the above contributions, such deep personal involvement with the experiments concerning the physics of the fission process could have grown more intense and also extended for a longer period but for the rude shock for the entire Indian Atomic Energy programme as well as for the whole country in Dr. Bhabha's untimely and tragic death in an air crash over Mont Blanc in 1966. In the changed scenario, Dr. Ramanna saw his mandate of establishing firmly the Atomic Energy Programme in India, arising out of the vision of Dr. Bhabha, as his legacy. He felt this even more as Dr. Vikram Sarabhai, another visionary and the architect of the Indian Space

Research programme, who succeeded Dr. Bhabha as the Chairman, AEC also died prematurely within a few years (1971). A change in focus in his frame of mind and his activities is very evident from even a cursory scrutiny of his research publications at this time. It appears that his personal involvement in experiments in the area of fission physics came to an end around 1966. He had by then established a very competent group of scientists, who nevertheless carried on this activity, but Dr. Ramanna often would not share the credit in the publications that ensued. He however kept up his interest in this area by occasional review talks in the national conferences and other forums. Further, he worked on some theoretical approaches for the fission process and on a geometric foundation for the nuclear shell structure and the binding energies of atoms. Even this activity appears to have taken a back seat by 1971. He did not work for his personal glory. He had other and greater priorities in the cause of the nation.

This is not to say that he abandoned his interest in basic research. On the contrary, he had a great passion for it. As many who were his students or life long associates would testify, his desire was to establish major research facilities and Institutions that were on par with the advanced countries. He provided direct leadership in the establishment of the Dhruva Reactor for neutron scattering research at Trombay, the Variable Energy Cyclotron Centre at Kolkata

and the Centre for Advanced Technology at Indore. As of today, while the former two are already established research facilities in the country, India's first Synchrotron Radiation Sources- Indus 1 and Indus 2 have both been built up and commissioned at Indore. There has been tremendous technological fallout from this programme in the areas of lasers, accelerators, cryogenics, high vacuum, superconducting magnet and other technologies as well as in the areas of electronics and instrumentation. It is gratifying to note that to honour and perpetuate the memory of Dr. Ramanna, this Centre has now been renamed as the Raja Ramanna Centre for Advanced Technology.

Before we leave the topic of Dr. Ramanna and basic research, two other points should be mentioned. The first one relates to his high ethical standards in the matter of scientific publications. He must have been very pleased with his model of the nucleon exchange (mentioned earlier) in the last stage of a nucleus undergoing fission, that he sent the manuscript of the paper for comments to Professor Wigner, a leading physicist at that time and also an all time great. Professor Wigner was impressed with the idea and on his own forwarded the paper to the reputed Journal, 'Physical Review' who wanted to publish the work. Meanwhile Dr. Ramanna had it published elsewhere and he wrote about it to the Journal, stopping the publication and also explaining

his innocence in sending the paper to two publications simultaneously. Dr. Ramanna himself has recorded this incident in his autobiography.

The other point has to do with his everlasting passion for creativity in science and his desire to establish profound results. His early student and now a very distinguished nuclear physicist, Dr. S. S. Kapoor remarks that Dr. Ramanna always worked on contemporary problems but chose a line away from the beaten path. His nucleon exchange model, later established firmly by the work of his student and now a national S&T leader, Dr. V. S. Ramamurthy is a prime example. His work on the geometrical interpretation of nuclear structure and binding energies was another attempt in that direction. This passion for profundity stayed with him till the very end. In the nineties, even after he had a short stint in the Union cabinet as a Minister of State for Defence, he worked on a problem seeking the connection between mass and lifetimes of unstable elementary particles. He wrote a series of papers on this subject, in the decade starting from 1993 and was active on this problem till almost a year before his death. In a significant paper in this series, entitled: 'Flavour of fundamental particles and prime numbers', he pointed out that prime numbers not only play an important role in the synthesis of fundamental particles, but that many aspects of

unstable nuclear phenomena can be understood through a simple equation that he proposed, that connected the mass and the lifetime.

