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A Life in Science

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VIGYAN PRASAR

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Content

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Foreword

We are privileged to bring out this commemorative volume on the life and work of Professor Yash Pal on the occasion of his 80th birthday.

Professor Yash Pal has been an iconic figure in India. He is a scientist, institution builder, educationist, communicator, – all rolled into one. It is not uncommon to find him engrossed in discussions either with school children, or with senior scientists. He is equally at home with both. To the young, however, he is a role model and a constant source of inspiration. He is a phenomenon.

Professor Yash Pal has been associated with Vigyan Prasar ever since its inception, and has been a guiding spirit in many of its activities and campaigns. In particular, I would like to mention his interest and involvement in the national campaigns built around the events of the Total Solar Eclipse of 1995 and the Venus Transit of 2004. On both the occasions, he was instrumental in bringing these events live on our television screens.

Most of the information and photographs in this volume are appearing for the first time, and bring forth the hitherto unknown facets of Professor Yash Pal's illustrious life and career. These memoirs have been lucidly penned down by Biman Basu in his own inimitable style, himself a well known author and a science communicator. We are

thankful to him for undertaking this challenging task and accomplishing it so exquisitely and expeditiously.

We do hope this commemorative volume would be successful in passing on the thrill and excitement of doing science that Professor Yash Pal himself has experienced, and inspiring the youth to take up a career in science.

Benedictions ! Professor Yash Pal !

Vinay B. Kamble
Director
Vigyan Prasar

26 November 2006

Preface

Prof. Yash Pal embodies several personalities – scientist, manager, educator, and communicator – all rolled into one. There are few Indian scientists who have done so much in so many different fields, and have done it with such fervour. And at the age of eighty he still remains as active as ever, chairing expert committee meetings, answering children's questions, and doing a host of other things – all with equal ease.

Prof. Yash Pal spent almost 35 years doing research in Tata Institute of Fundamental Research, Mumbai, where his main areas of research were cosmic rays and high-energy physics. He also built up the Space Applications Centre at Ahmedabad and was the key person to plan and execute the yearlong Satellite Instructional Television Experiment (SITE) during 1975-76, and bring in a new dimension in educational communication in India. But not many are aware of the kind of obstacles he had to overcome both during his research years and in the execution of SITE. Often, the kind of solutions he found, the kind of innovations he had to make, and the kind of hard decisions he had to take to get things going appear incredible. They also bring out the true grit of a person with deep conviction who is never prepared to accept defeat.

As Chairman of the University Grants Commission he tried to bring about radical changes in the university education system. Although he was not quite successful in everything he tried he did succeed to bring about some new innovations in the shape of the Inter-

University Centres, Academic Staff colleges, and the Media Information and Library Network (INFLIBNET).

Later, he became popular as one who could explain science in layman's language. His regular appearance in the TV science programme 'Turning Point' to answer questions sent by viewers made him almost a public icon. He developed his own unique style of explaining science – not giving direct answers but making the viewers think and understand to get to the answers.

The material for this brief biographical sketch is mostly based on his own reminiscences recorded during several sittings with me. I am grateful to him for sparing his valuable time for the recordings and also for explaining many of the complex scientific experiments conducted at various times. But this is not a book of reminiscences; I have also drawn extensively from his speeches delivered at different forums and various other resources. The intention was to bring out his multifaceted personality as best as I could. I am also grateful to him for the priceless photographs he has made available from his personal collection for the book.

The common thread that runs through whatever Prof. Yash Pal has done in his long and productive life in science is the emphasis on innovation and independent thought, and the fact that often it is more important to invent a thing yourself than to procure it. Unfortunately, most of our researchers do not do much of these things nowadays. It is hoped this brief biographical account would inspire readers, especially the youngsters, to take a cue from his life and encourage them to take up any challenge in life.

Biman Basu

1
Early Years

Yash Pal was born at Jhang (now in Pakistan) on 26 November 1926. His early childhood was spent in Quetta (Balochistan). A massive earthquake in 1935 demolished the family home and most of Quetta. Yash Pal remembers the devastation in which not a single house was left standing. Indeed Yash and his brother were dug out from rubble of mud bricks just in time before they were lost. After that his mother, brother and sister had to move to their native place, first to a village, Kot Isa Shah, where his maternal grandfather ran a flour mill and lived in a house built on top of the mound left over by several earlier floods of the river Chenab during which his home had repeatedly collapsed. Yash went to school there, very different from what he was used to.

He remembers well the cruel way in which the teacher used to punish iterant children, along with many beautiful facets of village life in rural Punjab of that time. He remembers that the river Chenab rose once again during his stay there, but not so much that they might have needed to clamber up the date palm trees to save their lives; that was part of the memories of that village. The family moved to Jhang a few months later where he attended two schools in two years. Jhang was an ancient town and littered with old fortifications, crumbling ramparts and, out in the open, loads of broken red pottery littered over flat areas uncovered occasionally by drifting mounds of sand. Life there was different, but pleasant in its own way. Quetta was almost forgotten till the military decided that families could return to the town that had been partly rebuilt using earthquake-proof architecture.

A massive earthquake in 1935 demolished Yash Pal's family home and most of Quetta

In the next two years he remembers the outings into the hills around, visit to Chaman, the border town with Afghanistan, camping trips with school. He also remembers how one of his Pashtoon and Hazara friends had given him a nickname 'Mota Sir' (thick head) because he was able to answer all the questions of his teacher. The world of learning was beginning to open. One day he and friend Lali heard the noise of an airplane from a corner of the sky, upon which he came running, urging him to get on his bicycle and come with him. Lali knew the location of the airport where once every few months a plane would land. They walked up to the plane and talked to the pilot pottering around inspecting it. The pilot let them see it and sit in it. They were amazed to learn that it had taken only two days to come all the way from Calcutta.

Yash Pal would have gladly lived all his life in Quetta, but his father had been transferred to Jabalpur and they all moved there. Going

from rather the barren, dry and hilly area of Balochistan to the lush green forests of Madhya Pradesh was an enormous change. Yash could not believe that the world could be so green.

In Quetta, and before that in Punjab, the medium of instruction and the language of his school had been Urdu, though English was taught as a language. When he arrived at his new home location he found that he had to choose between Hindi and English mediums. He had no choice because he knew very little Hindi. Since his mother had put him in class nine, one grade higher than his level in Quetta, he had to study a lot to catch up with his fellow students, especially because part of the year had already gone by.

The need for self-study turned out to be a boon, largely because one of the subjects he hard to learn was Euclidean Geometry. He did not even know that there was a subject like that. But after he dug into his textbook he was fascinated. For the first time he had encountered something that required logic and truly engaged his mind. He still recalls the joy of thinking that first came to him in that solitary engagement with geometry. He feels he might have missed this joy if he had not discovered it by himself! Another bonus of being in that school, not well known for its infrastructure or academic distinction, was the presence of a teacher named Pawar, who, Yash Pal recollects, "taught mathematics, geography and physics. He emphasised understanding, not memorising. He often went off on a tangent, ranging over history, independence movement and styles of living, with a quiet sense of humour. All this while he was teaching the geography of Europe at War! (World War II was raging there while Gandhi was about to launch his Quit India movement). He never lectured. He only conversed." Yash Pal singles him out as the person who first introduced him to a life of learning. Indeed he sought him out after 50 years and went to Jabalpur to pay his respects. He was thrilled when Pawar humoured him by saying that he still remembered his student Arya – this was the name Yash Pal had taken in high school (more on this a little later). After finishing school Yash Pal travelled to Lyallpur (now Faisalabad, Pakistan) to stay with his aunt (mother's eldest sister) and study at the

Government College in that town. This step was taken because of a rumour that his father might soon be transferred out of Jabalpur.

Yash Pal refers to a happening in the first year of his college that might have influenced the rest of his life centrally. After four months into the first year in college he fell sick. It was typhoid that went on and on with a relapse and then double pneumonia. He was pretty serious and his mother was called from Jabalpur. He recovered after three months but had become very weak. His mother insisted that he give up his studies for a year and come with her to Jabalpur. She first took him to her father's house at Jhang to fatten him a little. While going there Yash Pal borrowed some books from the college library, one of which was the Autobiography of Jawaharlal Nehru.

As Yash started reading it he got completely absorbed. He was just 16 and did not have much practice in reading large English books. But he soon developed reading skill as he dug deeper into the mind and world of Nehru. He discovered India, and its personality. And he discovered Gandhi. As he travelled home for rest one book followed another and he went on and on. After Gandhi came Tolstoy, not just his novels but also other books like *What then must we do?* Going this route it was natural to get on to Ruskin, Emerson, Thoreau and many others including Tagore – *Personality: Lectures Delivered in America*, *Religion of Man* – and others. This immersion for six months changed him. He started wondering whether doing science alone would be completely fulfilling. He asked himself again and again "What do I want to do with my life"? He even invented forms in which he could combine working in a laboratory and commuting to a hut in the countryside to engage with rural life at grassroots. The spirit of the times, when the national movement was peaking, combined with adolescent dreams created an amalgam that was to keep him in permanent adolescence of sort all his life. He says he feels grateful for that sickness that made him 'lose' a year, because he actually gained much more than a solitary year during those six/eight months following his sickness. One wonders whether the personality of varied engagements that has characterized his life was seeded during that year after his sickness!

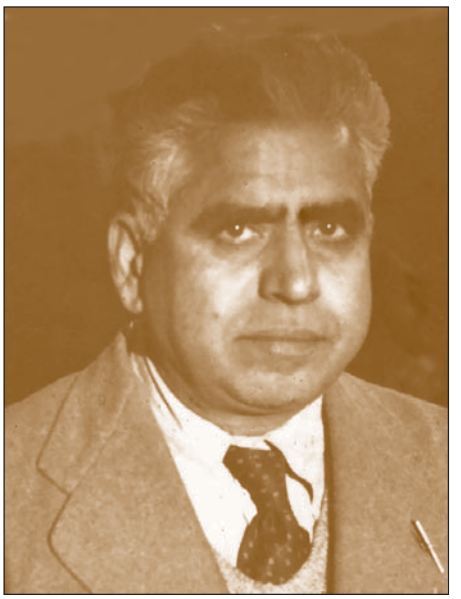
2

Turbulent Days

Yash Pal grew up in an Arya Samaj home. "It was an act of faith that all wisdom was encapsulated in the four *Vedas*. While the *Upanishads* were just commentaries on *Vedas*, the *Puranas* were mostly lies. While Rama was a just and noble human being and there were many moral and ethical lessons to be learnt from the *Ramayana* and the *Mahabharata*, and of course the *Gita*, all miracles therein were corruptions introduced probably by unscrupulous persons later. Of course, the ancient Aryans knew everything there was to know, and we would too, if we could read, understand and master the *Vedas*," he reminisces.

This teaching had a strong influence on his young mind. His family was strongly against caste system, or idol worship. They believed there was just one God and that the stories about a multitude of gods were created by some persons for their own purpose. He says, "In one sense the past I had inherited was made very simple and rational, indeed rational to the point of being dry and dull, with no room for uncertainties and ambiguities."

As non-believers in the caste system Yash Pal's family had already given up using their surname. But when he was thirteen and had to change his school, he took on the surname of Arya, "with all its



Father Ram Piyare Lal (1949)

connotations". That was the name under which he passed his matriculation examination. But, in 1942, at the age of 15, when he joined college, he took on the surname of Bharati. He read a lot, joined the students' movement, first the Students Federation and soon the Students Congress. Then he also gave up the surname of Bharati after a couple of years, but never thought of using the family surname of Bhutani, even after everyone else in his family, including his parents, started using this surname. But, interestingly, he could not escape having a surname. He acquired one after he started publishing scientific papers. People started calling him 'Pal'.

Yash Pal moved to Delhi during the turbulent days of the partition, which left a lasting impression on his mind. It was a very momentous year for the country. Discussions were going on about the transfer of power from the British, and also about the partition of India. It was a very unsettling period. Even in Lahore, there were riots. At that time he was a student of B.Sc. Honours in the Physics Honours School in Punjab University, Lahore. His father was a government official in Lahore; but in 1947 he got transferred to Delhi. Yash Pal had come to Delhi to spend the summer vacation with his father. He had planned to go back to Lahore after the vacation to finish his final year of Physics Honours, but that was not to be.

Delhi on 15th August 1947 was a scene of celebrations and rejoicing. But it was also a day of grieving for hundreds of thousands who had lost their near and dear ones or had to leave behind their ancestral properties on the other side of the border. The house where Yash Pal's family stayed in Delhi became the first stop for a large number

of refugees, including many of his relatives, who just happened to be in Delhi at that time.


Mother Lakshmi Devi (1950)

It was not easy to pass time in the midst all that was happening around. Then it occurred to Yash Pal and a friend of his that they ought to be doing something. But what could they do? Everything appeared to be in turmoil. Then they discovered that there was a refugee camp, which had been started for migrants from Pakistan, at Kingsway, beyond the University on Mall Road. When they reached the camp they found some barracks and refugees all around. It did not take them much time to decide that they would work in the camp and they expressed their willingness to the camp commandant Choudhary Sher Jung, whom Yash Pal describes as a "fantastic person who was in the Gadar Party earlier; very well educated, literate; the same brand as Bhagat Singh and that kind."

But he was greatly disturbed seeing the pathetic situation around the camp. Strange thoughts came to his mind: What was he going to do in life? What point was doing physics, with all the horrible things happening around after the riots? But he also had good company where he would find solace. He reminisces, "Wonderful people came. There were artists, writers, theatre people, social scientists, and politicians."

But camp life was not uneventful. Often tempers ran high among the refugees. Every day something big would happen. When Sardar Patel and Gandhiji came to visit the camp, people in the camp were so agitated that there was apprehension that they were going to beat up Gandhiji. "I broke up a cot and took out one of the poles to act as a volunteer to save him," Yash Pal reminisces.

But one incident left a deep mark on his mind. One day, the hospital across the road was attacked; quite a few people were killed. No one was sure who were the culprits, but suspicion fell on the refugees from the camp. A few hours later a car came and stopped before the camp office. Jawaharlal Nehru stepped out; when he heard about the incident and visited the hospital he seemed to be certain that refugees from the camp had done it. Nehru's reaction was severe. Yash Pal recalled, "He (Nehru) started shouting, 'Where is the camp commandant?' When the camp commandant came Nehru started shouting, 'Is this what we had fought for? Are we going to have a country like this?' 'If this happens again,' he said, 'I'm going to blow this camp into smithereens.' He almost broke down. He spent an hour and a half or two in the camp and I must say he was really hurt. His agony had such an influence that we had a far better peace in the camp after that.'"

Meanwhile large numbers of refugees were pouring in from Kashmir, hordes of them. When they came to the camp Yash Pal and others had to provide them food. Food had also to be prepared for airdropping for the Kashmiri refugees on the way.

It was such intense day-to-day, hour-to-hour life that whatever he had thought of doing earlier – physics and all that – had no meaning. He did not get time to seriously think of doing anything else. Soon, however, he discovered that quite a few of his class fellows from Lahore were in Delhi, as were some of his teachers. There was a glimmer of hope that he could after all continue with his studies. But where could they hold the classes? Where could they find a space? That too soon became available.

Yash Pal and his classmates along with their teachers went to Dr. Daulat Singh Kothari, who taught physics at Delhi University, to request him to arrange for some rooms for them to study and do some experiments. Dr. Kothari readily agreed. But merely getting a place to have classes would not be enough; if students were to come from Lahore to study in Delhi where would they stay? There had to be hostel accommodation for them also.

So, with Dr. Kothari and Elizabeth Gauba, a German lady, who was running a school in the city, they went to the Deputy Commissioner's house. M.S. Randhawa was the Deputy Commissioner. He took the whole group and his personal assistant in his car and drove them around the university to show round a few barracks, all empty after War. The barracks were ideally suited for hostel accommodation. Randhawa asked his PA to immediately issue orders allotting those barracks to be used as a hostel for students of East Punjab University coming to Delhi for study. Arrangements were soon made for cots and food for the students by various voluntary groups.

It was a great relief for Yash Pal and his friends who had made up their minds to continue studies. He recalls, "It was a time of great tragedy, but also a time of tremendous hope, and something new was beginning to happen. That students like us could do this, that people would listen, that others would be cooperative. That there would be people like Dr. Kothari all over, people like Randhawa all over. That was the atmosphere and that was a very important thing to happen."

These experiences played a major role in his life. The contacts made at that time and the impressions of that time became part of his character and personality. This was the kind of background that led to the kind of creative person that he became. He completed his B.Sc. Honours from Delhi and was doing his M.Sc. when he got an interview call from TIFR.

Vikram Sarabhai (centre) with D.S. Kothari (right) and P.R. Pisharoty (left) at the TIFR conference (1950)

C.V. Raman at the TIFR conference (1950)

3

TIFR and Balloon Flights

In 1949, East Punjab University's Physics Honours School was located in the campus of Delhi University, where Yash Pal was doing the final year of his M.Sc. There was an advertisement of Tata Institute of Fundamental Research (TIFR) for position of research students. Although he had not finished his M.Sc., he applied and got an interview call. Soon, with some colleagues he left for Bombay (now Mumbai). This was to be his initiation into a long and brilliant research career spanning more than three decades.

At that time TIFR was located in majestic colonial building of the Old Yatch Club near Gateway of India. Yash Pal had planned to do work on nuclear emulsion technique for his M.Sc. dissertation. But there were hardly any facilities available in Delhi for that kind of work. They did not even have a dark room, leave aside possibility of processing nuclear emulsion plates. But he had done enough preparations. The interview at TIFR turned out to be very friendly and the outcome totally unexpected. After learning about his plans to work on nuclear emulsions the interview committee promptly asked him to do the work at TIFR. This was unprecedented, as he had not yet completed his M.Sc. To work at TIFR it required him to be admitted as a research student first, for which he needed to complete his M.Sc. But after the interview he was told that he was admitted as a research student and that he could

Peters (left) and N. Feather at the TIFR conference (1950)

do the work for his dissertation at TIFR. It was a golden opportunity for a young aspirant to prove his research talent, and he did not allow it to go waste.

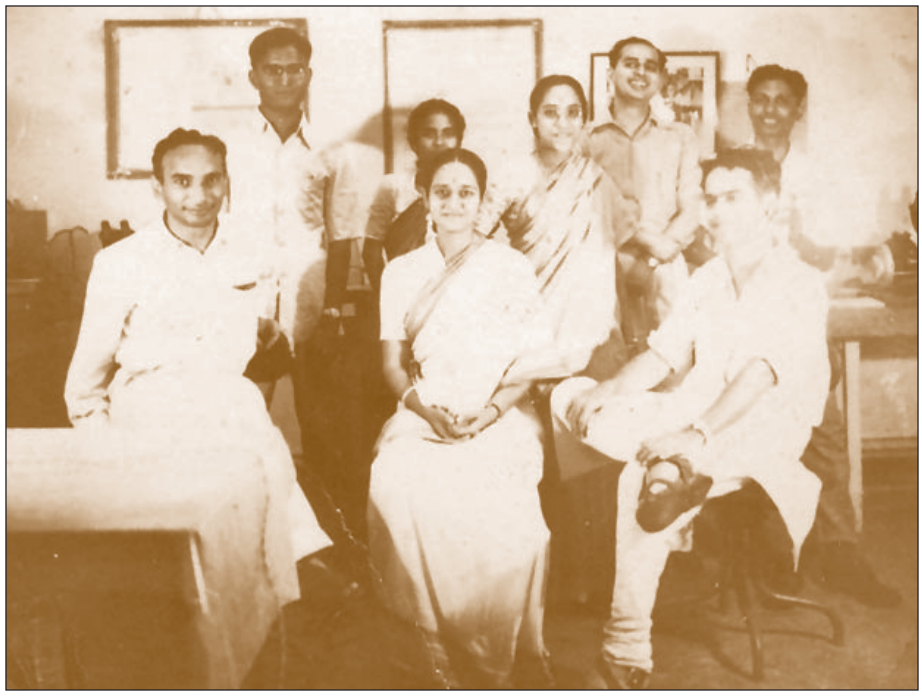
But before he could join TIFR, he had to get permission from the University authorities in Delhi, which took a while to come. Finally, the University had to give permission because there were no facilities at all for doing that kind of research in Delhi University. So finally he went to Mumbai to join TIFR, and thus began his long association with India's premier research institution and a highly productive career in science.

Work on the nuclear emulsion technique had been going on at TIFR for a while. The nuclear emulsion technique is one of the oldest photographic techniques that helps scientists study what happens as

Shanti Swarup Bhatnagar (right) and John Mathai (left) at the TIFR conference (1950)

high-energy particles in cosmic rays or nuclear reactions decay or interact with other particles. The fundamental rebirth of particle physics during the 1950s was especially due to the development and spread of the technique, by using which research groups in many countries were unravelling phenomena the existence of which no one had suspected. Other techniques that used electronic detectors, were blinded by the radiation flash, and required much more care and development to function reliably.

When Yash Pal joined TIFR not a great deal had been done there on nuclear emulsion technique. They had a laboratory and there were a few people who knew about it. So he had to work late nights, almost without any break, in order to finish his dissertation in time and the time was short – only about a month and a half. One of his fellow



The nuclear emulsion group at TIFR: Yash Pal (sitting on the stool at right), with Ram, Mrs. Krishnan, Sandhya, Biswas, Daniel, Aruna, and Neelakantan (1952)

students helped type it and get it bound. Finally he submitted his dissertation in Hoshiarpur in Punjab, where East Punjab University had moved by then, and got his M.Sc. degree, securing a first class and second position in the university.

Meanwhile, his appointment at TIFR had already started, and this was very unusual because they did not ask for any certificate or anything. "In fact," says Yash Pal, "I don't have any certificate for my matriculation, B.Sc., or M.Sc. degrees to show that I've passed these exams. I think I do have one for my PhD from MIT." So he went back to Mumbai to begin a new phase of his life.

He was naturally very excited. A new world had opened before him. But after the initial excitement wore off the work seemed a bit routine and he was worried if he had made the right choice. Then things suddenly changed with the arrival of Bernard Peters, a distinguished

cosmic ray physicist, who had discovered the presence of multiply charged heavy nuclei in cosmic radiation. He fondly recalls, "Peters was a fantastic input not only in terms of science which he had done (and he was very famous already), but also a personality with which I resonated. A Jew, he had been incarcerated in Germany and escaped to America, worked as a labourer, and finally ended up joining Oppenheimer as a student though he had never studied undergraduate physics.

"Oppenheimer took him to work with him even on the Manhattan Project. And he prepared lecture notes on quantum mechanics by Oppenheimer, which became famous. Then, pretty soon, he joined the University of Rochester and started using nuclear emulsion technique and he was one of the earliest to use the technique. They discovered the existence of heavy primaries in cosmic rays. They also discovered the presence of other chemical elements in cosmic rays. Not only that, they did a fair amount of work from which it became clear that it's possible that some of the elements that we observe in cosmic rays, or which may be observed – elements like lithium, beryllium, boron – could not have arisen in isolation originally because these are elements which are actually nuclear fuels and would be consumed within stars and their cosmic abundance is very low. So they must be produced in passing through interstellar space and in collision of heavier nuclei. And this became quite an important issue to settle and remained unresolved for quite a while."

Bernard Peters had come to TIFR on the invitation of Homi Bhabha to conduct balloon flights to study the composition and nuclear interactions of energetic particles in cosmic rays. Within a period of less than eight years that he spent at TIFR, Peters made a huge impact on the quality of research in the fields of cosmic radiation, high-energy and elementary particle physics and geophysics. Yash Pal reminisces, "I think Peters was responsible for introducing a certain way of selecting issues and problems in science for working on. You don't have to work on everything, but work on something which has a meaning. You ask yourself a question, if you find some answer, no matter what, and then take it

With Devendra Lal (right) during the Madras balloon flights (1950)

up. If you don't get an answer to that then don't take it up. It is not realised how much of a difference Peters made to this particular culture of science – experimental science particularly – at that stage in TIFR."

The greatest contribution of Peters was to establish within a short span of time an important fact that scientists in India had all the capability to make discoveries and to do fundamental research, at par with the best in the world, only if they could develop confidence in themselves. He assured the TIFR group that they had the basic capability and that the confidence had to be built by asking good questions and

doing well-thought-out science. It would not be an overstatement to say that the contributions of the cosmic ray group comprising Peters, Yash Pal, Devendra Lal, and a few others during the 1950s helped greatly in putting TIFR, and India, on the global science map.

Under the guidance of Peters the TIFR group did some balloon flights. Peters had brought an apparatus that he had developed at Rochester for use in balloon flights. Balloons were flown from Madras (now Chennai) and Yash Pal was stationed in Vellore as a theodolite observer to see which way the balloon went. Taking part in balloon flights was a fantastic excursion for the team members. Although he had to work with many people for preparing the instruments for the flights, one person that Yash Pal fondly remembers is Devendra Lal, his associate at TIFR, who became his life-long friend.

Lal and Yash Pal worked together and did all kinds of "marvellous silly things". They had realised right from the beginning that if they wanted to do new things they would have to innovate. There are some very interesting examples of their innovative thinking. Since large Mylar balloons used later for cosmic ray research were not available those days the TIFR team had to use much smaller meteorological balloons made of rubber. They used to tie up several meteorological balloons together to carry the payload. So there would be 70, 80, or 100 balloons tied together, and they would carry the payload up. The problem was that these balloons were not of the same quality. They would burst randomly as they went up, and the height finally achieved by the payload would depend on how many balloons were finally left to take the payload up. But somehow, because of various other factors, the TIFR team did manage to get some level balloon flights at 80,000 - 90,000 ft altitude (24,500 - 27,500m). The worry was, when a balloon burst not only did it lead to a loss of lift, but the heavy neck of the burst balloon also became a dead load. If that dead load could be somehow removed then the balloon would certainly go higher; so a way had to be found of removing the dead load.

Yash Pal and Lal had lots of fun thinking about this issue. The solution appeared simple. If somehow the dead load could be

The only photograph available showing Yash Pal with a balloon (1950)

automatically detached from the payload after a balloon had burst it could solve the problem. But some members of the team thought differently; they said it would be very difficult to separate 80 strings, which could get entangled, and the dead load would never fall.

But Yash Pal and his friend would not give up; they thought of a novel scheme. The idea was to use cotton strings and tie tiny small tubes of concentrated sulphuric acid to them with little bits of cotton tape. When a balloon burst the string tied to it would drop downwards; then the acid would come on to the cotton tape and burn it, dislodging the balloon neck, which would fall away.

Then somebody pointed out that there would not be enough oxygen at that height and it would not work very well. But Lal had fantastic ideas. As a school student, he used to make fireworks for fun. He was very good at that. And he quickly found a solution – just soak the tape in a solution of sugar and potassium chlorate and dry them. The chemistry logic was simple: Potassium chlorate would supply the oxygen, and when sulphuric acid fell on it, the cotton tape had to burn. The whole arrangement was tested in a vacuum to make sure that it was perfect.

Lal's scheme made the launch of balloons an elaborate affair. After all the balloons were up on the ground and were filled and tied to the common line, Yash Pal and Lal went round with test tubes of sulphuric acid and taped them on to the strings, hoping that it would work. But, as Yash Pal frankly admitted, no one knew if the arrangement really worked, but said it must have worked!

Sometimes it can be real fun doing new things that has never been done by anyone else, and that is what Yash Pal and Devendra Lal had been always doing – trying out unconventional ways to achieve goals. It occurred to them that perhaps they could control the flight of the balloons a little bit by shedding load when somehow its carrying capacity got reduced during flight. By shedding load the balloons could perhaps be made to go up again. The idea seemed quite simple – to put some extra load of sand bags that could be emptied as required. They just had to procure some clean sand and use a funnel to put it in bags.

But before the sand could be released how does one know from ground whether the balloons were going up or down? Remember, in those days instruments were very expensive to import and were not easily available. Again a streak of genius worked here. Yash Pal and Lal decided to fill one of the balloons in such a way that it had neutral buoyancy; that is, it would neither rise nor fall to the ground when released near ground. Although, as it expanded after it was released along with and tied to the other balloons the buoyancy would change a little, but that, they said, would not be a problem. So, when the other

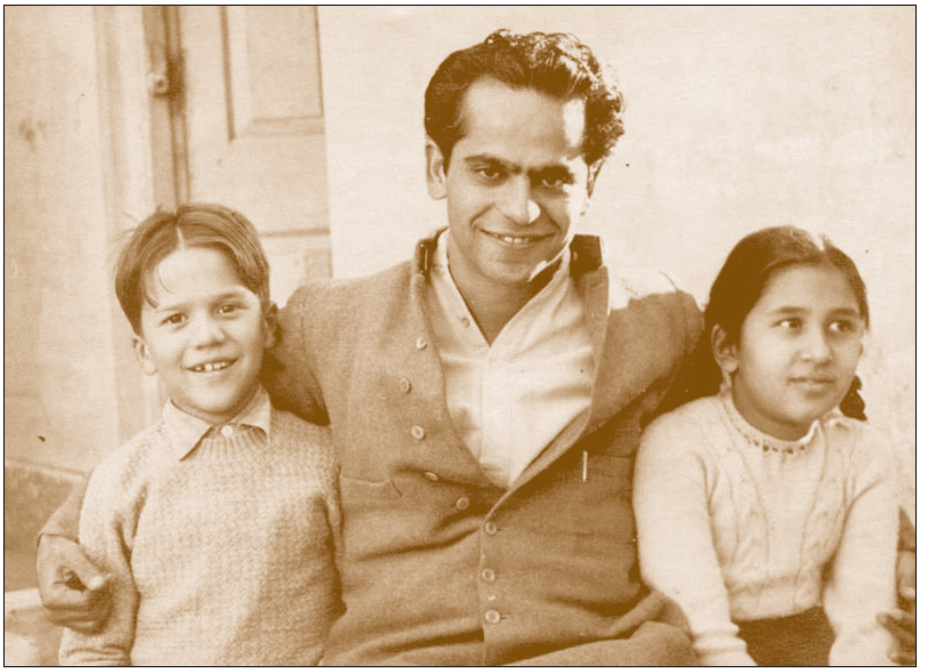
balloons were going up the neutral buoyancy balloon would drag behind a little; but when the other balloons were coming down it would rise up a little. So all that had to be done was to take a funnel at the end of the sand-filled bag and have a stopper with a lever arrangement so that when the neutral buoyancy balloon was rising up as the other balloons were going down it would open, releasing the sand and that would make the other balloons with the payload rise again.

But before the idea could be put into practice sand had to be procured – very dry, clean sand. Being in Mumbai it was quite natural to think of getting the sand from the beaches where it is available in plenty, but law did not permit picking sand from the beaches. So, they were left with no alternative but to collect sand from the Chowpatty beach clandestinely at midnight. They filled up some bags of sand, cleaned and dried it, and had the sand bags ready to fly with the balloons. The TIFR team tested the mechanism on ground and it worked. Although no one knows for certain whether the mechanism worked as planned during flight, it was undoubtedly a remarkable piece of ingenuity at work, which Yash Pal and Lal revelled in doing.

Another necessity for the balloon flights was to have a barograph to measure the air pressure as the balloons rose, which would give an indication of the height reached. But normal aneroid barographs of very high quality were beyond the means of Indian researchers to import from outside. So, P.N. Krishnamurthy, a colleague of Yash Pal, developed a barograph. It was nothing but a small mercury manometer made in such a way that its height could be measured as pressure. But to record that in flight it was necessary to take a picture of the mercury column. And so a bulb had to be put in for lighting, a lens to take the photograph, and a strip of film that could be moved. The motion was to be provided by clockwork. So, clocks were bought and had to be cleaned of any residual oil that could damage the film.

Small lenses were also needed and good lenses were not available in India. Someone had the brilliant idea of getting them by cannibalising Kodak Brownie cameras, which had fixed focal-length lenses. The

Family picnic with Mohindra Chadha (extreme right) (1951)



With a friend's children (1951)

Relaxing at a friend's place in Delhi (1951)

cameras were bought and taken apart and the lenses used to make the recording set-up in barometers for measuring the pressure and recording the altitude as the balloons went up. It was yet another remarkable piece of innovation.

Batteries to power the bulbs for lighting were another problem; sometimes they would go bad. But, again, Lal found an easy way out; he suggested that a hole made at the bottom of the box housing the whole device could let in light from the illuminated Earth below to provide the necessary illumination. It was a brilliant idea, but never occurred to anyone else.

Under the guidance of Bernard Peters, the TIFR cosmic ray group went through a period of balloon flights. Some were successful; some were not. But they provided the group members an opportunity to travel all over the country. Yash Pal describes that experience as his "Discovery of India", particularly South India, Rajasthan, and many other states. They got some good flights and managed to do some real first rate research.

While talking of the balloon flights, Yash Pal repeatedly stresses on the fun in doing research, especially if you don't copy anybody, and narrates the thrilling experiences he had had in arranging those flights. Once they had planned to fly a very large stack of nuclear emulsions that could be used to trace the track of particles. It was a pretty tedious affair, but that was the technology that was coming up at that time. In planning that balloon flight Yash Pal and others had followed almost childlike new ways of doing things. "When a stack of 200 emulsion layers is used it is necessary that there is a means to follow a track from the top layer to the bottom layer. One had to align them, cut the plates, mount them on frames, and yet mount them in such a way that one is able to align a track, which is only a micron or two thick. It was a difficult task," he says.

Bernard Peters had an idea. He suggested the use of a 'grid' between the plates, which could make aligning the tracks easier. The

grid could be drawn of a material, which was slightly radioactive. Of course, a beta active source could not be used, as it would mess up the whole thing. But an alpha active source would be okay, and the best source would be polonium. But where could one get polonium?

Thanks to the young brains at work, a source was soon found: spent radium needles used for radiotherapy of cancer in hospitals could be used as a polonium source because radium ultimately decayed into polonium. A colleague of Yash Pal from TIFR, who had joined the Tata Cancer Hospital in Mumbai, was requested to provide the spent radium needles that were of no use for the hospital, and he gladly obliged. So a polonium solution was prepared and grids made of thin polythene wires were soaked in them. The grid was stamped out on cardboards. The radioactive grids turned out to be of great help in aligning the tracks.

And so, there was a stack, which was to be flown from Delhi. Normally, after launch from ground, a pre-set alarm is used to release the payload, which then parachutes down to ground and is recovered for analysis. To plan the recovery, it is necessary to know the wind speed and direction so that the approximate point of landing of the payload can be estimated.

It was winter. For the balloon flight from Delhi the wind direction as given by the met department was westerly at high altitudes where the balloons were expected to fly. So, a flight lasting 4-5 hours was expected. But the team did not want to lose this stack at the end of the mission after it had parachuted down to ground. They did not want someone to open and break it before it could be recovered. After discussing with government authorities the team could arrange for an aircraft to follow the balloon (actually a bunch of balloons) during its flight. The Indian Air Force also provided a parachutist to pick up the payload when it landed. The plan was to follow the balloon by staying under it. When the balloon flight was terminated by an onboard alarm clock and the payload released, the parachutist would jump and recover the payload from ground and get it back to the team after return.

Yash Pal was given the responsibility of going on the flight. So, after launching the balloon the team rushed to the Safdarjung airport and got into a Dakota (DC-3) aircraft, which had a transparent dome on the top through which the balloon could be seen. He had to stand on a stool to look for the balloon. Since the balloon had already drifted, the Dakota had to catch up with it. Soon he spotted the balloon and started giving instructions to the pilot to keep track of it. Since the Dakota moved much faster than the balloon the pilot had to do several loops to stay under the balloon. The alarm on the payload was set for four hours' flight at high altitude. So, for four hours Yash Pal had to keep standing, keeping a watch on the balloon and giving instruction to the pilot. "It was a really very tiring experience", he reminisced later.

When time came for the payload to be released, he started looking for the parachute that was to open to carry the payload down. But nothing happened. He waited for half an hour more, and half an hour more, but nothing happened. At this point the pilot informed him that he could not go any further, as it would mean crossing into Nepalese territory, and he had no permission to enter Nepal. Also, he did not have enough fuel to go into Nepal and had to turn back to Delhi. So, there was no way the Dakota could follow the balloon further, and the team had to turn back. Yash Pal felt terribly disappointed and unhappy, and so did everybody else in the team because they had invested a lot of effort into it. But not all was lost, as it soon became clear.

For balloon flights it was common practice to put notices on the outside of the payload requesting anyone finding it to contact TIFR, and a reward of Rs.100 was also offered for its safe return. A month after the flight a letter written on handmade rice paper arrived at TIFR. It came from somewhere in Nepal and said the payload was lying with the writer and requested the researchers to collect it after paying the reward money. The writer of the letter also gave directions to the place from where it was to be collected. It meant an arduous journey from the border by bus and on the pony back, and two days' travel on foot, to a place near Pokhara in Central Nepal.

At TIFR, the cosmic ray team was elated. Yash Pal and a colleague of his rushed to Delhi to get visas, but they were told by the Nepalese Embassy in Delhi that the permission for going to Pokhara could be obtained only from Kathmandu. So, they flew to Patna, and from there to Kathmandu. They arrived in Kathmandu at 3 o'clock in the afternoon and rushed straightaway to the Indian High Commission to inform them that permission was immediately required to go to Pokhara. But they were told that there was only one flight a week to Pokhara from Kathmandu and the flight was on the next day. This meant the two had to somehow get the permission the same day. Desperate to catch the next day's flight the two young researchers from India rushed to the secretariat and, as only raw, young people can do, confidently asked if they could see the Nepalese Foreign Minister, who happened to be in a Cabinet meeting at that instant. They were directed to see the Deputy Foreign Minister to whom they narrated the whole story – of the balloons being launched from Delhi and landing in Nepal. The Deputy Foreign Minister was also shown the letter received from the person who said the payload was in his custody.

Yash Pal candidly narrates what followed:

"He (the Deputy Foreign Minister) said, 'Look, on my own I can't give permission; I have to talk to the Foreign Minister.'

'Then please talk,' I urged.

'But he's in a Cabinet meeting,' he said.

'Please call him there. Tomorrow is the flight,' I said in desperation.

So he telephoned the Foreign Minister and spoke for a while. After a while, he told us that the Foreign Minister knew about the issue and he had already told the Prime minister about it, and they were coming to see us.

We asked, 'What's the matter?'

It turned out that the Prime Minister of Nepal had heard the conversation between the Deputy Foreign Minister and the Foreign Minister and had asked the Foreign Minister, 'Are you talking about something falling from the sky? You know, the Commander-in-Chief was touring the area and he heard stories about things falling from the sky and something that looked like a bomb fell from the sky. They went and investigated and he's brought it here. It's lying downstairs.'