Dr. Ramanna had the greatest regard and admiration for Dr. Bhabha as a visionary leader. He felt he had inherited a large legacy from Dr. Bhabha and it was his duty to protect his legacy and pursue with the Programme, as Dr. Bhabha would have liked to. It became a challenge and a mission for him for the rest of his life. Thus it should come as no surprise that Dr. Ramanna had a life long commitment to the nuclear power programme in the country and to the implementation of the vision of the three-stage nuclear programme of Dr. Bhabha. To give impetus to the programme, he even coined the slogan of '10000 Megawatts by 2000 AD'. Although the growth has been slower due to various factors, like the availability of financial resources, the difficulties in the domestic mining of uranium even from known deposits, some due to non technical reasons and the technology control regime imposed on us by the western powers, this slogan has given a much needed impetus that has resulted in the more rapid growth of the power programme that we are witnessing today. In the year 2004, when Dr. Ramanna passed away, there were 14 nuclear power reactors operating well in the country (the original two units at Tarapur, four units in Rajasthan, two units at Kalpakkam, two each at

Narora, Kakrapara and Kaiga; eight more reactors were under construction, two each at Kaiga and Rajasthan, two larger PHWRs at Tarapur and two 1000 MWe Light Water Reactors of Russian design at Kudankulam).

Dr. Ramanna was always keen on self-reliance. He analysed every project in terms of obstacles if depended on external factors like imports and more so for major programmes. We saw that this was his philosophy when he led from the front in the development of advanced instrumentation for basic research and he succeeded remarkably well. Dr. G. Venkataraman has recorded a little known fact that goes back to 1955, the early stages of planning the Indian nuclear energy programme, when Dr.Bhabha was having discussions with Canada, France, UK and US. UK had, by then, agreed to provide fuel for the Apsara Reactor and Canada had offered help to build the CIRUS reactor. With Dr. Bhabha thinking of a power reactor project as the next step, Dr. Ramanna, who had earlier attended two international conferences on heavy water reactors, came out strongly in favour of heavy water reactors operating with natural uranium as opposed to enriched uranium fuelled light water reactors being built in US. He reasoned that indigenous development of the technology of uranium enrichment would take time, while supply of enriched uranium may not be guaranteed if we relied on imports. Later events proved him right.

Dr. Ramanna also played a crucial role in the establishment of the fast reactor programme, the technology of which has been so successfully mastered at Kalpakkam to the level of our potential to become world leaders in this sphere of reactor technology. It was Dr. Sarabhai who decided to give shape to Bhabha's vision of the development of fast reactors by setting up the Reactor Research Centre at Kalpakkam to promote the science and technology of Fast Breeder Reactors. He entrusted Dr. Ramanna with the Chairmanship of the Programme Implementation and Coordination Committee. Dr. Sarabhai brought in the French connection for initial guidance in this difficult technology and particularly when Dr. Sarabhai passed away soon after the start of this programme, it was left to Dr. Ramanna to give the programme both support and structure. As is well known, in the last three decades, due to the dedicated and sustained work carried out at the Indira Gandhi Centre for Atomic Research, at Kalpakkam, the Fast Breeder technology has reached maturity in India and a 500 MW prototype Fast Reactor is already under construction. IGCAR has also set up a tradition in basic research in physical, chemical and metallurgical sciences and in engineering research.

The success did not come easily. The reactor (FBTR) had reached an advanced stage of construction in 1982. The reactor vessel was received and installed during that year.

The stage had arrived for a decision on the reactor fuel as it became clear that that the prospects had receded for procurement of the required quantity of enriched uranium from France, as originally proposed. Dr. Ramanna took the bold decision of allotting about 50 kg of plutonium from the available stock for FBTR. A fuel rich in plutonium oxide was not acceptable as it was found to be not compatible with liquid sodium, which serves both as a coolant and for heat exchange in a fast reactor. A unique plutonium rich carbide fuel was decided upon and this was the first time that such a fuel was being used anywhere in the world. The fuel was fabricated, in BARC, in the form of sintered pellets and loaded into stainless steel tubes and sent to Kalpakkam to be put together as fuel assemblies. The reactor was charged with liquid sodium and fuel assemblies were progressively loaded into the reactor commencing from early October 1985. First criticality was reached on the night of October 18, 1985 amidst great excitement and jubilation. Dr. Ramanna was present along with senior scientists and engineers of the Department to share the joy of the event. After low power physics experiments, the reactor could be taken to higher power levels. With progressive addition of more fuel assemblies, the reactor has been taken to a power level of 17 MW thermal. En route, steam generation and power generation have been demonstrated. The reactor has so far operated for 20 years and the fuel has reached a burn up