Sure enough, there was our equipment, guarded by a policeman and an Army man. We were completely taken by surprise. We were relieved, but also very unhappy, because we *wanted* to go to Pokhara. Nonetheless, that balloon flight turned out to be very very successful.'"

The balloon flights were not only adventure and thrills; there was also a lot of serious science to do. The TIFR group was among the first groups in the world to develop emulsion detectors. These detectors were exposed to cosmic ray particles during balloon flights. Occasionally, while scanning through the emulsion plates evidence of a strange particle was found – a charged hyperon (a class of unstable elementary particles heavier than proton and neutron) decaying, or K-meson decaying, and so on. It was amazing that several particles – sigma, and K, and so on – produced together were found. Yash Pal, Devendra Lal and Bernard Peters published several papers on the work. In a sense, one of the first evidences of associated production at that time was obtained at TIFR in 1953.

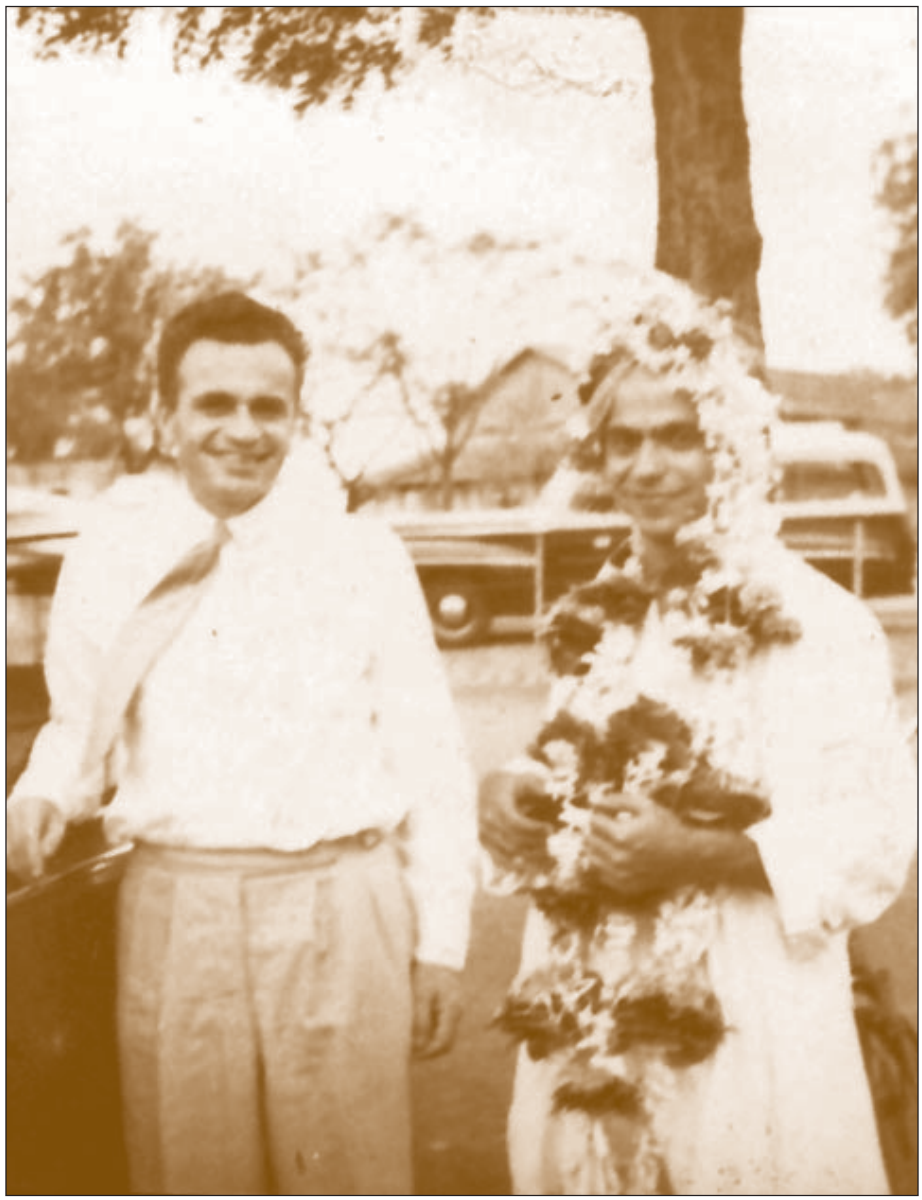
By the time Yash Pal left TIFR in 1954, to do PhD at the Massachusetts Institute of Technology (MIT), Cambridge, Massachusetts, USA, particle accelerators had become available and Bernard Peters could clearly foresee that a whole lot of particle physics thereafter would be done with accelerators, and his interest shifted to interaction of cosmic rays and what came out of it. It was found that in addition to all the high-energy particles and air showers, radioactive nuclei would also be produced. This started another programme in which Lal worked very actively with Peters and others. They wanted to find out, if radioactive nuclei were produced which were those nuclei,

how to detect them, how to find them in the rain water, how to use them as tracers for rain masses, tracers for movement of water, and all kinds of things. And that was the kind of research that Peters started in which Lal was very active as were many others who later went to the Physical Research Laboratory in Ahmedabad.

Yash Pal was doing quite well in all the activities that he took up and was producing good research papers. He reminisces, "We felt that our place was as good any in the world in this area. We did not feel inferior, and we found that we were recognised the world over very early in our life. I could have sat and got down to write a thesis and got my PhD; enough was done already. But having been through the partition and having been through East Punjab University and so on, I became conscious of the fact that I hadn't had enough graduate courses. That is why I went to MIT to do my PhD. And I am glad I did. It was hard work, after having been out of university for five-six years, to start doing courses again. I had forgotten everything. I even flunked my qualifying examination in the beginning. That is a wonderful story."

Nirmal, his wife, while Yash Pal was courting her (1952)

With Nirmal at the Mughal Gardens in Delhi (1952)



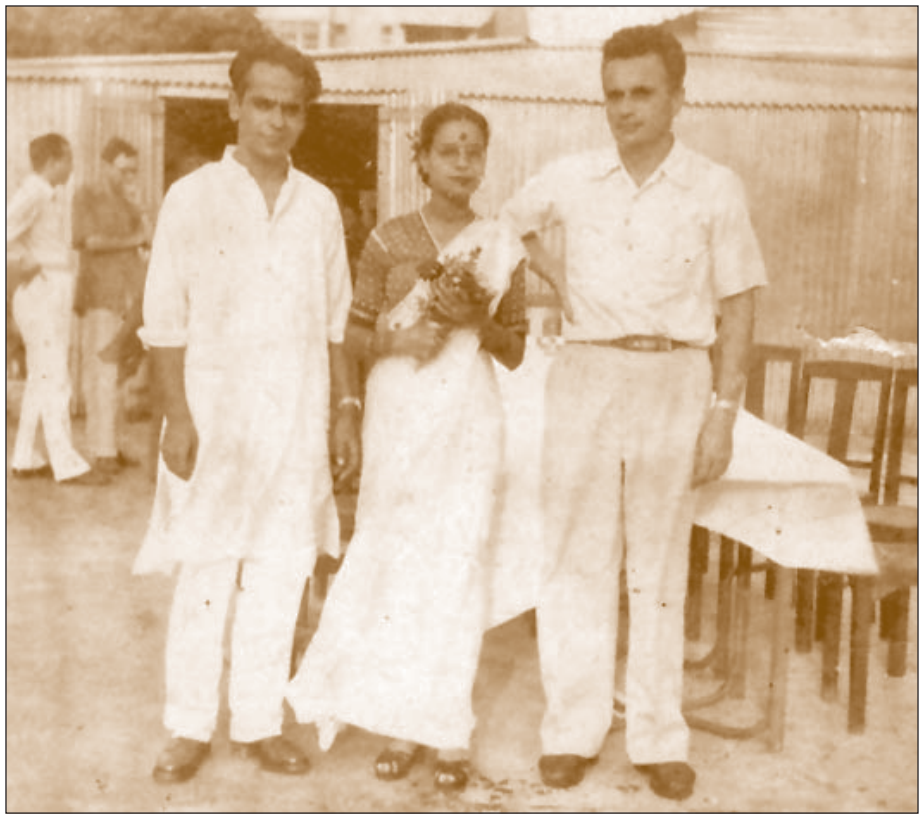
Yash Pal getting married at Kirkee with Bernard Peters the only one in the wedding procession (1953)

4
The MIT Experience

As soon as Yash Pal arrived at Massachusetts Institute of Technology he learnt that in two weeks he had to appear for a qualifying examination for the PhD. It was an uphill task for one who could not even remember any equation or anything of the sort. So he sat down and went through the books as fast as he could, but two weeks was not enough. In the qualifying exams there were eight questions, and he had to struggle to write the answers, as he had to derive every equation. So he could do only four questions and the time was up. It was a terrible experience for him; it had never happened before in his life.

It is said that sometimes truth is stranger than fiction. In Yash Pal's case it was indeed so. He passed the qualifying examination! At first he could not understand how he could pass after performing so badly. But soon the reasons became clear.

After the fiasco at the exams, Yash Pal had met Bruno Rossi, who was his advisor at MIT, and told him what had happened. Rossi then went to Philip Morse, Chairman of the Physics Department and explained to him what his Indian ward had done. Morse called for his answer sheet and saw how he had spent all the time trying to derive the equations, and how he had answered the four questions and could not get to the others. A few days later, Rossi called Yash Pal to his room and gave him ten problems to solve, which the latter did in just



Nirmal and Bernard Peters with Yash Pal before he left for MIT to do his PhD (1954)

about six hours. Rossi showed them to Morse and next day Yash Pal got a letter saying that he had passed the qualifying examination. Years later, he described this incident as "an important lesson" for him.

He had gone to MIT on deputation from TIFR. In fact, he was asked by Peter Demos, the then in-charge of the Laboratory for Nuclear Science at MIT why he wanted to be a research student at MIT; he could as well get a research associateship on the basis of work that he had already done. But Yash Pal wanted to be a research student though that meant very little money. After his wife joined him later at Cambridge, Massachusetts, it was very difficult for some time to pull through. Surprisingly, when he received a cheque for a fair amount of money as his deputation allowance from the Embassy of India a few

With Nirmal on the steps of the Kresge Auditorium of MIT, Cambridge, Massachusetts (1955)

months later, he sent it back. Possibly it was self-confidence and a sense of pride that made him do so. Later, after a year or two he was made a research associate and it became more comfortable financially.

At MIT he had the privilege of working with a very large cloud chamber – in fact, the largest in the world at that time – with several collaborators, which helped him learn quite a lot of cloud chamber technique and also about accuracy in measurements and so on. He also had the opportunity of working with the first high-energy accelerator in the world, the Cosmotron. But at that time the Cosmotron was having its teething troubles. And so the experiments, which involved putting in negative pions and protons into the chamber to study their interactions and so on, got delayed.

His most important work at MIT was the elucidation of properties of Strange particles produced in interactions of pions and protons that the Cosmotron could deliver into a large cloud chamber. These Strange particles – K particles (also called "kaons") and hyperons – are produced in pairs and were suspected to have lifetimes ranging from 10^{-10} second to a few times 10^{-8} seconds. Since the cloud chamber was large in size it was possible to get excellent values for both these life times as also that for the Lambda zero hyperon. Even greater challenge was to establish the validity of the particle mixture theory for the first time and also to measure the mass difference between the K_1^0 and the K_2^0 components of neutral K particles.

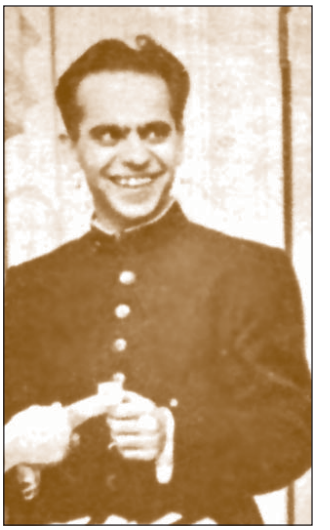
The existence of particle mixtures was a new idea at that time. K^0 and K^0 bar, while being anti particles of each other, were proposed as orthogonal mixtures of K_1^0 and K_2^0. Similarly, these two could be considered as mixtures of K^0 and its anti particle K^0 bar. After production the wave functions of K_1 and K_2 components would attenuate with their characteristic decay constants, but they would also oscillate at slightly different rates because of a slight difference in the masses of K_1 and K_2. The changing difference in their amplitude would then manifest in different patterns of superposition and regeneration of a K^0 bar component in the wave that started as a pure K^0 component. The K^0 bar component was detected through the pattern of hyperon production far away from the production point of K^0. This data was also adequate to provide the difference in the oscillation rates of the K_1^0 and K_2^0 components and hence their mass difference.

That was the first time that the truth of particle mixture theory and mass difference between two mixing particles was explored. Experiments with better statistics were done afterwards, confirming the results that Yash Pal and his colleagues had obtained. In recent times particle mixture theory has been used to explain the long-standing discrepancy between the theoretical and observational fluxes of neutrinos produced in fusion reactions at the center of the Sun and continuously raining down on Earth. This explanation simultaneously established that the neutrino mass cannot be absolutely zero. This is

As a graduate student at MIT, feeling lonely before Nirmal's arrival (1955)

With Nirmal outside MIT lab where Nirmal was a technical assistant (1955)

because particle mixing implies the existence of a mass difference between interfering entities. This difference might be miniscule but it must be there.



Compering at Diwali function in Boston (1955)

While reminiscing about his time at MIT Yash Pal talks with great warmth and appreciation about the support and learning that came to him from two fellow graduate students, Elihu Boldt and Hale Bradt. They remain his dear friends.

Yash Pal describes his stay at MIT as a "very learning, satisfying, productive period." He finished his PhD exam in 1958 and everybody expected he would stay on in USA for a while. He even had an offer from Columbia University. But he had something else in mind; he did not even wait for getting the degree and immediately returned home.

Ravi Shankar (centre) at Yash Pal's home in Cambridge, Massachusetts, where a concert was organised by them in the Kresge Auditorium (1956)

With first son Anil at Cambridge, Massachusetts (1957)

Fond parents (1957)

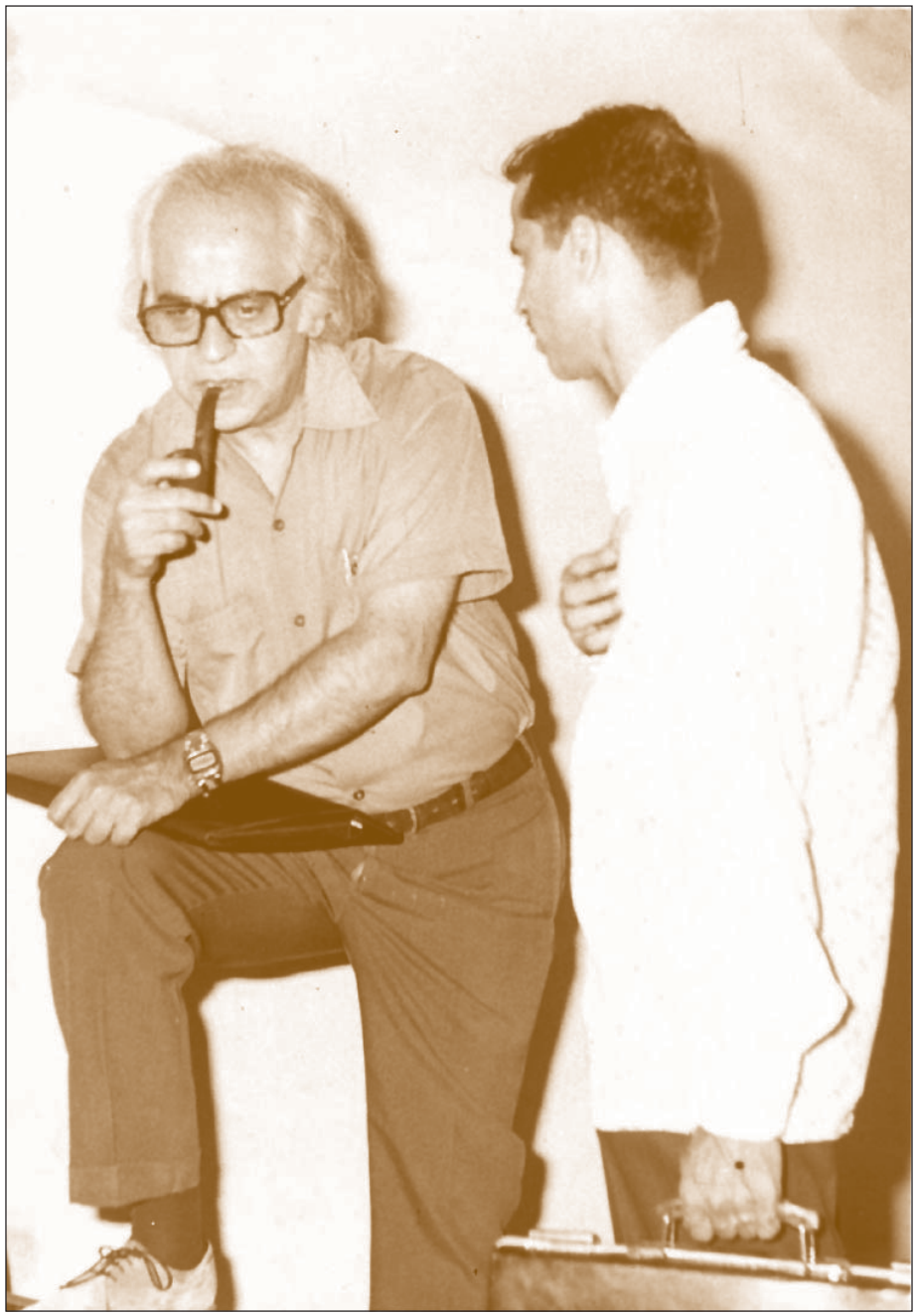
Asiya (second from left) and Obaid Siddiqi (middle), and Aruna (extreme left) and Devendra Lal (extreme right) with Nirmal during a visit to Yash Pal's home in Pasadena, California (1971)

Soon after returning to India he started work on nuclear emulsions and cloud chamber. TIFR had a cloud chamber that was being used at Ooty for cosmic ray research. So he designed, together with a new student named Siddheswar Lal, a novel experiment to study interaction of cosmic rays in that cloud chamber using a carbon target at the centre and a number of brass plates inside to allow the development of showers from gamma rays, and so on. The equipment was built and after some initial troubles, it turned out to be a very productive experiment and gave very good results.

A mechanism had to be set up for analysis of the data and so on, and here again Yash Pal's innovativeness came to the fore. He designed a novel arrangement of strings to measure the path of particles in the cloud chamber. It worked very well. It showed how innovation and invention could be used in many different ways. Using that cloud chamber they did a whole lot of experiments with pions and other particles and extensive papers came out of that.

Aruna and Nirmal at San Diego, California (1971)

He got into nuclear emulsions again a bit later and did experiments at CERN, Geneva, Switzerland, using sandwiched carbon and tungsten plates, and exposing them to the beam. The idea was to compare the interactions of protons and pions. The CERN beam had a total power of 25 GeV, so the available power was less than 25 GeV. Even then, it could be shown that the difference between the interactions of pions and protons was because the protons going forward really carried a large fraction of the energy and the particles which came from the decay of the excited protons dominate.



In conversation with a young participant at a conference in Vadodara (1974)

(From left) Bernard Peters, J.R.D. Tata, Francis Perrin, P.M.S. Blackett, and the then Chief Minister of Bombay, B.G. Kher at the TIFR Conference (1950)

At the Peters residence with Bernard working with his “hovercraft” lawn mower (1980)

Reception at an accelerator conference in Geneva (1960)

With Roy Daniel and others at an international conference on cosmic rays (1960)

5

In Quest of Cosmic Particles

Back at TIFR Yash Pal had very good graduate students and collaborators. Among them were Ramnath Cowsik, Shyam Tandon, R.P. Verma, T.N. Rengarajan, and many others. One of his first students was K. Babu who went to Caltech, did his PhD in theoretical physics and then shifted to molecular biology. Yash Pal hesitates to call them his students. He says, "I don't know whether I should call them students because they were learning from me; but I was also learning from them. We had a continuous kind of a seminar going on all the time, day and night. It was such a productive period at TIFR, experimentally and theoretically."

And then it turned out that simultaneously at that time, Bernard Peters was on a visit to TIFR. Peters invited Yash Pal to the Niels Bohr Institute in Copenhagen, first for a few months and then, after a year or so, as a visiting professor. "It was primarily because we both started thinking in terms of the importance of excited states in high-energy interactions," he reminisces. They recognised that excited states of nucleons are very important in nuclear interactions, and they came to this conclusion partly from accelerator results, but largely looking at the cosmic ray phenomena; for example, the ratio of positive mu mesons (also known as 'muons') and negative muons in cosmic rays. It was clear that there was positive excess in interactions of cosmic rays, which

could come only if they were preferentially produced by the forward moving nucleons. The positive excess in the incoming cosmic rays could come only if they preferentially transferred their energy to positive particles; otherwise positive excess would not be noticed.

They quantitatively calculated the positive excess and that really led them to the result that the energy in an interaction of high-energy cosmic rays is preferentially shared amongst a few particles – only 3-4 particles. Cosmic ray energy spectrum is very steep; that is, if one goes to higher energy then the number of particles is very small. The combination of the fact that the spectrum of cosmic rays is steep and the number of the particles that share the charge is few clearly showed that the domination was due to excited states. All the other large number of particles produced, they calculated, would get a small fraction of the energy and there would not be any positive excess. It was this kind of argument, which was carried through in detail, and then the spectra of all particles in the atmosphere were calculated, and neutrinos were one of them. It turned out to be a significant piece of work because at that time it was not known which excited states were involved.

The initial thinking was that only a couple of excited states were involved in general. Later it was found that this was essentially true; one could have very high excited states and the results would be similar. This was called the "isobar fireball model" of Pal and Peters. 'Isobar', because it essentially involved nucleons, and 'fireball', because there is also a cloud. For cosmic rays what they had done was to take essentially this model with a couple of hypothetical isobars, and so on, and then calculate the fluxes of muons, the spectra of muons, the spectra of neutrinos; that is, underground high-energy spectrum of everything that was observed in cosmic rays.

Yash Pal and Peters presented their work at the 1963 International Conference on Cosmic Rays in Jaipur, which was dominated by discussions of this paper. And later on, what emerged in particle physics was that actually the excited states go very high. And if they did, one should also get large transverse momenta of the particles. And values

of a few transverse momenta were measured, and all that was consistent with the model proposed. As a result, the importance of excited states in cosmic rays became very important, and that really went into this model and which, in all probability, affected the thinking further in high-energy physics. However, the "Isobar-fireball model" did not receive universal acceptance immediately; some questioned its veracity. But Pal and Peters had enough reasons to be sure about their work, because "if everything fitted, roughly speaking, the model had to be correct."

Yash Pal's next forays were into the study of gamma rays in the atmosphere, and neutrinos underground, because TIFR was beginning to do neutrino experiments. Sometime later, TIFR collaborated with a British group in the UK in measuring muons and neutrinos, but in their final paper they never referred to what work Yash Pal and his group had already done. Yash Pal described this as "very unfortunate."

A very interesting thing came up when some cosmic ray researchers were getting the spectra of very heavy primary particles like uranium in cosmic rays, and also spectra of not-so-heavy particles. Theoretically, if they were very heavy they would not have traversed a lot of matter coming down because then they would break up in interaction in interstellar medium. So from where did the heavy primaries come? One explanation could be that there were two sources of cosmic rays – one for heavy primaries and the other for protons. Yash Pal, Cowsik, and Tandon showed that this was not true and that there was no need for any special artificial division of two sources. They proposed a model, which they called "Leaky box steady state containment of cosmic rays model" that solved the problem of propagation very neatly.

Later, at the high-energy conference in Dubna, Russia, a group of scientists including Louis Alvarez, Fred Reines and many others got excited about studying high-energy interactions at a high mountain site using a liquid hydrogen target. Yash Pal was requested to participate in discussions in several laboratories across the United States about the

feasibility of this project and what might be interesting to pursue. One of the ideas that emerged was based on the recognition that even at high mountain altitudes most of the arriving high-energy particles would be accompanied by showers of electrons produced in interactions high in the atmosphere. If such a particle were significantly heavier than a nucleon then it would be delayed somewhat with respect to the accompanying electron shower. Looking for such delays might allow us to detect such heavy particles if they really existed. Detailed calculations in this regard were done along with S. N. Tandon. Experiments in this direction were taken up in Denmark and also by Sreekantan's group at TIFR. None of these experiments detected any heavy particles. [Incidentally, liquid hydrogen target experiment was done by Larry Jones's group at an altitude of 11,000 feet (3,350 m) at Echo Lake, Nevada, USA].

It is well recognized that our universe would not look any different if it were all made of anti-matter instead of matter. An atom made of an anti-proton and a positron would have the same energy levels as the hydrogen we are familiar with. This would also be true of all other chemical elements. Therefore it is a mystery how only one of the two possibilities could have been chosen. If a very distant galaxy were made entirely of antimatter, we would not know just by looking at it through our telescopes because all the spectral lines would be the same if it were made of matter. We need an actual material sample from that galaxy in order to decide. This was the motivation for an ambitious experiment planed by Yash Pal along with his colleagues, R. Coswik, S. V. Damle, S. N. Tandon, R. P. Verma and others. They set out to check if there were any anti-helium nuclei in high-energy cosmic rays, because these rays represented the only sample of matter that we could get from very far away.

The idea was to make several balloon flights with an instrument in which a magnet would be used to look for negatively charged primary cosmic rays. Helium is the most abundant particulate component of cosmic rays next only to protons. A permanent magnet they managed to put together and energise had a field of 4 kilogauss over a path length

With Vikram Sarabhai (second from left), Nirmal, Hannah Peters (extreme left), and son Rahul at the residence of Peters at Hellerup, Copenhagen (1970)

of about five centimeters. Minimum kinetic energy of helium nuclei is 7 GeV per nucleon or 28 GeV at latitudes of Southern India. In order to detect and measure the tracks made by these particles while going through their magnet the recording and measuring system had to have extremely high accuracy. For this they devised the following system after a year of design and development:

The primary visual detectors were wide gap spark chambers. In these a clean spark goes along the ionization path produced by the charged particle. The spark chamber operation requires a pulsed voltage of about 80 kilovolt. This voltage pulse was generated through a Cockroft-Walton generator, which involved charging some condensers in parallel and discharging them in series. The trigger pulse was given by a set of multi-wire proportional counters that selected particles that produced four or more times the ionization produced by a relativistic singly charged particle. Two cameras located at right angles to each other recorded two orthogonal images of the sparks and standard reference marks.

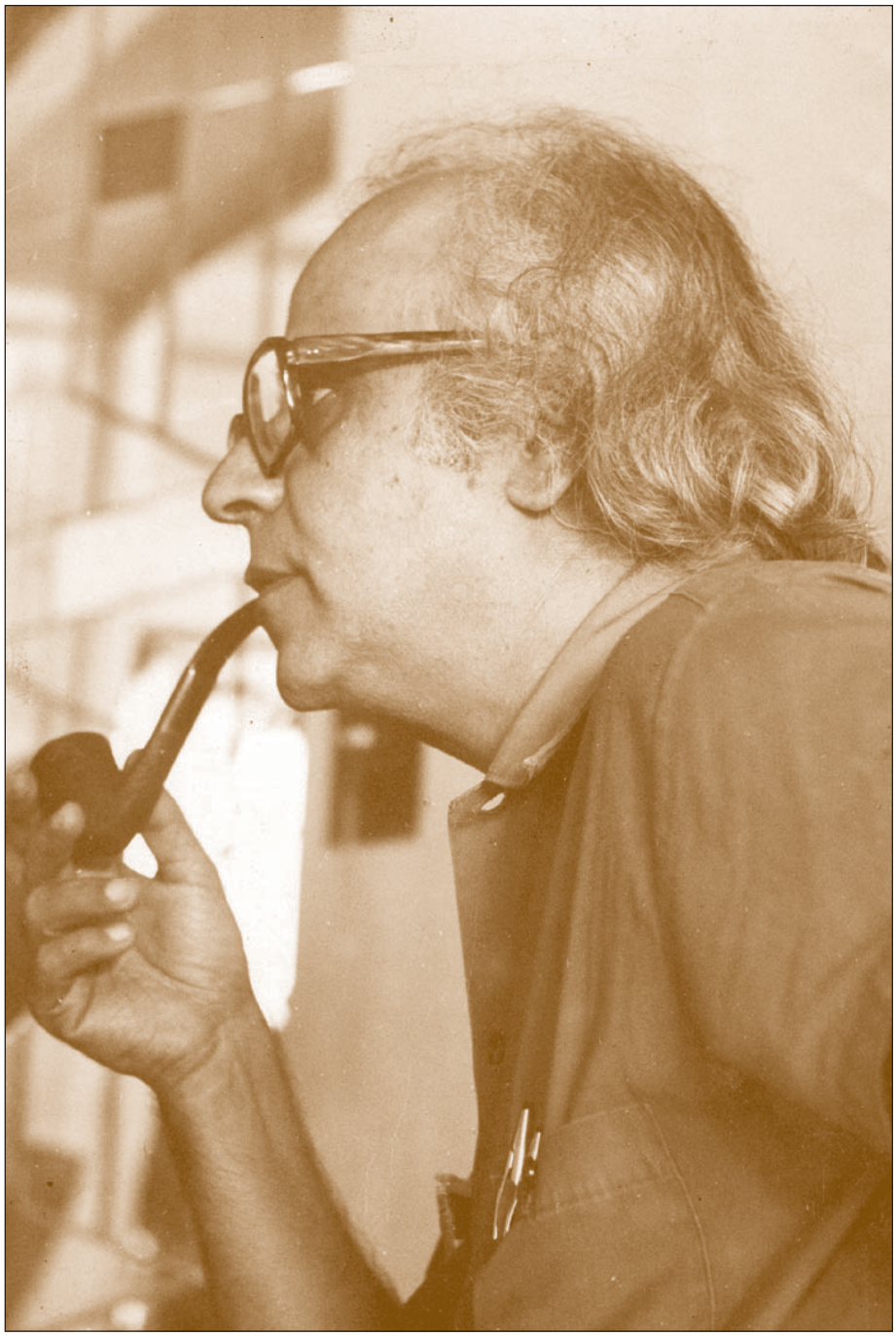
Speaking of the experiment, Yash Pal says, "The spark chamber images were fine but nowhere close to providing the accuracy of measurement required. They could give us an accuracy of a tenth of a millimetre while we wanted one micron or better. That challenge was met by using the spark chamber positions to locate the tracks made in nuclear emulsion plates mounted next to the spark chamber. These were not plates that we could order from a supplier. Six months were spent working with optical laboratories to produce 1 mm thick glass plates ground optically flat on both sides. These plates were cemented into optically ground glass frames and nuclear emulsion was poured on both sides one after the other. The optical frames holding these plates were held against an optical pillar during the balloon flight. Other effort was to take care by measurement and modelling the slight sagging of the plate when emulsion was poured on.

"Technological sophistication of this experiment surpassed any thing even TIFR had done till then. It has to be remembered that all elements were locally designed and fabricated. There was no procurable or standard items – they did not exist anywhere. Even the permanent magnet was assembled and energized in the laboratory. The whole instrument weighed about half a ton. Some flights were made using Indian made polythene balloons, which had not yet achieved the performance they now have. Pretty good limits were placed on the abundance of negative helium. The experiment could have been more useful if one or two imported balloons had been allocated for this flight. It still rankles a bit that they were not".

Yash Pal's group at TIFR also did a lot of theoretical work, for example, on the production of gamma rays by collision of high-energy cosmic rays with a hypothetical neutrino sea. This work on neutrinos was later continued by Cowsik, who determined the limit of neutrinos and the neutrino mass.

Yash Pal went abroad for a year to work with Gaurang Yodh at the University of Maryland in USA. They worked together using a method that had been earlier suggested by the Russians, of trying to

determine how the cross-section of nucleon interactions would go at very high energies. They used available experimental data and a cosmic ray propagation module to drive the behaviour of cross-section as function of energy; the manner of increase was obtained unambiguously. It goes to their credit that a few years later the same results came from accelerator experiments. In other words, they could derive from cosmic ray experiments something that was related to high-energy physics.

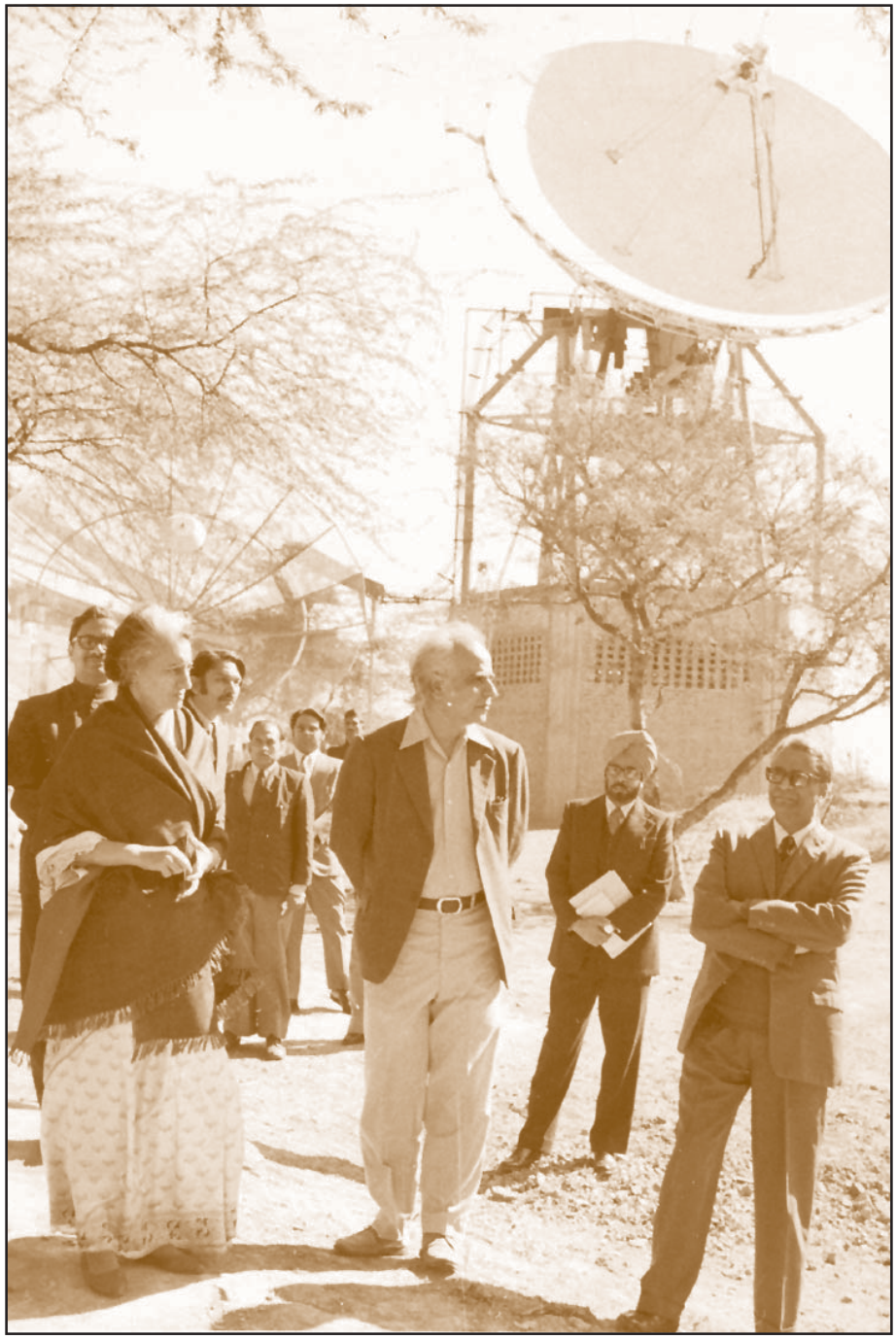


Engrossed in thought during the intense days at Ahmedabad (1974)

6
The Magic of SITE

One of the landmark achievements of Yash Pal was the setting up of the Space Applications Centre (SAC) in Ahmedabad, which played a pioneering role in the spread of development communication through satellite in the country. Here his role was more of a science manager – a role that he shouldered with undiminished commitment. India's pre-eminent position in the field of satellite-based mass communication owes a great deal to his visionary approach and dedication.

But his leaving a research career at TIFR in 1972 and taking up the reins of the Space Applications Centre in Ahmedabad was not of his own volition. He attributes it to "a social blackmail in a way, very nice blackmail, by the then Chairman of Space Commission, Prof. Satish Dhawan." He recalls, "Prof. Dhawan told me, 'Look Yash, Vikram Sarabhai had said that we should use space for education and development. And we have this major experiment, which he had thought of – the Satellite Instructional Television Experiment – to be done. Otherwise, too, if we are getting into space we have to develop a strong space applications programme, which will involve all aspects of space. We keep talking about this. Now, why don't you come to Ahmedabad for a while and help to consolidate a centre? Some groups are already there to put together the Space Applications Centre. India's



With Indira Gandhi during her visit to the Delhi earth station. P.V. Krishnamurthy, P.P. Kale, and Nilambar Pant are also seen (1975)

space programme should be really driven by this space applications interest.'"

And so, Yash Pal took five years' deputation from TIFR, and went to Ahmedabad to build up the Space Applications Centre almost from scratch. Once in Ahmedabad, there was so much to be done and he got so involved that he "did not have even time to breathe – from morning to night," he reminisces. "I had never worked this hard; I did not know what happened. Firstly, the Satellite Instructional Television Experiment (SITE) was very much delayed. In fact, I remember some people came to see me as soon as I was there and told me that people are saying that those who have joined the SITE team better get off before the ship sinks! And that kind of talk was going around. The Americans who were to provide the satellite for the experiment were telling us that we were not getting ready, and it was true that we were not getting ready."

But, Yash Pal has a remarkably capacity to face any challenge and motivate people to work, even under the most difficult situations. And in a short time work on SITE got off in full swing and it was a fantastic amount of technological work done by the "marvellous people at SAC – young people who grew in an amazing way." This was an experience in institution building and also in giving responsibilities to people in order to make them grow, and instil in them the confidence to "do it ourselves," whether it was the low noise amplifiers, antennas, earth stations, or anything. If a piece of equipment could not be bought from outside or if it was taking too long to import, Yash Pal encouraged his young team to do it themselves. "I think we tried to do everything ourselves and succeeded in most cases," he recalls with pride.