level of 150,000 MWd per tonne without any failure of the fuel pins, of which the Centre can be justifiably proud. Dr. Ramanna had felt very happy and proud about the successful completion of both the Dhruva research reactor at Trombay and the FBTR as examples in self-reliance and achievements in high technology. Today, in the context of the country, Fast reactors are considered crucial in providing the much needed energy security.

Even as Dr. Ramanna foresaw the feasibility of significantly raising the share of nuclear power in electricity generation in the country, he also appreciated the need for a credible regulatory agency to effectively review the safety of the nuclear installations. Soon after he took over as Chairman, AEC in September 1983, he took steps to implement plans for a full time regulatory body for radiation protection, such as was conceived first by Dr. Bhabha in 1963 and later proposed by Dr. Sarabhai when he succeeded Dr. Bhabha in 1966. The proposal was discussed many times thereafter without a final decision on it. In November 1983, the Atomic Energy Regulatory Board was constituted by a Presidential decree with powers to prescribe safety standards and oversee radiation protection measures in the country. Dr. Ramanna chose Dr. A. K. De, a former Director of IIT, Bombay as the Chairman with other members of the Board also from outside the DAE to enable outsider review of radiation safety

in the DAE facilities as well as in the medical institutions and industries in the country.

Dr. Ramanna had a Midas touch in that whatever new programmes he started have flourished and have grown in stature over the years. In effect, he worked on any assignment with complete dedication and thoroughness. The shining example is his creation of what is now known as the BARC Training School. It followed once again as a vision of Dr. Bhabha who made the oft quoted observation as early as in 1944, "… moreover when nuclear energy has been applied for power production in a couple of decades from now, India will not have to look abroad for its experts, but will find them ready at hand". The concrete way of achieving this manpower development came about by the setting up of the then AEET Training School in 1957 under the leadership of Dr. Ramanna. Dr. Ramanna took a great personal interest in the organization and conduct of the Training School in the initial years until it took a firm root. In the nearly fifty years of its existence, the Training School has produced more than 7000 scientists and engineers many of whom are engaged in various programmes of the Department of Atomic Energy in various parts of the country. Today, almost all the leaders in the Atomic Energy Programme, the Chairman of the AEC included are alumni of this Training School.

Another institution that we owe entirely to Dr.Ramanna is the Annual DAE Symposium. Started in 1957 by him, when conferences and symposia were non-existent or rare, it has now fissioned into two, the Nuclear Physics Symposium and the Solid State Physics Symposium to quote Dr. Chidambaram, to cater to the increasing level of scientists and scientific activity in the country. They are well attended by the practicing scientists from a large number of Universities and other research institutions in the country and the talks and discussions have always been of a high order, thanks to the continued tradition of excellence in the technical organization of the Symposia. To give an idea of the growth, the Solid State Physics Symposia alone, in the present times, are held for a full five working days with a total participation of upwards of 500 delegates from all over the country with a good mix of senior scientists and young researchers and with about 35 invited and other talks and about 350 contributed poster presentations. To compare, the first Symposium in 1957 was held in a single class room in the Institute of Science in Bombay. The year 2005 marked the Golden Jubilee of both these Symposia, both meetings held at BARC, Mumbai, at different times in December 2005. Not surprisingly, Dr. Ramanna was remembered and was also sorely missed at both these gatherings.