SITE was primarily a satellite-based communication experiment, and for sending signals to and receiving signals from the satellite, earth stations were needed as part of the ground segment. An earth station was to be set up in Delhi, as a back-up station to the Ahmedabad earth station. It turned out that all the equipment had to be imported; that was the original plan. Wing Commander Rao, who was in charge at that time, said it had to be imported. But cost apart, the total time

In a pensive mood at Pij village, as Indira Gandhi inaugurates SITE (1975)

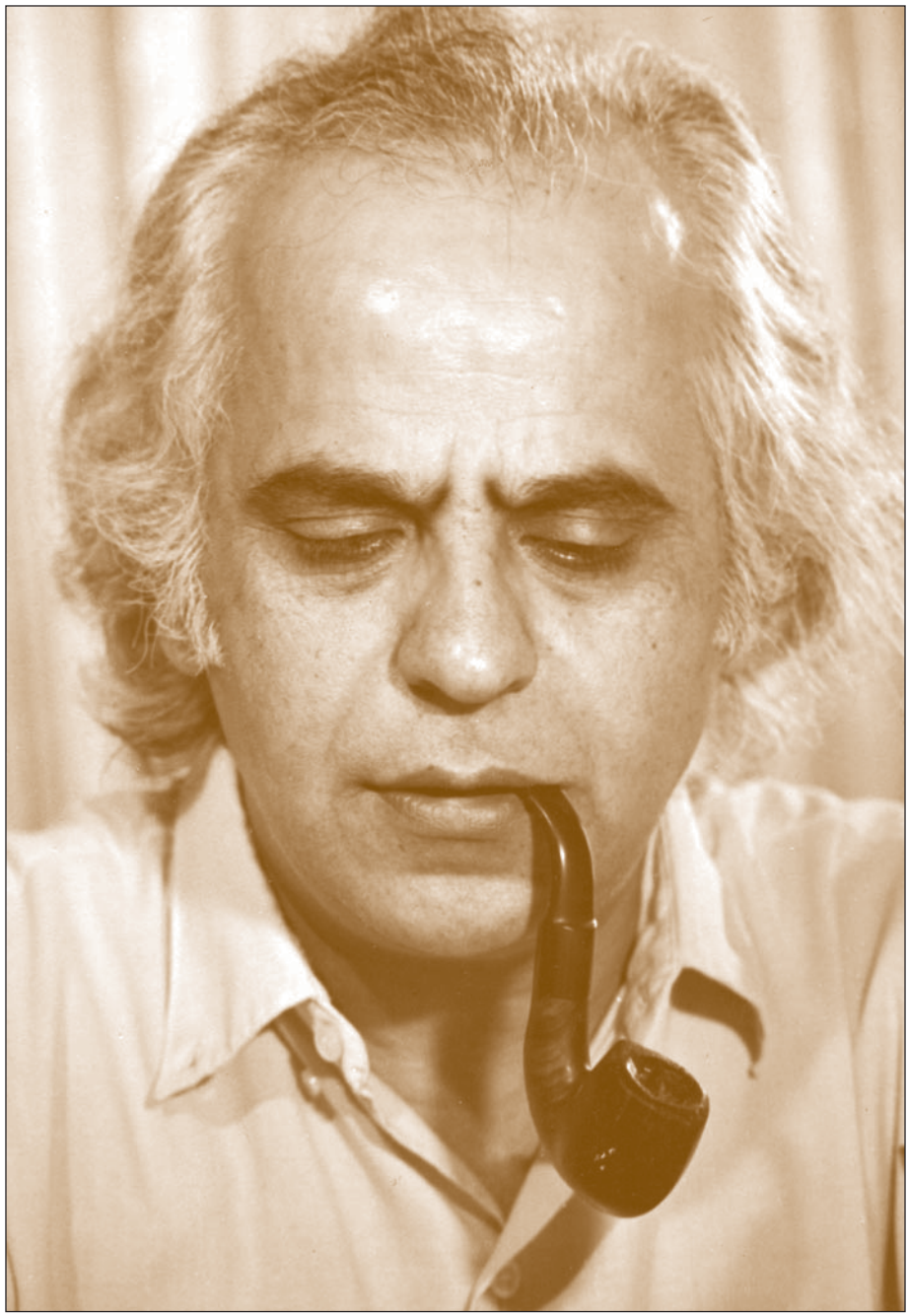
required for the import was to be rather long and it would not have come in time for the experiment. So, Yash Pal and E.V. Chitnis sought the opinion of Nilambar Pant, who was then the head of the satellite communication in ISRO and coordinated the chains, whether it could be done locally. After getting a positive response they lost no time and went straight into the job. Site selection, electronics, and a host of other things had to be taken care of to ensure that everything was ready within the specified time for the SITE experiment, which was to begin in August 1975.

Yash Pal and others went around the Delhi ridge and they did a lot of survey and found a place finally in the forests adjoining Malcha Marg. Then there was the question of getting permission for setting it up there. The Air Force objected; they would object to anything that gave off some radio waves of any sort. They were assured that the earth station would not interfere with their communication or navigation frequencies in any way, but they would not listen; they did not understand that a dish antenna produces only a narrow beam of radio waves directed into space that cannot interfere with normal radio

communication. Finally, the then Prime Minister Indira Gandhi called a meeting with the Air Force officials. Yash Pal came from Ahmedabad with the data and he spoke quite strongly in the meeting. He strongly asserted that nothing would happen if the earth station were set up at the selected site. Mrs. Gandhi ultimately took the decision at the meeting that the earth station would be set up there, but then she had to bow down and agree to the demand of the Air Force that the facility would function only for a year, during the period of the experiment, and would be dismantled thereafter. As planned, the transmission from Delhi during SITE was done from this earth station and it is still operational. The interesting thing is that some of the equipment – the high-power amplifiers, low noise amplifiers and so on, which were designed and built at SAC at that time, are still working at this earth station. SAC engineers built several earth stations later, including the Master Control Facility at Hasan in Karnataka for the control of the *INSAT*s and other satellites.

When talking of indigenously built earth stations, the problem was not over after the site selection. There was a critical time when the engineers at SAC designed six units of the low noise amplifier, which goes on the top, at the focus of the dish antenna at earth stations. It is used in the downlink for amplifying the weak signals received from the satellite. These days such amplifiers can be bought from anywhere, but in the mid-1970s they had to build it indigenously; there were no companies manufacturing them anywhere in the world. At that time SAC was a new centre and was not well equipped with all the testing facilities. There were no environmental facilities for testing. For hot testing the only thing available was the Sun, and for cold testing they used an old refrigerator! There was nothing else with which the equipment could be tested.

At that time ISRO was collaborating with NASA in certain aspects of the space programme. So some eight units of low noise amplifier that were built were sent to NASA for testing. Within a few days, Y.S. Rajan, who was at NASA at that time, sent a telex to Yash Pal saying that the units were not at all satisfactory; and that they were horrible because they were very sensitive to fluctuations in temperature. The



In deep thought working at his desk at SAC (1976)

message further said that NASA thought that Indian space scientists did not know how to design low noise amplifiers, and that ISRO should send their engineers to Goddard Space Flight Centre in USA to work with NASA engineers for some time. The original idea was that SAC would design the low noise amplifiers and Electronics Corporation of India (ECIL) would manufacture them later. So Yash Pal was naturally worried after getting the message from Rajan. But, as was his nature, he did not give up. He called all those who had designed the units and had a discussion at length on what had happened and what could be done. He asked them to have a second look at the design.

It was soon realised that the problem arose due to a strange constraint that the ISRO designers had to face in designing the low noise amplifiers. The plan was to build thousands of them for use when the *INSAT*s came later and these were to be cheap. So the designers were asked to use the most inexpensive components. Integrated circuits were not being thought of, as they were not available anywhere at that time. So the most inexpensive transistors were chosen for the units, which could not compensate for fluctuations in temperature. So this lacuna had to be rectified.

To be on a firmer ground, Yash Pal sent telex messages to a few radio astronomy people – to Govind Swarup, to the person who designed the radio astronomy receivers for them, to C.V. Raman's son V.R. Radhakrishnan – to some four five people like this. In his telex message he explained to them the position and requested them to stop whatever they were doing and immediately rush to SAC at Ahmedabad for a two-day meeting to review the design of the low noise amplifiers. So they came, looked at the design and made suggestions for change. Within a week some eight new units were built with the modified design and again sent for testing to NASA. Within a few days a telex arrived; it was good news – the new units had passed the tests; they were fantastic!

"This I consider to be a very important moment in building self-confidence," says Yash Pal. He believes if the SAC engineers had been denied the chance, it would have been difficult to develop the

Discussing the philosophy of Pij television with Indira Gandhi at Delhi (1976)

atmosphere of creativity that came to pervade the SAC. He is forthright in expressing his conviction. "Some people forget that often it is more important to invent a thing yourself than to procure it. Unless the taste of discovery is established early, it will never come," he asserts. "I'm afraid we do not do much of these things now a days; we've stopped doing that," he laments. He strongly believes that "a civilization that protects its young from the hassles of doing things themselves deprives them of great joy and ultimately leads its society into a state of permanent dependence."

SITE was primarily an experiment in mass education and it had a large sociological component. So Yash Pal and his group were also required to do a social evaluation of the experiment afterwards and so eminent social scientists like Binod Aggarwal and others were taken in the group. Also, a large number of social scientists were assigned to do the surveys – pre-SITE survey, middle survey, and post-SITE survey. During and after the yearlong experiment they did some 20,000-30,000 interviews, three times. Social scientists were also doing needs assessment surveys and gathering audience profiles to find out what

kind of programmes should be there. There were nine anthropologists who stayed for a year-and-a-half in some of the villages to see what happens when television comes in far off villages. It was an enormous amount of work.

The village selection itself was a massive effort. Yash Pal himself visited a large number of villages; other teams went to some 7,000 villages to select some 2,400 for SITE. They had to look for a clear site, a place available in a school or some place. Having done the selections, consent of the state governments had to be obtained and that itself turned out to be something of a problem. Yash Pal recollects, "In many cases we had found the names of villages and after that we asked the state governments for approval, but we wouldn't get a reply to begin the installations. But when we threatened to select another village in its place promptly came the reply."

Sometimes, even after the consent had been received, it would be discovered at the last moment that although the selected villages were identified as electrified villages, the schools in which the TV sets were to be installed did not have electricity connections. Electric lines had to be drawn from the nearest poles, which, in some cases, lay at a distance of 300 metres or so from the school building, and meters had also to be installed. The question came up: Who would pay for the electricity?

A software expert of SAC, K.L. Sondhi was requested to go to the capital city of each state where SITE was to be launched and talk to the state officials regarding the matter. And it worked in most cases. In Patna, for example, the common refrain was: no wires or meters available for installation in the villages. The chief secretary then asked about the amount of electricity it would consume. When told that it would be about 60-80 watts, he said, "Suppose we consider them as street lights and put no meters?" And it was done. Things of this kind had to be done and was done. Otherwise it would have been impossible.

While most community sets were deployed in electrified villages, about 150 battery-operated sets were deployed in un-

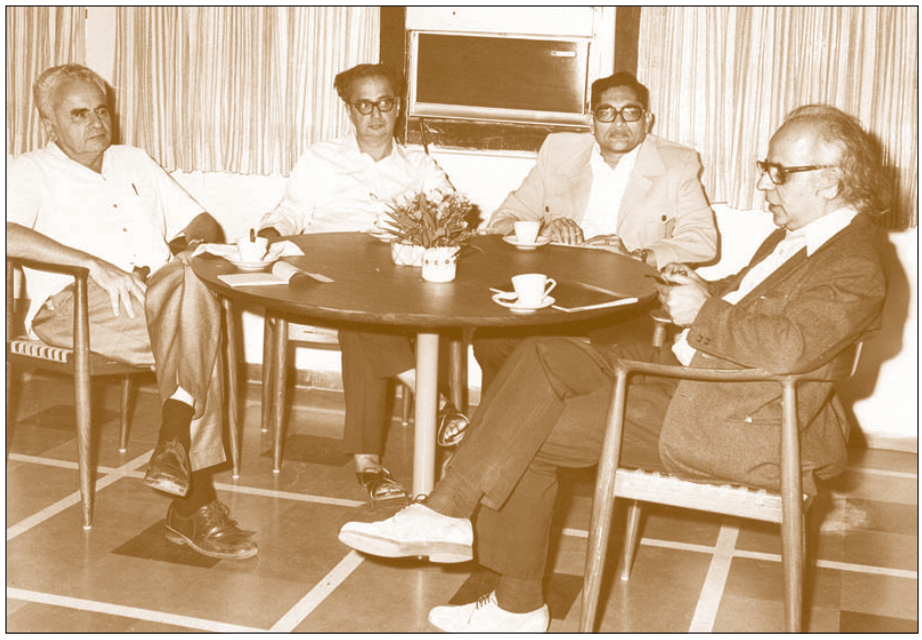
At a discussion on Pij television with Indira Gandhi. B.S. Bhatia is also seen (1976)

electrified villages as part of the experiment. Arrangements were also to be made for caretakers to look after the TV sets in schools. Yash Pal called it a "strange combination where a technological institution got involved in social evaluation, discussions, visits, and also programme production."

Then they got into a local problem. At that time itself it was felt that while the satellite experiment was going on, a low-power transmitter should also be put up where some local programmes could be generated, in addition. So a low-power transmitter was designed at SAC. A tower was needed for doing the transmission and there was also need for a microwave link. But the question was: Where to put the transmitter? At that time there was no TV centre in Ahmedabad; so if the transmitter were to be set up very near Ahmedabad and the local programmes were received in Ahmedabad, there would be a demand for regular TV service in the city and they would want their kind of programmes and not the rural programmes developed for SITE. Yash Pal found a clever way out. When told that the range of the 100-watt transmitter would be about 50 kilometres, he called the others – Pramod Kale, E.V. Chitnis, and S.R. Thakore – and sat with a map of the Ahmedabad area before them. Then he took a divider and drew a circle with a radius of 50 kilometres, and found a village called Pij just outside this circle, some 60 kilometres south of Ahmedabad. It was in Kheda district of Gujarat. That is how Pij was found. So it was decided to set up the local transmitter in Pij.

Then there was to be a microwave link and a transmitter on a single tower, but the Posts & Telegraphs Department objected to the proposal; they said a TV transmitter antenna could not be put up on a microwave tower. The SAC team had to demonstrate that it would not interfere. So the transmitter and microwave link were put up at Pij. Thus Pij acquired the first rural TV transmitter in India, which provided programmes in local language along with common programmes from Delhi via satellite.

Often, when a new programme is taken up some basic requirements get overlooked. Here too, before putting up a local



A memorable photograph with Bernard Peters (extreme left) in Ahmedabad. Others in the picture are (from left): B.V. Sreekantan, Director, TIFR; Devendra Lal, Director, PRL; and Yash Pal, Director, SAC

transmitter in Pij that was to telecast programmes for the local people, no one thought of getting the TV sets to receive the programmes. It was estimated that some 500-600 sets would be needed. So Yash Pal invited George Kurien of Amul Dairy to SAC and told him about the problem. He also told him that SAC would like to work closely with Amul in producing programmes on animal husbandry and requested Kurien to bear the cost of the TV sets. He readily agreed and that is how the TV sets were installed; Amul paid for them. Veterinarians from Amul were involved in making lots of programmes; they were also taught how to make TV programmes.

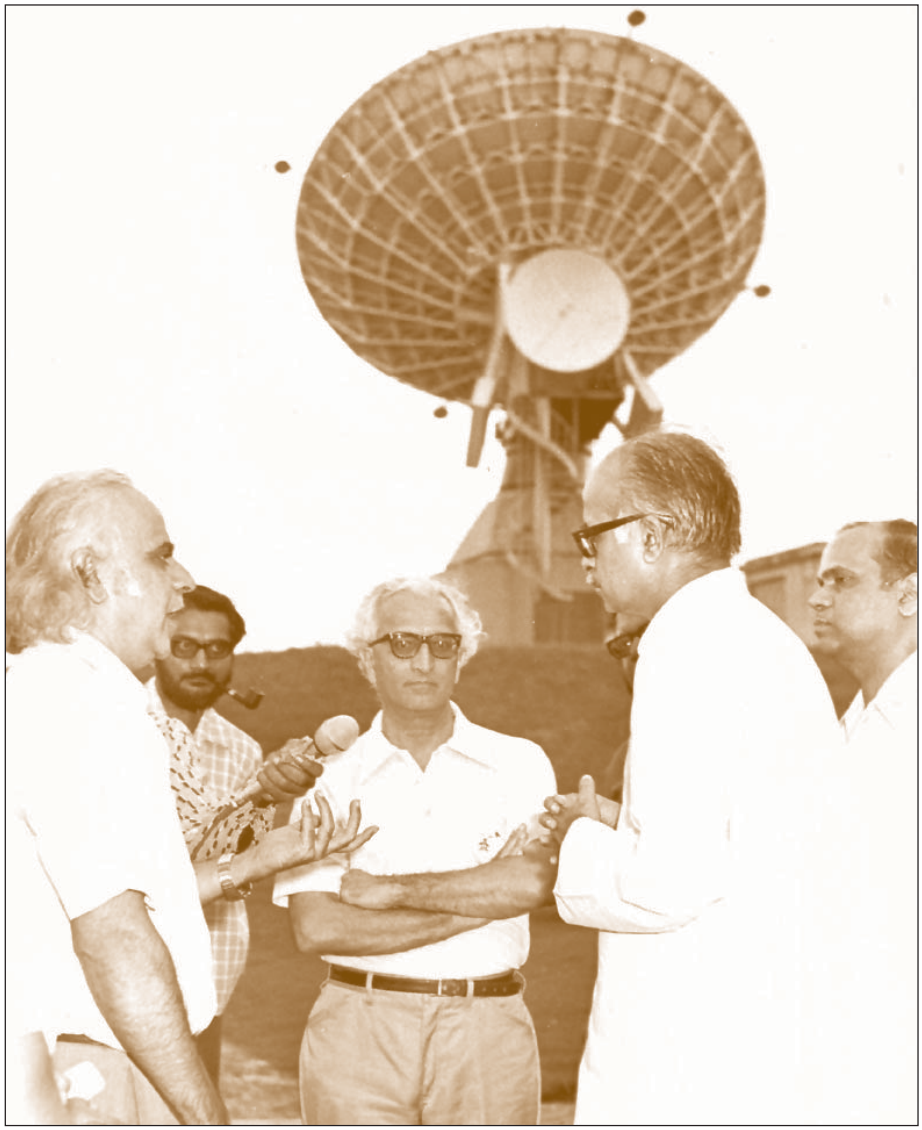
By that time developments were also going on to find out how simple porta-paks could be used for making programmes that could be used for transmission. The porta-pak was the first consumer video camera, which was inexpensive and portable. It was technically less sophisticated than professional equipment, but was self-contained: it could record, playback, and users could edit the tape by physically cutting and pasting. Normally,

the porta-pak was not suitable for making programmes for transmission. In porta-pak the recording was done in JPEG format, which could not be transmitted unless a time-based character was put in. So, digital time-based characters were designed by G.C. Jain's group. Technicians at SAC learnt to make them also, and time-based characters were put in porta-pak tapes for transmission.

For making the local programmes in Gujarati for the Pij transmitter, production people had to be recruited. There was also the need for a studio for making the programmes. Pramod Kale and others designed and built a studio in Ahmedabad. There was not much experience in India at that time in building studios for TV production because only Delhi had television studios. So, the Ahmedabad studio was built and it was used for making programmes for the Pij transmitter. A microwave link was established.

But there were more hurdles to be crossed before transmission could be started. Till that time All India Radio (Doordarshan) had not given SAC the permission to make TV programmes. Ministry of Information & Broadcasting said that the only people who could make programmes on anything for transmission should be in the Ministry of I&B. It cannot be done in any other way. Yash Pal and his team then had several meetings with Ministry officials but to no avail. Finally he threatened to quit the SITE project if he was not allowed to produce the programmes, because he wanted to encourage and involve other people to learn how to make these programmes. Prof. Satish Dhawan discussed it with the Ministry officials and a very clever solution was found. It was decided that the producers would be in Ahmedabad and they would work in Ahmedabad. SAC would recruit them, but All India Radio would post a station director in Ahmedabad and the transmissions would be in his name. "You know, you need these innovations in order to do things," says Yash Pal with a smile.

Before SITE, Doordarshan was making television programmes in Delhi. When it was time to make science programmes for children, Doordarshan asked SAC to do it. They said they could not do it. To meet the objectives of the SITE Yash Pal involved nearly 200 social



With Prof. Chitnis explaining satellite communication to L.K. Advani (second from right), the then Minister for Information and Broadcasting (1977)

scientists. Fresh producers were recruited by SAC – most of them just out of the Film and Television Institute of India, Pune. The team learned to build studios, to modify inexpensive cameras for fieldwork, and get familiar with programme production. But what kinds of science programmes to be produced? It was quite a difficult question to answer.

Yash Pal recollects, "I had been to villages and I had by that time started believing that science can be learnt only through doing. You must have experiments and you must do things to learn science properly. But in villages there were one/two-room schools, with no equipment; some did not even have a blackboard. If we had to make science programmes for them what were they going to do? I had a miserable time thinking and wondering for two months and then I wrote down a credo, which was that the objective of the science programmes would be to help children realise that science is everywhere. Science is in the kitchen, science is in the village pond, science is in the bicycle, science is in the flora and fauna, science is everywhere. Having done that I prepared some briefs and worked with producers."

One great attribute of Yash Pal has been his readiness to seek professional opinion wherever possible. This time also he did the same. He wrote down a letter and sent it to all the people he knew in education, including Philip Morrison, a distinguished American theoretical astrophysicist and interpreter of science and technology for the general public, who was at MIT, and to friends in TIFR, including V.G. Kulkarni, with whom he was involved in various other educational activities. He requested all of them to prepare some briefs on science programmes and send them to him for discussion. The kind of response that his letter evoked can be judged from the fact that within a week he received a letter from Morrison containing 100 briefs/ideas! Then he called a meeting with Kulkarni and others in Mumbai, locked them up in a room and held discussions to prepare detailed briefs for the programmes. The programmes were then assigned to producers; farm science people were assigned to work with them. There was a time when many of the scripts for these programs were honed up around the coffee tables in the West Canteen of the TIFR, which became the place in Mumbai where all the time interactions were going on; the work was going on between producers and others.

The science education programmes for SITE were conceived with the following aims:

To make children realise that science is everywhere – that their immediate environment can be questioned, understood, explained and manipulated by them, using the scientific method; and to emphasise the learning of the scientific method, more than mere transfer of information. The programmes were to be prepared keeping in mind the fact that the only laboratory most of these children could access was their natural environment, their play and their homes.

Even though the programmes were finalised, there was no production studio in SAC at that time. Then a space for studio was made available in one of the buildings of Bombay Municipal Corporation courtesy Madhuriben Shah, the then Education Officer of the Bombay Municipal Corporation with whom Yash Pal and Kulkarni had earlier worked on some projects for SC/ST children of Bombay Municipal Schools. But for setting up a TV studio a cyclorama was needed. (Cyclorama is a large curtain or wall, usually concave, hung or placed at the rear of a stage.) M.S. Sathyu, the famous film maker, managed to get someone he knew to do the work. "They put two knitting machines next to each other and produced the cyclorama and it was put up there in the studio." Sathyu, Habib Tanvir, Dina Pathak were all friends who were "emotionally involved in the project. It wasn't something that suddenly came. It was wonderful to discover that when the objective has value and you seek help, worthwhile people consider it a favour that you asked them," he observed.

Finally, there was need for a person to oversee the production of the programmes. And Kiran Karnik was appointed the head of this whole enterprise in Mumbai – the production unit for science programmes. Science programmes were produced by the unit and they were evaluated. So there was a "mission within a mission within a mission, and so on – one emerging out of the other." A total of 160 science programmes, each of about 10-12 minutes' duration, were produced in Hindi and dubbed in Oriya. Almost 1,200 minutes of Gujarati programmes for Pij transmitter were also produced at Ahmedabad. These science programmes were pre-tested in Madyha Pradesh, Orissa, Rajasthan, and Mumbai.

It is significant that, unlike most government projects, no project report was prepared for SITE in the beginning. "If it were there," says Yash Pal, "we couldn't have even thought of doing it in this way – new ideas wouldn't have been approved because there would not be any prior allocation of budget for them. We did not exceed the allocated budget but we did not allocate it head-wise in the beginning either."

For SITE, direct reception TV receivers, augmented with 3-metre parabolic antennae and front-end converters, were set up in isolated villages in parts of six states – Rajasthan, Bihar, Orissa, Madhya Pradesh, Karnataka and Andhra Pradesh. The transmissions started on 1st August 1975 when 2,400 community TV sets came alive in as many small villages spread across the country, receiving programmes directly from the high-power American geosynchronous satellite *ATS-6* located 36,000 km above the equator over Kenya. Programmes on agriculture, education, health and family planning were beamed to the satellite from earth stations in Ahmedabad and Delhi.

Technologically speaking, the achievement of SITE was amazing, especially because it was done in so short a time. Sociologically also, quite a few gains were seen. Videotapes were prepared by Doordarshan in Delhi, transferred to the Ahmedabad Centre and beamed from its ground station to the satellite. The simple direct reception community television sets and the efficiency of their maintenance was sufficient to keep 90% of the sets working at any time at a picture quality better than the normal VHF receivers in Indian cities. One and a half hours of broadcasting in the morning was devoted to school children and two hours in the evening to general audiences, which averaged 100 people per set. It was during SITE that special attention was directed towards children in the age group of 5-12. A systematic credo was worked out, and programmes were produced, mainly with the objective of helping children to learn community living skills; installing habits of hygiene and healthy living; promoting aesthetic sensitivity; and making children aware of the entire process of the modernisation of life and society around.

The programmes also achieved considerable progress in the areas of information, awareness and knowledge of health, and hygiene,

Receiving Marconi Award in Australia with Nirmal and Marconi's daughter Joia Braga (extreme right) (1980)

political consciousness, overall contemporary thinking and family planning. Many of the viewers of SITE programmes were first generation mass media participants, in the sense that they were never exposed to radio, newspapers or cinema. Most of the first generation mass media participants were illiterate and came from the poorer sections of the rural society.

SITE was more effective than all other media in attracting the female audience, and altogether, female audiences were keenest and learnt the most, as several statistical analyses showed. In addition, 50,000 rural teachers were enrolled during the experiment in a multimedia package, training them in the teaching of mathematics and general science. Case histories of farmers showed that innovations were adopted, provided that no additional expense was involved.

Later, speaking at a conference on the impact of space exploration on mankind held at the Vatican in 1984, Yash Pal commented, "For the

1,500 people directly engaged in the experiment, SITE was a deep human experience. It generated new capabilities, demystified space technology, and helped to nucleate a large island of self-confidence. But of far greater significance was the generation of new kinship between technologists and the grassroots problems of the country, a common concern for the ultimate social and human goals."

In 1976 he was Awarded Padma Bhushan by the Government of India for contribution to science and space technology. In 1980 he was awarded the Marconi Fellowship in recognition of his "wise and humane leadership in applying modern communications technology to meet the needs of isolated rural villagers in India." Established in 1975 the Fellowship is given to an outstanding individual for lasting contributions to human progress through innovations in telecommunications technology or science.

The SITE program provided great impetus to India's space program and led in subsequent years to the establishment of a national television network utilising a communication satellite to link a large number of terrestrial broadcast stations and transmitters. As the world's first direct broadcast satellite television system, SITE proved the value of using satellites for education in developing countries. It was justified that satellites could be used for education communication and development. Furthermore it was demonstrated that India had the capabilities to do this kind of things.

In addition to communication, work on the other major space applications of remote sensing also began at that time at SAC. Yash Pal recalls, "One of the things I remember is that soon after I got there I learnt that the Americans had sent up the *Earth Resources Technology Satellite* (*ERTS*) – the first remote sensing satellite. And so people came and showed us photographs taken by the satellite, and they were wonderful. We also had a mandate that we have to develop a satellite remote sensing programme. But we were too far from that; we had no satellites in space yet, and no detectors and scanners."

So, one of the first tasks that he had to attend to after taking charge of SAC, besides preparing for SITE, was to constitute a group of experts who could take up the remote sensing programme. But finding the right persons was not easy. One person that he could immediately think of was Pisharoth Raman Pisharoty, who organized the first successful mission of coconut wilt-root disease eradication by remote sensing techniques "using Soviet aircraft and US equipment, but Indian scientists." Like Yash Pal, he believed that one could get anything good done in India, if one were not anxious to get the sole credit for it. And there were one or two other people, but really no technologist was available. But the general feeling at SAC was that the only way to develop this programme was to select some three or four persons – good ones – and send them abroad to work with the Americans so that they could start the work after coming back.

But, again, Yash Pal did not like the idea of sending people abroad for training. So he asked a simple question, "Where did the Americans, who had launched their satellite only a year back, send their people for training?" And of course there was no answer to that. So it was decided to build up the capability in-house and a search began to get the right persons for the job. There was George Joseph who was working on the infrared astronomy programme as part of Yash Pal's team in TIFR. So he was requested to join the team at SAC. Yash Pal told him that the only difference from what he had been doing would be that rather than pointing his telescope skyward he'd have to point it downward towards the Earth and design the telescope to scan the Earth! A few weeks later Joseph and another person Yash Pal had similarly bamboozled – D.S. Kamath, who had set up the first TIFR computer – joined SAC. The third person to join was Baldev Sahai, a nuclear physics man. Later Joseph turned out to be the guiding force for the development of earth observation remote sensors, data products, image processing and applications.

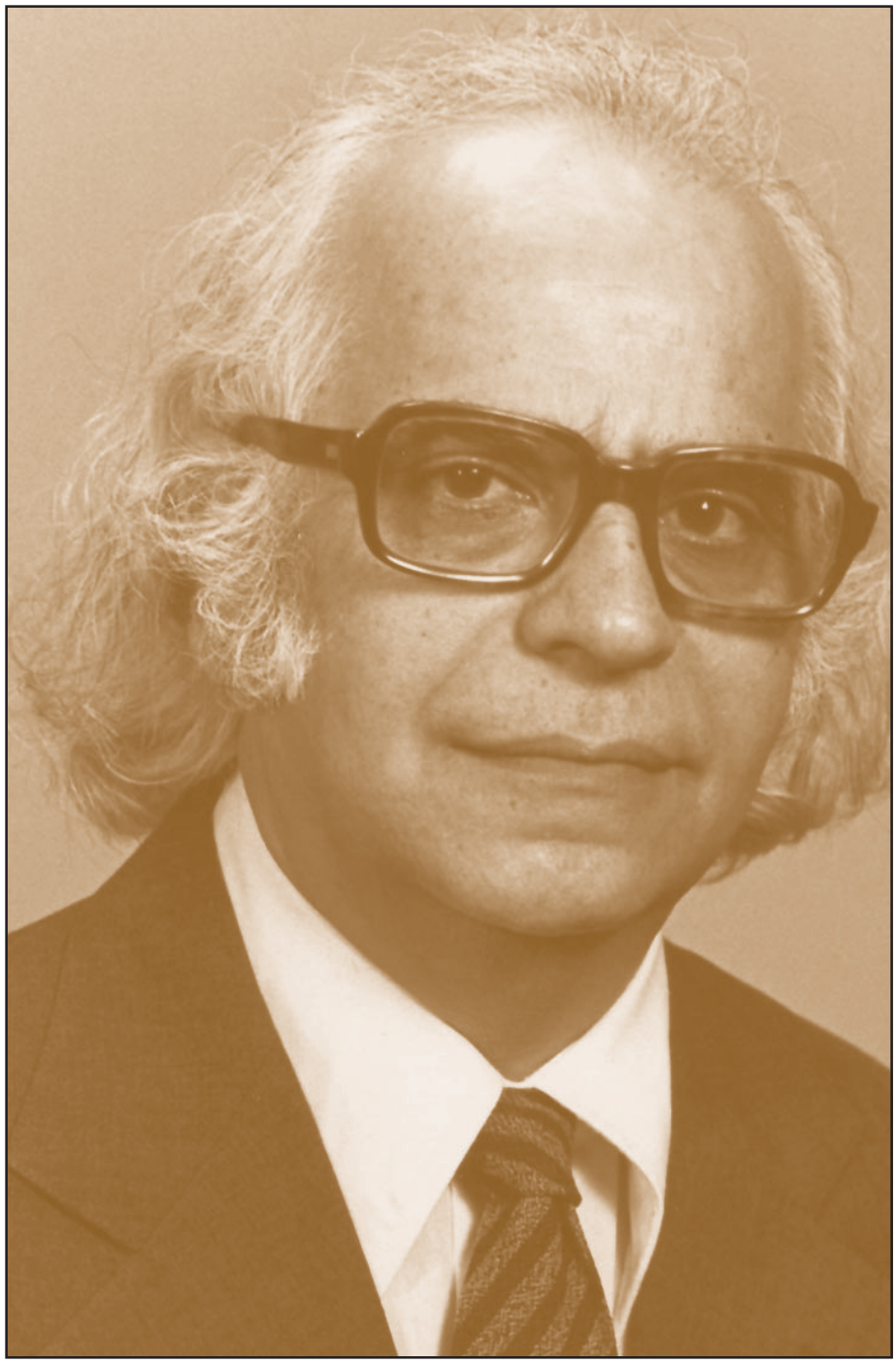
Joseph and Kamath together, in terms of technology, got down to it in a major way. Other people also joined the group. They built a multi-spectral scanner. The satellite *ATS-6*, which was used for the SITE experiment, also had a radiometer on board for taking pictures of clouds.

So the SAC team planned ways to receive the data from the radiometer. But the radiometer failed, and nothing could be done about it.

The remote sensing programme at SAC was started using ordinary low-cost TV cameras. An aircraft was rented and equipped with these TV cameras for taking pictures of the ground to get images for analysis, but they did not allow much possibility. When the multi-spectral scanner got ready with a scanning mirror that was also used on the aircraft using different filters to test what would show and what would not.

Yash Pal is all praise for the efforts put in by the young team at SAC. He says, "These people came out in such a fantastic way accomplishing things. Not only that, our first remote sensing imager was a vidicon tube (a small television camera tube that forms a charge-density image on a photoconductive surface for subsequent electron-beam scanning), which was put in our own *Bhaskara* satellite. That vidicon tube had to be obtained from France, then filters were put, and so on." Thanks to the solid groundwork prepared by Yash Pal and his team, it was possible to launch the first Indian experimental payloads for remote sensing into orbit within four years, even earlier than our communication payloads. While communication satellite abolished distance on Earth, remote sensing has enabled us to get a new look at the planet Earth and understand their relational aspects – we can see forests, while on the ground we were only aware of trees. Today India has operational remote sensing satellites whose performance compares favourably with those of others launched by any nation.

So it all started really from grassroots, building up on itself. Microwaves were important, so radiometers were built – at least the technologists at SAC learnt how to make radiometers and show that when it goes from land to water surface you can see the difference – although it was not very high-resolution radiometer. Side by side they also took up image processing. The capability building in that area happened very fast, and played a major role in the development of the *INSAT* meteorological payloads. On *INSAT* there had to be a radiometer for cloud imaging and that was a big challenge.



During the UN conference days (1981-82)

7

Changing Hats

Having done so much for India's space programme, Yash Pal often represented India at the United Nations, which meant two to three trips to New York in a year. So he got involved in international space politics. At that time, of course, there were many things that were new. One was in the process of defining principles governing satellite broadcasting, frequency allocation, and contentious issues like that. People were objecting to others broadcasting in their country; many said no one could broadcast into their country without their permission. There were other problems. There was an Outer Space Committee, and the UN Secretary General invited him to be the Secretary General of the 2nd UN Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE-II), which was to be held in Vienna, Austria in 1982. It meant that he had to stay in New York. He accepted the invitation and played a key role in the conference. Following the recommendations of UNISPACE-II, the United Nations programme on space applications was considerably strengthened and expanded, resulting in increased opportunity for developing countries to participate in educational and training activities in space science and technology and to develop their indigenous capabilities in the use of space technology applications.

Before taking up the UN assignment, he had requested Prof. Dhawan to appoint a new Director of SAC because he wanted to go back to TIFR after return. So E.V. Chitnis was appointed Director of SAC. Yash Pal returned to SAC in 1983 as a Distinguished Scientist,

At the round table at UN on Alternate Space Futures (1982)

but essentially his intention was to go back to TIFR. Prof. Dhawan suggested that he join the Headquarters of ISRO, but he was reluctant.

In the meanwhile, something else was brewing in Delhi. While at the UN Yash Pal had had some correspondence with Mrs. Indira Gandhi, inviting her to the UN conference. So, when he returned, he got a message that he should see P.C. Alexander and Mrs. Gandhi and that she wanted him to go to Delhi. He went to Delhi and met her. During discussions several suggestions came up. One was that he should join the Ministry of I&B; that would have been all right, he says, if there were a vision of some kind. Finally he was appointed Chief Consultant to the Planning Commission. He liked that very much because that gave him the "opportunity of essentially bringing about a bridge in Planning Commission."

In Planning Commission there are various departments, "which only think about themselves." There are divisions, which look after various departments. To Yash Pal such divisions appeared ridiculous. He thought the Planning Commission should look after the overall plans – it may be education, it may be communication, it may be anything, and in the existing arrangement nobody was looking at it in totality.

So he did a few things in a year and-a-half or so in communication, in meteorology, in starting medium-range weather forecasting, getting a supercomputer and such things. And all would arise out of something actually happening.

He narrated an interesting experience, "Suddenly it occurred to me while talking to people in the power sector: doesn't the power sector need any communication system? When I did a study I found the situation was horrible; if there was power shedding somewhere they did not have a means to communicate with a surplus region for additional power. So I got a study done on the communication needs of the power sector, involving the Communication Ministry, Department of Space, and others. Many things were revealed. They were communicating only over telephone lines. Then there were microwave links of the Railways, which others did not use. I found the whole thing shocking. So that was a very substantive report."

"Similarly, with Kiran Karnik we prepared a report on Communication. I told Mrs. Gandhi and her press secretary H.Y. Sharada Prasad about what one should do in that plan for communication. I said the way the things are going what we need to do in communication, in addition to microwave links, satellite communication, and everything else, is a messaging system in all habitations of India. At that time there was no Internet, but what I implied by a messaging system was precisely that kind of a thing. I said we should have it even before we have telephone in all the villages."

The report was put in the Planning Commission also; then it finally went into the plan document and the Ministry of Telecommunication, which got it converted into a "better communication system in all villages" rather than a "messaging system in all villages", as Yash Pal had envisaged. Around that time there were only 60 places in India from which weather information could be sent by somebody in the Meteorology Department to Delhi to be used for weather forecasting. There was a need for a much better communication system.