For reasons of impact, the single most important contribution for which Dr. Ramanna was known all over the country and infact in the whole world was his leadership in the planning and the execution of the nuclear explosion in 1974. Right from his PhD research days, the subject of neutron physics and particularly the physics of fission fascinated him. The development of the first atomic bomb in the Manhattan project and the intellectual inputs provided by the brightest of scientists and engineers led by Dr. Oppenheimer as well as the power of the explosion caused by the bomb dropped in Hiroshima, although destructive, made deep impression in him. He candidly admits that this was the reason for his choosing neutron physics and nuclear fission for the topic of his research during his Ph.D. and after. Neutron and fission physics—these are the underpinning science for both the generation of nuclear power and for nuclear explosives.

There is another reason that led Dr. Ramanna naturally to the nuclear explosion programme. Dr. Bhabha wanted that India should have its own expertise in nuclear explosion technology and so steered the programme towards self-reliance in all the required constituent technologies, which broadly are the same requisites for the generation of nuclear electricity. Those were also the days when there was considerable interest and discussion in the nuclear explosion

technology being harnessed for peaceful uses and several discussions pertaining to it had been taking place in the IAEA forums. Hence, Dr. Ramanna saw in it a constructive program as well, apart from its deterrent value. Unlike the nuclear electricity programme, the development of nuclear explosion technology needs specific clearance from the political leadership. It was Dr. Ramanna's stature and rapport with Mrs. Gandhi, the then Prime Minister of the country and the confidence he infused in her that helped get the necessary approval to go ahead with the planning and the execution of the nuclear test in Pokharan in 1974, though he was not at the helm in the DAE at the time.

It is now history that the world was stunned by the news that India had exploded a nuclear device in the deserts of Rajastan on May 18, 1974. Dr. Ramanna was clearly the guiding spirit. The organization and the execution of the project were superb. It was a distributed effort in BARC involving many Divisions, ably coordinated by Dr. P. K. Iyengar and Dr. R. Chidambaram and also involving the cooperation of the DRDO. The whole project until the execution was kept a closely guarded secret. It demonstrated the Indian S and T capability and strategic planning as of a high order, matching western standards. Dr. Ramanna was legitimately proud of this achievement in technology.

Around 1978, Dr. Ramanna started feeling a bit uneasy in the Atomic Energy Department and that he was not enjoying the freedom that he would have liked. He felt that some change would do him good. We do not know the background or the details, but one fine day he was transferred to Delhi as Director General, DRDO with the parallel designation of Scientific Adviser to Raksha Mantri (Defence Minister). For him, atomic energy had been the first love and he also enjoyed building up on Dr. Bhabha's vision. He found the atmosphere in Delhi too officious and stifling. But, he was not going to complain and he settled down to work as early as was possible. As things stood, the DG, DRDO had only the rank of a Joint Secretary. He worked hard to convince the then Defence Minister Jagjivan Ram that the formation of a separate Department for Defence R&D with its own independent Secretary was essential. This was agreed to and the new Department became the nodal Department for overseeing all the activities of the DRDO and other Defence Research Programmes.

The DRDO was a conglomerate of laboratories scattered far and wide in the country, each with its own mandate. Dr. Ramanna enjoyed traveling and made it a point to visit all the laboratories one by one, meet all the service officers down to the junior level and talk to them about their work. This direct approach of Dr. Ramanna transformed the morale

in the laboratories by inspiring the scientists to think afresh about their work and responsibilities. He noticed that many of the programmes were small in size and not challenging in their technical content. He progressively encouraged the staff to think of larger programmes – involving where necessary more than one laboratory for the proper growth of the organization. For example, it was he who launched the main battle tank project, which resulted in the Arjun tank. Again, it was he who laid the foundations for the missile programme. As this was a particularly large programme requiring a good leader, he took the necessary steps to obtain the services of Dr. Abdul Kalam who was then with the Department of Space. For this, he had to talk to the Prime Minister to obtain the reluctant consent of Dr. Satish Dhawan, then Chairman, ISRO. If the development of missiles of different ranges (Prithvi, Nag, Akash, Agni etc) has taken place successfully, we owe it not only to Dr. Kalam but also to Dr. Ramanna who had the foresight to pick the right person for the job.