As Secretary General at the UNISPACE-II conference in Vienna. (1982)

Then the position of Secretary, Department of Science and Technology fell vacant. At that time the Council of Scientific and Industrial Research also came under the Department of Science and Technology. Yash Pal recollects, "I did not want to have CSIR. Dr. S. Varadarajan was DG, CSIR; he felt that he should be in charge of both CSIR and DST. So I didn't want the DST post, but Mrs. Gandhi asked me to take charge as Secretary, DST. I told her what I had been doing while in Planning Commission, where I was very happy. If I find the kind of things related to education plus interconnecting needs of various sectors through communication I think it'd be something worthwhile

to do. She said, 'who told you that you shouldn't go on doing it?' I said, the way the Ministries are divided…, but she assured me that she'd send around a note to all the Ministries informing them that I'd been involved in all aspects related to communication, broadcasting and interconnecting and that I could go on doing that. She did send it, but you know a letter doesn't mean anything after a while. It was amazing she sent the letter to everybody."

So Yash Pal moved to DST in 1984. He says, "That was also very good; not bad and many things could be done." Then Mrs. Gandhi

With Nirmal at Star City, Moscow (1981)

died and Rajiv Gandhi took over. Rajiv started a new system of the discussion in the various Parliamentary Committee meetings. He started setting a theme on which the members had to give opinions. He put forth a theme 'Science in Education'. So Yash Pal prepared a presentation and the Education Department was also there. In the meeting he said, science in education does not mean only what science is to be taught in education but also how science can influence education. He recollects, "I think somehow this got stuck in his (Rajiv's) mind; it was quite a long presentation that I'd made, covering all aspects of the subject."

A few months later the position of the Chairman, UGC fell vacant when he was in a conference in New York called by the UN Secretary General. He got a telephone call from Gopi Arora of the Prime Minister's office telling him that Rajiv wanted him to take over as Chairman, UGC. His response was sharp. "I was annoyed with him. I said, how can he ask me to take over UGC without any discussion? I said if he doesn't like my work in DST, I could do something else. He called me again and again and I told him the same thing. Then Rajiv called me. I told him if he didn't think I was doing the DST work right, probably he might find a better person. He said it was precisely because I was doing things right he wanted me in UGC. If there is no science in educational establishments what's the point of doing science?"

But Yash Pal is not a person who can be easily convinced. He told Rajiv that science was not only there in the universities, which were controlled by UGC but also in medical institutes, the national labs, in engineering institutes, and they were all under separate controls. And the situation was such that if something had to be done together it would be very difficult. Rajiv said, "Since precisely this kind of ideas have been occurring to me, don't you think we should do something?" Here Yash Pal mentioned about the creation of an Education Commission and Rajiv agreed. He told Yash Pal that there should be a Higher Education Commission, which should include medicine, agriculture, engineering, and what we call general education, and asked him if he would come if this were done. Yash Pal wanted to discuss further.

After he returned from New York there was a message waiting for him from Rajiv. He went and met him. He recalls, "I must say he (Rajiv) was so serious about this that he called the Cabinet Secretary, he arranged meetings with the Agriculture Minister, Health Minister, Education Minister – all the people together and separately, and he told them about the idea. It was amazing. I was assured that an Education Commission would be formed and I then joined UGC.

"Narasimha Rao was given the responsibility of organising things for setting up the Commission. They were in the process of getting

With U.R. Rao and others at the Indian Space exhibition at the UN in New York (1981)

various reports. Two weeks later Rajiv met me and asked if the Education Commission had been set up. I told him that being in UGC I can't take any initiative; something is cooking but I don't know. Gopi Arora came to see me a couple of times. And then Narasimha Rao and others produced a report. They had come out with something where there would be a Minister in charge and a coordination committee, and stuff like that. By that time I had got in and said if this was the way, it would create more bureaucracy and it was not going to work."

And then Rajiv Gandhi was out of power and no further headway could be made. But Yash Pal did not want to give up entirely; he wanted to do some retrofitting. And that is how the idea of Inter-University Centres, the idea of university students coming to Nuclear Science Centre, and science departments using facilities of Atomic Energy Department, and things like that came up. Some of these ideas did

work. Inter-University Centres, Academic Staff colleges, and the Information and Library Network (INFLIBNET) came up. INFLIBNET now covers a large network of universities. The Centre for Educational Communication is also doing a fair amount of work.

After about a year or so, even when he was in UGC, he came out with the suggestion that all laboratories, which were doing basic research, should seek a deemed university status. Some of the university Vice-Chancellors were very unhappy with him, presumably because they thought their power of giving degrees was being taken away. "On the other hand," Yash Pal told them, "if we looked at it from the point of view of education, if these laboratories had educational programmes, and they have good people, then that would add to education." So this was the kind of things he did while in UGC.

He did another crazy thing while in UGC because "the sociological situation in the country really bothered him." He wrote a letter and circulated it widely. In that letter he raised the question of the relevance of our education system when there was so much illiteracy, so much darkness everywhere. It also expressed his deep concern for the common people. He wrote, "Why don't we shut down all colleges and universities for a year? Shut down not to go on a holiday, but to venture out to interact with people, prepare entirely new courses, write diaries, and come back refreshed. And with this new course material you begin. Coupling with the country is important."

This suggestion was seriously discussed in the Planning Commission; it was Janata government in power at that time. Then some of Vice Chancellors asked if it could be done during summer vacations? And so on. Yash Pal went to see Rajiv Gandhi, who was in the opposition, and told him about the idea which Rajiv said was wonderful. "He asked me why I wanted to involve political parties. I said if anything like this has to be done, unless Parliament gives its consent how can you close the universities? If the idea went through it would produce reverberations throughout the country." Rajiv said the Congress party would fully support the idea. But here was a strange

With Vasant Gowarikar (extreme left), U.R. Rao (second from right), and Indira Gandhi at Vigyan Bhawan in New Delhi (1984)

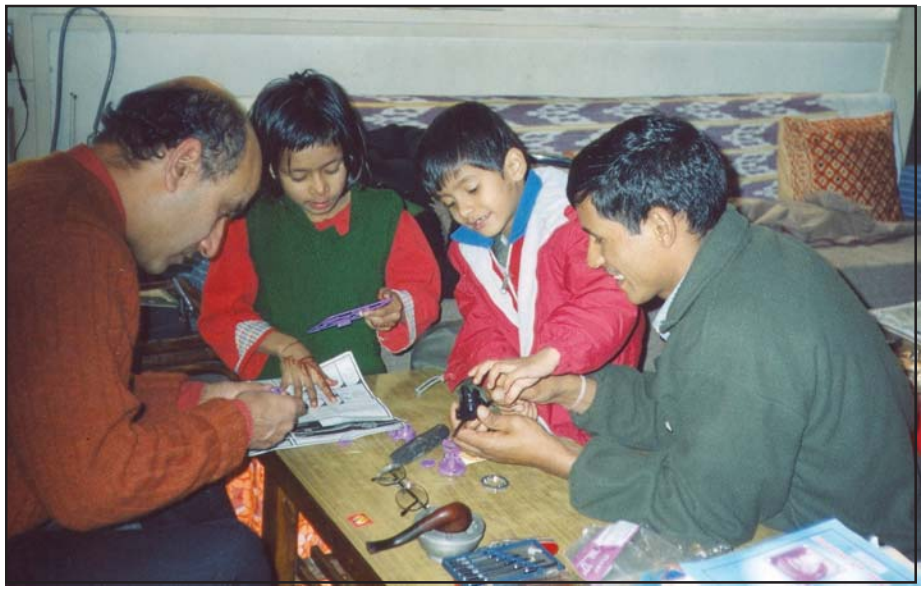
thing – the Chairman of the UGC wanting to close down universities; he goes to the Planning Commission; he goes to various political parties to get it done!

P.N. Haksar was very excited about this idea. He called a meeting of all political parties – there was BJP, there were left parties, Janata Party, Congress – all major political parties were there. In the minutes of this meeting the kind of statements made by those present were amazing. "But that was not surprising," says Yash Pal, "because, I made them ashamed that our country in literacy and education was behind the sub-Sahara region. I gave figures to prove my point. So we had to get all engaged in that, and it was a fantastic meeting." But unfortunately, Rajiv died, government changed, and Yash Pal left the UGC. So nothing came out of the exercise. Soon after that, in 1992, Yash Pal got involved in the "Bharat Jan Gyan Vigyan Jatha", a country-wide science movement, which was in a way spurred by the meeting Haksar arranged with the political parties. It was a massive effort on mass action for national regeneration spearheaded by the National

With S. Chandrasekhar (extreme left), D.S. Kothari (second from left), and Avtar Singh Paintal (sitting) in New Delhi (1985)

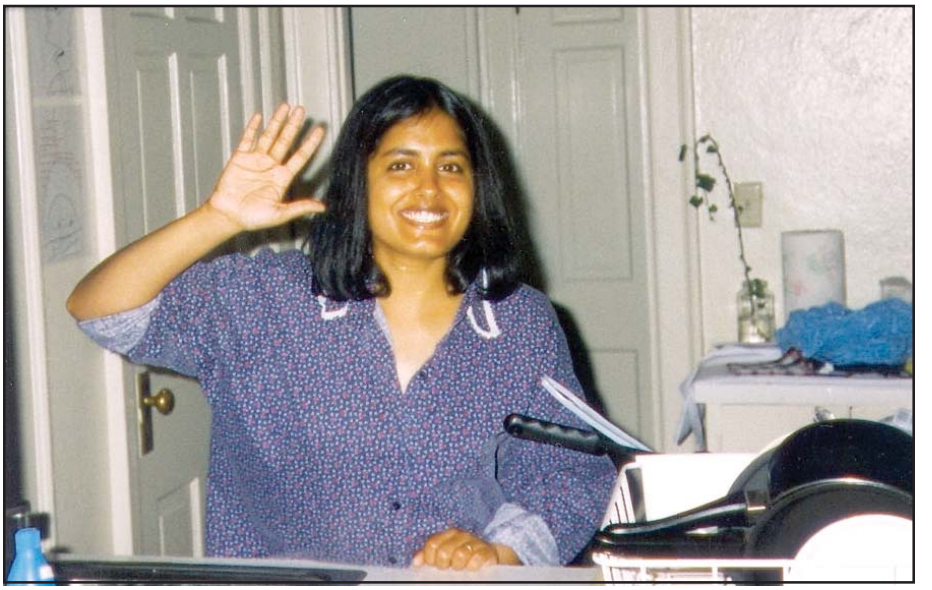
Council for Science and Technology Communication (NCSTC) that touched over 400 districts in the country. In 1995 he was made a National Research Professor by the Government of India.

With Nirmal, Rahul, and Bruce Dayton (extreme left) in front of the world's oldest tree in USA (1971)

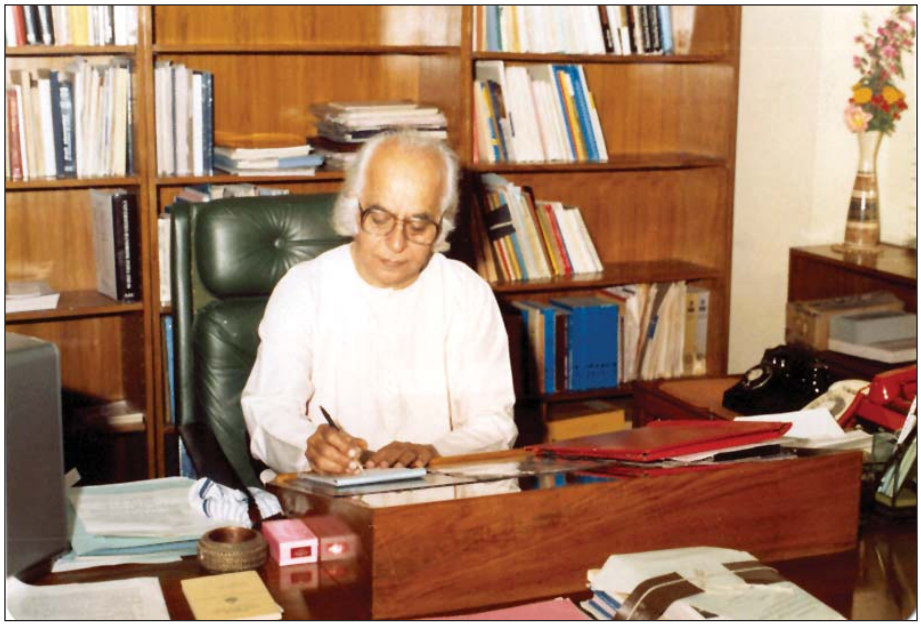


Yash Pal's 'extended family' (from right) Basudev, Naveen, Jyoti and Anil

Yash Pal's sons, Rahul (left) and Anil (right)



Daughter-in-law Shanthi



At work as Chairman, Univerity Grants Commission (1986)

With President Venkataraman in New Delhi. Mrs. Pupul Jayakar and Philip Morrison and Phylis Morrison are also seen (1986)

8

Explaining Science to the People

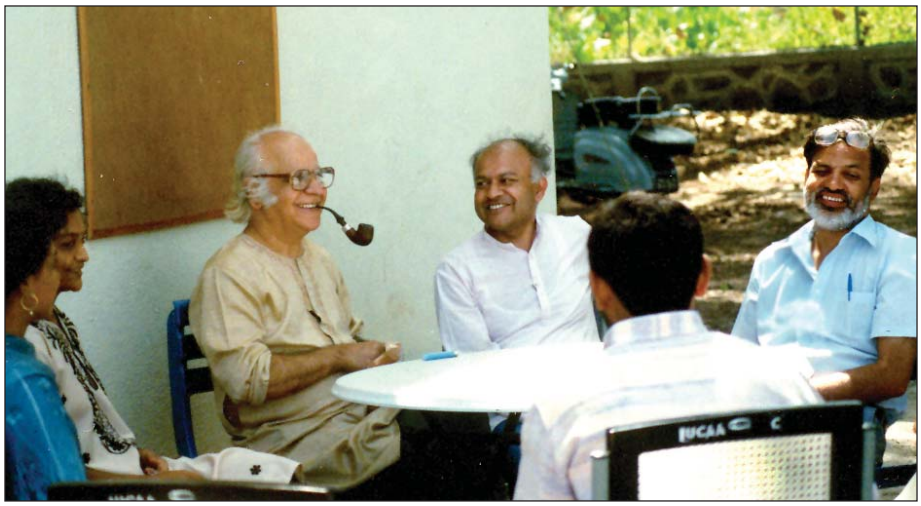
The "Bharat Jan Gyan Vigyan Jatha" was a very intensive jatha activity was organised all over the country – extremely intense, transformative kind of activity covering 50,000-60,000 villages. About the relevance and utility of such movements he says, "It is true that many of these things are not like projects or programmes, but many worthwhile people you see are spread all around – in communication, in education and so on. Somehow I have been influenced when I was connected with this, that's why a network. I don't get into this tension between People's Science Network and NCSTS-Network because I go to meetings of People's Science Network also. I am not a party man. When NCSTC-Network was involved in this – and there are 50-60 organisations, which are coupled with this – the National Children's Science Congress was started. I am the President of the NCSTC-Network; I don't do a great deal for them in children's science activities, although I occasionally come for the Children's Science Congress."

To lakhs of TV viewers around the country the Yash Pal's face with characteristic flowing locks of white hair has become a popular icon who can answer all your questions about science. His name has become synonymous with popularisation of science. How did he develop his unique style? How did he become so popular? He narrated

his experience, "If I try to remember when I first went before a camera to try to explain something in a way that people would understand – demystify things – one event I remember is the time when the American space station *Skylab* was to fall in July 1979. Somehow there was a rumour that it was likely to fall over Kheda district or somewhere near in Gujarat and people were very worried. I was at that time in Ahmedabad. I wondered how to tell people the truth. I sent a message to NASA and was constantly getting Telex messages about the position and the likely point of impact of the falling space station. I went on giving this information for the public over the local station of All India Radio – every half hour the AIR station would get the information from my office for broadcast.

"Simultaneously, I started preparing how to explain it in the evening on the TV. I had a globe and on that I asked the workshop to quickly make movable orbit of wire. If the camera were focussed on the globe the position of the orbit with respect to the spinning Earth could be shown. The idea was to explain also what the orbits are and in what way spacecraft and space stations travel and what happens. So I took that information and drew a chart showing the altitude of *Skylab* at various times and the probability of its hitting a particular place. I turned the globe and told the viewers how the path moved over the Earth as the Earth turned. And then I said that the probability of the space station hitting any part of Gujarat was out; it would cross over and would most probably fall over the southern Indian Ocean. This was done in a half-hour programme in Hindi. From that day in Kheda, I was known as the 'Skylab uncle'. So it is not just giving information; it is making the viewers or listeners understand."

When Yash Pal came to Planning Commission in 1983, Doordarshan was just across the road. The first *INSAT* satellite was launched, but it failed because its antenna got stuck. So Doordarshan people would come and ask him to make a programme. He made an *INSAT* antenna out of a pack of computer cards to explain how it may have got stuck and what options were there to release it. The people from the Department of Space were so happy because the problem was



With Prof. Jayant Narlikar (second from right) at IUCAA

so lucidly explained to the people. That is the kind of things he was doing in science popularisation.

There were demands from several other quarters too. Recalling how 'Turning Point', which was one of the most popular science programmes ever telecast by Doordarshan, was started, he says, "Naazish Hussaini was one of the producers who would come to me regularly and pester me to do programmes for Doordarshan. The result was 'Turning Point', which started in 1992. I must mention that Prof. M.G.K. Menon, who was a Minister in the Janata government, had first suggested that there ought to be programmes of that sort, of at least half an hour every week. So Turning Point started. It was Man Mohan Chaudhuri who made the first programme, which was a magazine programme. Naazish Hussaini was the executive producer. That was the beginning.

"Then Naazish approached me. She said a lot of scripts come; the scripts have to be looked at, and there are six producers. So I went to these producers and formed a sort of a consortium for discussion – critiquing each other's programmes. I said there were a whole lot of concerns about things happening around us. Suddenly they said why

At a National Children's Science Congress

don't people ask questions and can you give the answers? I said, I'll try. So that's how questions and answers entered Turning Point. And soon there was a flood of questions; sometimes we got over 200 letters a day with three questions in each. I didn't attempt to give exact answers but tried to make people understand. So I imagined who would be sitting in front of the TV set. And that was a very very enjoyable period."

For the programmes the producers had to send the scripts to him first. He would read the script; if there were something that he did not consider right, he would correct it. Often he would confront the producer with a barrage of questions, wanting to know why they were eager to show only work done in big labs. It might increase the glamour the programme but what did the common man get out of it? Why did they only put in information; why was there so little effort to make the viewers understand something? He would tell them frankly that if the programme did not help people understand, the programme would

Doing experiments with children

not be aired. So, sometimes they would rewrite the scripts; sometimes he would reject the scripts altogether. Approving, correcting, and continuously dialoguing with them did improve the content and quality of the programmes. He says, "I think they appreciated it afterwards. So that was partly responsible for the popularity of the 'Turning Point' in addition to my question answers. But I could answer only one or two questions every week and that was not really a great deal. But it stuck on and people still remember."