He also brought about changes in the structure for recruitment and assessment of staff in DRDO. Till then the recruitments had been through the UPSC, which was not the best route to spot scientific and engineering talents. The promotions were vacancy based and not totally merit dependent and there were many budgetary constraints that

were stringent and unreasonable. Dr. Ramanna's predecessor Dr. M. G. K. Menon had devoted some effort to change the structure and following on this he succeeded in convincing the UPSC to introduce flexible complementing that enabled in situ promotions for competent scientists and engineers (it would require a few more years and some more efforts before DRDO could become independent of UPSC for recruitment and assessment). Dr. V. S. Arunachalam, who succeeded Dr. Ramanna has maintained that the DRDO has been able to embark on large programmes like the LCA and the guided missiles only because of the administrative and managerial innovations introduced by Dr. Ramanna. After about four years of purposeful involvement with the DRDO, Dr. Ramanna felt it was time for him to return to the atomic energy establishment in Bombay. The Prime Minister Smt. Indira Gandhi was willing to transfer him back to Bombay as Director, BARC with the additional designation of Secretary for R&D, which would give him the freedom for action, that he was looking for.

It is abundantly clear that Dr. Ramanna had a lifelong reverence and admiration for Dr. Bhabha. He has also spoken of a few other people whom he admired greatly and who were inspirational in his life and work. It is no surprise that one of them was Pandit Nehru. Delivering the Jawaharlal Nehru Lecture in 2001, at the National Institute

of Advanced Studies, Dr. Ramanna observed, "But for Nehru, we would have been forever a backward country depending on scientific and technological know-how from other countries that were not even necessarily friendly. While it is true that other countries were surprised by our self-reliant achievements in atomic energy and space they did not like it nor would they give us any credit for it. They would do anything to stop it. It was only recently when the capabilities of the subcontinent have been recognized, because of information technology and software, we are found among the list of important technological countries. Nehru would have been happy to know we make our own nuclear power reactors all of them working at capacity factors greater than 80%. One may find fault with Nehru's economics, his foreign policy and his speeches were long but when he was inspired as on the night of independence or at the time of Gandhi's assassination, they were great moments. He was always an inspired writer and his writings were rightly shown as examples to students as coming from a master of the English language, These are small compared to his leadership first during the independence movement and later taking India to modernity. There can be no greater gift to India than this to face the world in the coming years".

Dr. Ramanna has also recalled with pride his speech in 1960 before Nehru, deputising for Dr. Bhabha where he asserted

that the Department of Atomic Energy was in a position to help our neighbors in the use of nuclear reactors for peaceful purposes like the production and use of isotopes for medicine and agriculture. He also warned that if the assistance program were not pursued with vigor, those countries would turn to Japan and Australia. Dr. Ramanna lamented that although Nehru appreciated his views, later, after Nehru died, India lost out on this to other countries due to the indifference of the policy makers. However, true to his views, Dr. Ramanna continued to advocate in the IAEA forums a close relationship with neighboring countries mediated through the IAEA, even in the global context.

At the political leadership level, it was perhaps with Indira Gandhi, that Dr. Ramanna had a close rapport. He was proud that he belonged to the period in which she was at the helm in the country and even when not, still a force in the Indian polity. Two major eventful occurrences, viz, his leadership and execution of the Peaceful Nuclear Explosion, PNE at Pokharan in 1974 and his shifting to the Defence and his reinstatement back in the DAE occurred in this period too. Speaking with emotion at the condolence meeting held at BARC, in November 1984, to mourn the tragic death of Mrs. Gandhi, he said, "…One thing I can state with certainty is that she was indeed the greatest woman of her age, if not of all time and all countries. I do not think there will ever be a

woman of that calibre, for a very long time to come…. While science was not new to the country to begin with, it required governmental support in a big way. This Panditji (Nehru) recognized. However, it was really Indiraji who set the whole thing in operation, realized this vision and enabled us to reach a stage when science could really benefit the people….” How aptly this description of Dr. Ramanna of Mrs. Gandhi fitted admirably to his own self with respect to his role in implementing Dr. Bhabha’s dreams! It is widely known that the renaming of the Reactor Research Centre at Kalpakkam as the Indira Gandhi Centre for Atomic Research was the initiative of Dr. Ramanna. He strongly felt that this was a debt that the DAE owed to the Nehru family for their staunch support of the Atomic Energy Programme. It is significant that Dr. Ramanna arranged this renaming to be done (in 1985) by Rajiv Gandhi during his tenure as the Prime Minister Of India.

For J. R. D. Tata, he had abundant admiration. He often recalled how being a JN Tata scholar and receiving a Fellowship enabled him to complete his PhD in London and also pursue his interest in western music. Speaking of JRD, he mentions, “It was much later that I got to know JRD Tata well. That happened after I left the Bhabha Atomic Research Centre and joined the NIAS. The Institute was his idea. I had worked out all the details and we had many discussions on it.

He depended on me for information and knowledge about science and philosophy. He may not have been a scientist, but he had a feeling for things. He was meticulous during meetings. At times we would even hold discussions while he walked down corridors. He was a keen listener”.

In 1988, Immediately following the completion of Dr. Ramanna’s tenure as the Chairman of the Atomic Energy Commission, Mr. J. R. D. Tata invited him to be the founder Director of a new institute at Bangalore. Mr. Tata had conceived this institute to serve two functions:

1) To organize integrated lecture courses for the benefit of middle level executives in industry and Government which will expose them to aspects of modern knowledge and broaden their minds, equipping them better for decision making - decisions which would have direct influence on the future course of science, technology, industry and governance in the country.

2) To conduct advanced research in multidisciplinary areas by taking up a few chosen research programmes in social sciences for societal impact.

The challenge of the assignment appealed to Dr. Ramanna and he agreed without waiting for the buildings to come up. The Institute was called the “National Institute of Advanced Studies”. Ramanna organized the first Course in Poona with

the participation of selected knowledge specialists in different disciplines. The theme of the Course was called "Integrated approach to knowledge and information". The response was good. Similar courses were then organized in Jamshedpur in 1989 and in Banglaore in 1990. By 1991, the buildings for the NIAS had come up in a campus adjoining the Indian Institute of Science in Bangalore. The Course has been organised here every year since then. A few endowed Chairs, like the Sarvepalli Radhakrishnan Chair, J. R. D. Tata Chair, and Homi Bhabha Chair were created for a few senior Faculty positions. Otherwise, to start with NIAS did not advertise any vacancies for Research Faculty positions. The Institute waited for qualified scholars keenly interested to pursue research in fields of their choice to apply for admission. The Faculty strength has grown gradually over the years and the results have been good. Dr. Ramanna led NIAS exactly on the lines conceived by Mr. Tata and Prof. Sreekantan remarks that the grand vision of JRD could fructify only when Dr. Ramanna agreed to take up the onerous responsibility of building the type of institution that JRD had envisioned. Dr. Ramanna spent all his time at NIAS when he was in Bangalore working on advanced studies and was a role model for others.

At NIAS, Dr. Ramanna used every opportunity to shape public opinion using non-governmental initiatives. Having

been the architect of the first nuclear explosion in the country, he was acutely conscious of the need for non-proliferation of nuclear weapons. He believed strongly that a better Indo-American relationship could be brought about by non-Governmental initiatives to the benefit of both countries. At NIAS, he held an Indo-American Joint meeting on non-proliferation and Technology transfer in Jan 1994, inviting a few prominent public persons in both countries. Those present included Robert McNamara and Pranab Mukherji. Robert McNamara mentions that Dr. Ramanna appealed to him as a wise man. Speaking at this meeting, Dr. Ramanna observed, "We all agree that nuclear proliferation is a great menace to the world. For countries, which have well-established atomic centers, production of weapons and their deliveries is not a particularly difficult one. Even supposing that the countries that have this strength behave with maturity, and agree to the total banning of the nuclear weapons, the question will always be there as to how to avoid nuclear weapons or nuclear materials getting into the hands of terrorists. Terrorists are the biggest menace to society, for they are willing to do anything to make themselves felt even when they have no particular aim. I believe that there is a feeling in America as there is in India that we should work towards a nuclear weapon free society. This will take a lot of convincing especially if we wish to include all countries, which possess nuclear power to stop