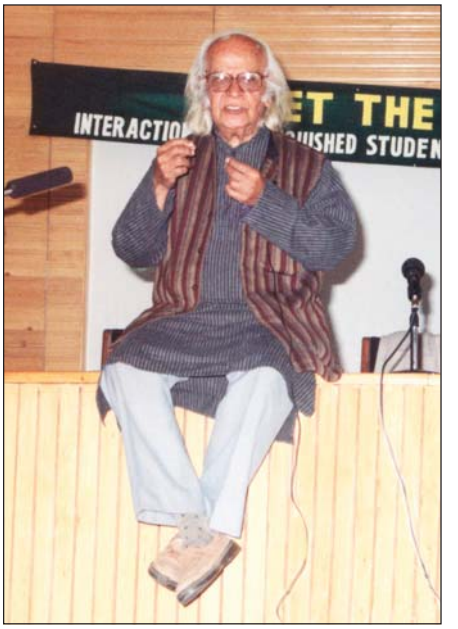
But, then, Doordarshan discontinued telecasting 'Turning Point'. They did not have to stop it, but commercial television came and they somehow felt that 'Turning Point' was not commercial enough. Yash Pal was greatly distressed. He says, "I think that was terrible because the producers who had gathered together were really capable and we had such nice presenters as Girish Karnad, Naseeruddin Shah, and others."

Addressing students in a public school

Besides answering questions in over 150 episodes of 'Turning Point', he was the Chief Advisor for the TV serials, 'Bharat Ki Chaap', 'Tur-rum-tu', and 'Race to Save the Planet'. He was the anchor for the live telecast of total solar eclipse programmes in 1995 and 1999, and the live programme on transit of Venus in 2004.

Although 'Turning Point' was discontinued, Yash Pal is not a person to sit idle. He found new activities to keep himself productively engaged. Somebody in his neighbourhood, a young girl, started working for a website called Egurukul.com. He went to her office and discussed possibilities of making and selling CD-ROMs. The topic of answering questions came up and he readily agreed. They announced it on their web site and there was a flood of questions. And so for a year-and-a-half he answered questions on the Internet; those questions and answers are coming in the form of a book now. There are some 270 questions answered in that book. He also started having chat sessions on the Internet on Egurukul.com. This could have continued, but when NIIT bought Egurukul.com, they were not interested in this kind of stuff.

Again, there was a new offer. This time he got a letter from Malayala Manorama; they wanted him to answer questions and so for a year and a half he was answering questions for them. He used to send them the answers in English, which they would get translated into Malayalam. Then, when *The Tribune* heard about it they also asked him to answer questions and they did it both in English and Hindi. In Hindi it appears in *Prabhat Khabar* published from Jharkhand, and is now a continuing activity.



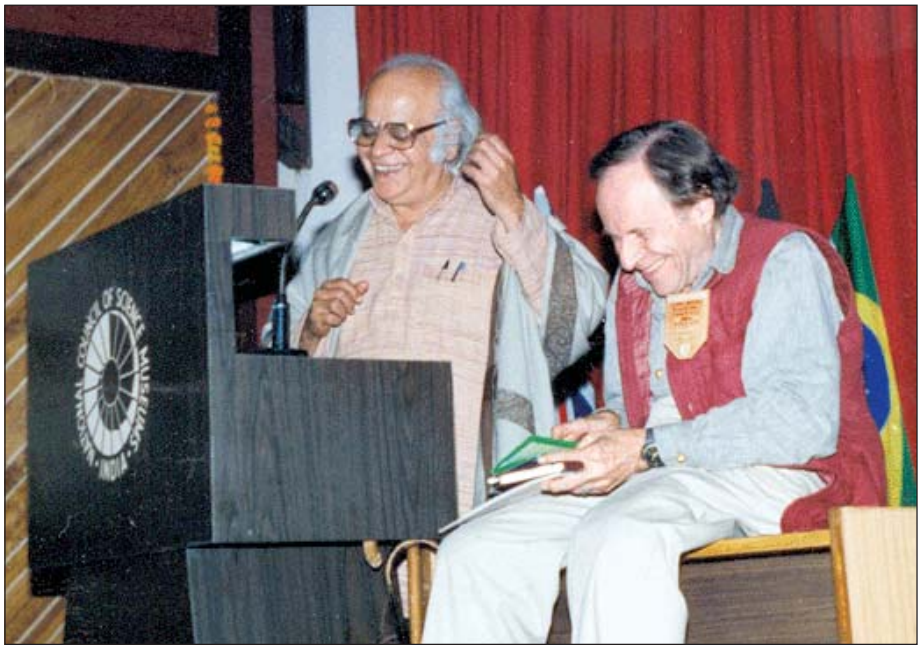
Interacting with Kashmiri students in Srinagar

How did he become so popular with the media? He says, "I think it all happened because of the accident of *INSAT*s and so on; I didn't train to be a media person or anything, but was connected with people's science movements. If I tried to be a scientist, I wouldn't be able to communicate. If you want to communicate you have to bring understanding rather than give the exact answer, which they can write in the exam. I don't have to say that the diameter of the Earth is exactly 12,000 something kilometres; only a rough approximation would do for understanding. I can say the Earth has a diameter of roughly 13,000 kilometres and its highest mountain is about 10 kilometres high. That's enough for one to understand the miniscule size of the highest mountain in comparison to the size of the Earth, and to get an idea of gravity, which puts a constraint on the size of the highest mountain on Earth. The exact numbers don't make a difference." Could anyone be more lucid?

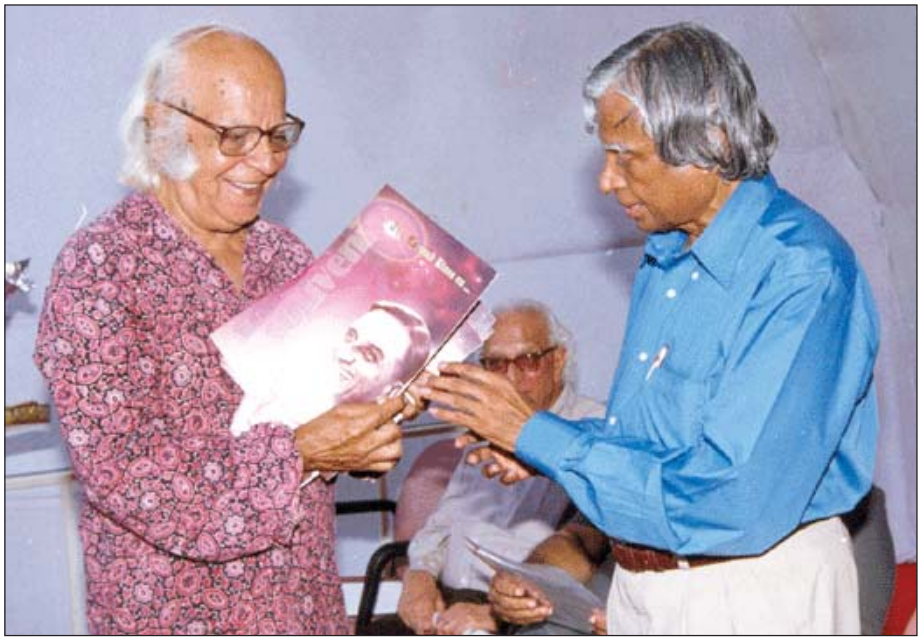
In recognition of his untiring efforts at simplifying science for the common people through the media, he was given the National Award for Science Popularisation for the year 2000 by NCSTC.

Nirmal and Yash Pal with Hanna Peters in her home in Copenhagen (2000)

With Nirmal in a jovial mood at a family get together



Sharing a humourous moment with Philip Morrison at the National Science Centre, Delhi.



At Vikram Sarabhai Space Centre, Thiruvananthapuram with Dr. A.P.J. Abdul Kalam on the occasion of the unveiling of the statue of Sarabhai. (2003)

In a class with V.G. Kulkarni (1973)

Interacting with underprivileged students in class in Mumbai (1974)

9

Reforming Education

Education reform has been a ceaseless concern for Yash Pal throughout his life. He has always had keen interest in education and the newer forms of learning. His emphasis has always been on the human contact and social interaction during education rather than a bookish education. When he was Chairman, UGC he tried to change university education in a radical way when he mooted the idea of shutting down colleges and universities for a year to enable the educators to reach out to and interact with people and rewrite courses. He did not succeed in his mission, but still, the concern for bringing about a change in the education system never left him. He always felt that there was something seriously wrong with our education system and has put in relentless effort to remedy the situation.

Education, as he perceived it, was not simply delivering knowledge but acquiring, constructing and creating knowledge. His idea of good education was "drastically reducing loads of sterile information and giving emphasis on comprehension and understanding, and sharing the joy of understanding." He wanted "boundaries between disciplines to be made porous and to seek tangential connections with real life experience, observations and happenings to enhance understanding and creativity." The need, he felt, was not necessarily to start with the basics to arrive at the familiar, the current and the exciting, but rather to take the opposite approach to catch the interest and imagination of children and ultimately try to make the basics more understandable.

With underprivileged students in a class (1974)

During the early 1970s, V. G. Kulkarni, a colleague of his in TIFR, who was also concerned about school education, conceived a unique plan to make physics more easily comprehensible to underprivileged children belonging to the SC and ST categories in municipal schools in Mumbai. He had observed that most of these children found it very difficult to understand the subject because of the pedagogic language of the school textbooks and so fared very badly in examinations. He undertook to rewrite the textbooks in a language simple enough for easy comprehension by these children. Kulkarni called Yash Pal from Ahmedabad to join him in conducting the unique experiment in teaching. Together they conducted pioneering trials in introducing the discovery approach to the learning of physics in a few public and municipal schools in Mumbai. And the results were fantastic. The same children who could not score marks earlier did exceedingly well in tests after being taught the same curriculum by a different technique.

The approach of Kulkarni and Yash Pal was totally different from conventional teaching methods. They adopted the "learning by doing" approach to teach physics, because they strongly believed that children should learn science by performing experiments with their own hands, recording their observations, and deriving independent conclusions

through discussions with their classmates and teachers. They encouraged the children to ask questions, critically examine evidence and analyse new situations that might arise. Rote learning of facts and definitions was an anathema to them. They believed that the role of a teacher should be that of a guide and helper rather than the "fountainhead of all knowledge." Yash Pal still holds this conviction, as is amply clear whenever he responds to a question from a child. Rather than giving a straight answer he always tries to make the child find the answer of his/her own by giving a few clues to work on. Often this has an electrifying effect on the child; he/she can enjoy the thrill of discovery!

In 1992, the Ministry of Human Resource Development set up a National Advisory Committee under his chairmanship to advise on the ways and means to reduce the academic burden on school students. The Committee submitted its Report to the Ministry 1993. It came out with recommendations, which can be only described as radical. The report observed that in the present school system "a lot is taught but little is learnt or understood"; it therefore inferred that "the load of non-learning or non-comprehension is the real load one should be concerned about."

The Report, which is also known as the 'Yash Pal Committee Report', touched upon almost every aspect of school education, showing the depth to which the Committee members had gone in not only to understand the real problems but also in order to come out with judicious recommendations. And to do that Yash Pal's long experience in interacting with children "in situations when they are not constrained by a prescribed syllabus," must have played a crucial role.

Referring to the load of books to be carried by the children to schools, the Report observed, "So far as physical load of the school bag is concerned, the situation has become worse over the past few years. However, the weight of the school bag represents only one dimension of the problem; the more pernicious burden is that of non-comprehension."

Interacting with underprivileged students in class (1974)

The Report was also highly critical of the way textbooks for schools were written. It observed, "experts commissioned to write textbooks for school students are isolated from classroom realities. Since they are not familiar with learning process of children, the textbooks prepared by them prove too difficult for majority of children." It found that most of the textbooks had high-density of concepts and the style of writing was very terse. The language used in the books in some cases was beyond the comprehension of most students.

The Report further observed, "The major well-understood defect of the present examination system is that it focusses on children's ability to reproduce information to the exclusion of the ability to apply concepts and information on unfamiliar, new problems or simply to think. Both the teachers and the parents constantly reinforce the fear of examination and the need to prepare for it by memorising a whole lot of information from the textbook and guidebooks. This sort of perception about the examination makes things difficult for children."

In an unequivocal language, typical of Yash Pal, the Report commented tersely on the present system in which, "Majority of our school-going children view learning at school as a boring, even

unpleasant and bitter experience. The limited purpose of preparing for examination is indeed a very important factor for the unpleasantness of learning. The child centred education and activity based teaching learning method are talked about but are seldom practised in our school."

While submitting the Report, Yash Pal in a letter addressed to the then Human Resource Development Minister said, "I am unable to persuade myself that the 'state' of our school education is an independent variable – that it could be altered without altering a lot of things in our social set-up!"

He was not making any overstatement. The present state of school education in the country, as exemplified by the proliferation of playschools in practically every nook and corner of our big cities and even small towns, bear testimony to this concern. Another worrying factor is the progressively lower age at which children are being packed off to these teaching shops that function in cramped drawing rooms. All because the perennial concern of the parents to get their child admitted to the 'best' school their money can buy. This state of affairs has been always anathema to him.

Addressing the National Learning Conference in Bangalore in 2005, Yash Pal made a very straightforward statement: "If I were asked to name one major direction that could drastically change the nature of our education and research enterprise from kindergarten to the university level I would say: 'Build on individual competence and exploration and couple with the life around you.' If this advice were taken seriously it would imply that: 'Learning is not delivered; it is created.'"

Elaborating on what a child should learn, he told the conference delegates, "The process of creation necessarily requires building on what the child already knows, what it observes and explores, the experiments it does while playing, studying and dealing with the world around." Since the experience of one child may be different from that of another,

Giving a science demonstration before underprivileged children in Mumbai (1974)

he suggested a different syllabus for each child. If that were so, he felt, then there would be no need for centralized examinations. "We would examine each child the way a music or dance *guru* examines his/her *shishyas*, or an *ustad* or craftsman trains his/her apprentices," he suggested. "We would not make children run a competitive hurdle race to get that extra mark of distinction. There would be no need of coaching classes that destroy education. Learning would not be confined within disciplines. Nothing would be out of course if it were comprehensible,"

Yash Pal has always revelled in talking to children and respected their curiosity. Those encounters, he says, have often opened his eyes to elements and aspects of the world to which he was blind or had consigned to a bin called 'No need to know'. "In their curiosity," he says, "Children are more current than the curriculum designers. Humans are born to observe, experiment and understand. These faculties are often extinguished or dimmed by our education system. I have come to believe that some day we would learn to design a way of

teaching and learning that will be largely based on the questions children discover and ask."

Reminiscing about his long and fruitful career he candidly expresses his feelings, "A certain degree of loss of excitement for doing active science always remains. But the point is, whatever one gets into one gets so involved and one finds such joys in doing that in a sense I can't say that I shouldn't have done what I've done or done only that. But one wonderful thing has been, and I am very very lucky about this, that right from the TIFR days, to space days, to UGC and so on, the contacts have remained. I work with Ram Nath Cowsik and Shyam Tandon with as much gusto now as I ever did. Now it is not the question of teaching them or telling them – I never taught anybody anyway – but essentially taking joy in what they suggest and also getting joy out of what they achieve. Yet, I was the Chairman of the project both for the Hanle telescope in Ladakh and the Ultraviolet telescope, which Shyam is leading to build.

"One feels so grateful that after so long these guys and people think that I can still contribute something. Ram Nath is as close in terms of what he does now as ever and so is Shyam. And then I find I have done a few marvellous things – the creation of the Inter-University Centres, like IUCAA and others, and various other things of this kind."

Yash Pal sums up his life's mission quite succinctly: "I do think that in my life I have done some serious science. Not so great perhaps, but serious and interesting nevertheless. That has given me intellectual joy. Even more, it has opened for me the doors of a lot of fascinating science done by others, many of them far more gifted than me. It has also opened avenues through which one may begin to address questions, which touch the realm of things spiritual. Yes, I do believe that there is something deeply spiritual in the intimate operational manuals of Nature, in the beautiful and logical connections between the microscopic and the macroscopic worlds, in the connections between the living and the non-living and being able to understand the stars, galaxies and the universe, not completely but to a large extent.

"One of the joys of living has been – I started at TIFR; I worked in laboratories like TIFR, and SAC; I had interaction with universities quite a bit; tried to knit universities and laboratories together; then I had people's interaction during SITE, and later, during these movements all over. Some people think that I have spoiled my career, but I think that connectivity stays. If I go to a space centre, no matter which, I feel I'm part of it. Why does the Chairman of the Space Commission still feel that if some space event is happening I should be there? It is almost 25 years since I left SAC. Why do the various IITs keep inviting me – mostly their students invite me. Why do schools keep inviting me? So it's the connectivity with the land that somehow I have been lucky enough to build on. And there are empathies with all minds of people; nothing is lost – it builds up."

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At A Glance*

Born:	26th November 1926
Education:	• Post-graduation in physics from Punjab University (1949) • Ph.D. in physics from the Massachusetts Institute of Technology (1958)
Area of work:	Cosmic rays; high-energy physics, astrophysics; science education; space technology; communication and development; education; science popularisation
Professional positions:	• Visiting Professor, Niels Bohr Institute Copenhagen; University of Maryland; California Institute of Technology; Danish Space Research Institute. • Professor, Tata Institute of Fundamental Research (up to 1983) • Director, Space Applications Centre, Ahmedabad (1973-81) • Distinguished Scientist, Indian Space Research Organisation (1980-83) • Secretary General, 2nd United Nations Conference on Peaceful Uses of Outer Space (UNISPACE-II) (1981-82) • Chief Consultant, Planning Commission (1983-84) • Secretary, Department of Science & Technology (1984-86) • Chairman, University Grants Commission (1986-91) • Chairman, National Institute of Design (1984-91)

	• Chairman, National Organising Committee, Bharat Jana Gyan Vigyan Jatha (1992) • National Research Professor (1995 -) • Jawaharlal Nehru Chair in Technology, Punjab University (1997-1999) • National Mahatma Gandhi Fellow (2004) • Chairman, Steering Committee for the National Curriculum Framework (2005)
Honours and Awards	• Padma Bhushan for contribution to Science and Space Technology (1976) • Marconi Fellowship (1980) "to recognise wise and humane leadership in applying modern communications technology to meet the needs of isolated rural villagers in India." • Dayanand Saraswati Centenary Gold Medal for Excellence in Science (1984) • Arthur C. Clarke Award for Communication and Space Technology (1994) • NCSTC National Award for Best Effort in Science Popularisation (2000)

*This list is not exhaustive.

Yash Pal: A Life in Science

Prof. Yash Pal embodies several personalities – scientist, science manager, educator, and communicator – all rolled into one. There are few Indian scientists who have done so much in so many different fields, and have done it with such fervour. He built up the Space Applications Centre at Ahmedabad and was the key person to plan and execute the yearlong Satellite Instructional Television Experiment (SITE) during 1975-76, which brought in a new dimension in educational communication in India. Later, he became popular as one who could explain science in layman's language. His regular appearance in the TV science programme 'Turning Point' to answer questions sent by viewers made him almost a public icon. He developed his own unique style of explaining science – not giving direct answers but making the viewers think and understand to get to the answers. This brief biography, profusely illustrated with rare photographs, is an attempt to bring out the multifaceted personality of Prof. Yash Pal, his emphasis on independent thought, and his innovative ways of problem solving.

Winner of the 1994 NCSTC National Award for best science and technology coverage in the mass media, Biman Basu (b. 1945) has been involved in science popularisation through print and electronic media for almost four decades. He has published several hundred articles for leading dailies and magazines and has scripted several radio and television features on science. He edited the popular science monthly *Science Reporter* for more than three decades and has authored more than twenty popular science books, including *The DNA Saga*, published by Vigyan Prasar.

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