them from making nuclear weapons. But there is good reason why this should be given priority, as many leaders in America and India believe that the very possession of nuclear weapons is dangerous to both the possessing and the receiving country. It may not be possible to eliminate the nuclear weapons immediately, but a group can be started to explain the internal and external dangers of nuclear proliferation so that all well-intentioned people in all countries can be convinced that the only answer to nuclear proliferation is a total ban on weapons. One can hope this can be done within a period of a decade or even earlier, but the aim towards it must be made a common cause".

Dr. Ramanna's life emphasized that man is here for the sake of other men. From involving in the civic problems in Bangalore to the proceedings of the Rajya Sabha at the other end, he was willing - in fact even keen – to look at a variety of problems in the country and to suggest ways towards reasonable solutions. In the process, he developed a heart that was becoming more and more generous and an intellect that was becoming more and more compassionate. Dr. A. Ramachandran rightly described him as a citizen of the world. In a world that is becoming more and more complex, Dr. Ramanna's life beckons all of us to get concerned and involved in the problems of the world we live in and to devote our efforts as much as possible to improve

the conditions with maximum optimism and without ever getting dispirited in the process.

There is also another message one can read from Dr. Ramanna's life. As he moved after retirement from the high offices he held in the Government with focus on specific problems to occupy other positions, whether in the Parliament or in the NIAS, where he had to address wider issues of society, he adapted himself with ease to cope with the difference. Dr. Chidambaram observes that Dr. Ramanna got along with various kinds of people. He could as easily interact with the Paramacharya, the fountain head of wisdom and spirituality, and bureaucrats like Robert McNamara as with politicians, military brass, common people, students and of course scientists- in spite of being pretty outspoken. He could be witty, humorous and satirical. He could use his power of repartee effectively. However, he was never known to be acrimonious. He never intentionally hurt anybody. He had the ability to analyse himself. While writing his autobiography, when asked as to why he was doing it so soon, he said in a matter of fact way, that he wanted to have his say first, before anybody else had a chance. He was often solicited for presiding over meetings and functions and he said jocularly that he was listed in the Yellow Pages for this job. When asked to comment on what he achieved as an MP, he said in a lighter vein that he became a specialist in

watching the Governments fall. He had the distinction among scientists to be caricatured by the inimitable R. K. Laxman and as somebody remarked, his face, glasses and portly physique seemed custom-made for a Laxman cartoon.

Although he did many things effectively and well, he had no strong attachments to anything. He accepted with equanimity vicissitudes in life. Thus, when he was transferred to DRDO, although people associated with him in the Atomic Energy Programme were agitated, he carried on in the new environment and contributed well. Once when he was involved in an air crash and narrowly escaped, he was totally unperturbed. He was what the Bhagwad Gita calls a "STHITAPRAJNA". Dr. Ramanna led a rich life, dwelling in the highest of planes in many aspects, science, music, spirituality and philosophy. He was proud of the Sanskrit culture of our ancient land that he described as the greatest in the world. He had made a deep study of philosophical literature of Hinduism (advaita) and Buddhism. In anything he did, he left a unique stamp of his character and personality.

Professor C. V. Sundaram

C. V. Sundaram is a metallurgist who has had a career long association with the Indian Atomic Energy programme, since 1952. He is well known for his contributions to the extractive metallurgy of rare and reactive metals, particularly zirconium and beryllium. He was Head, Metallurgy Division, BARC during 1975-82, and Director, Indira Gandhi Centre for Atomic Research, Kalpakkam during 1982-89, when the Fast Breeder Test Reactor was brought to first criticality. He was President, Indian Institute of Metals during 1981-82 and President, Indian Nuclear Society during 1991-93. From 1991 - 2002 he was a Visiting Professor at the National Institute of Advanced Studies, Bangalore. His research interests include Energy Options, Advanced Materials, and History of Technology. He has co-authored a book entitled "Atomic Energy in India – 50 Years."

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