

Professor Satish Dhawan – A gentle integrator

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It is now 18 years since Satish Dhawan passed away and we are close to the starting of the centenary year. I was fortunate to have had the opportunity to work with him for a long time, over 22 years, from 1972 to 1994. Even after his retirement as the Chairman of ISRO in 1984, I was constantly in touch with Dhawan till my retirement in 1994. He had taken up the challenge to lead the fledgling organization built by Vikram Sarabhai, nurtured it and ensured that it developed and matured into a strong national organization capable of delivering the operational space systems in a self-reliant manner. Dhawan will always be remembered as the person who brought together all the different independent ISRO units functioning in Ahmedabad, Bangalore, Sriharikota Island and Thiruvananthapuram and integrated them into a vibrant, forward-looking and functioning national organization.

I always fondly remember my first meeting with Dhawan. I had gone from Physical Research Laboratory (PRL), Ahmedabad to Thumba Equatorial Rocket Launching Station (TERLS) for a rocket launch and preparation of the tracking system in early December 1965. I saw a tall, handsome and impressive person there at the guest house. H. G. S. Murthy (Range Director, TERLS) introduced him as Satish Dhawan, Director of the Indian Institute of Science (IISc), Bangalore. He was visiting TERLS for the Indian National Committee for Space Research (INCOSPAR) meeting. I introduced myself to him and we started talking about all the facilities at TERLS. He took interest in my work. I told him about my visit to IISc and HAL as a student. I also told him that I would be moving from the PRL to the Space Science and Technology Centre in Thiruvananthapuram in about a month. Apart from the work on the Nike Apache and Centaur rocket payloads, I was able to discuss with him about the comparative performances of our GNAT aircrafts made in India and F-104 aircraft of US origin used by Pakistan in a recent conflict.

When I told him that I would be visiting the National Aeronautics Laboratory (NAL), Bangalore on my way back to PRL to understand their instrumentation systems, he immediately extended an invitation to me to visit IISc and meet him. After finishing work in TERLS, I went to Bangalore. Before going to NAL I visited him at IISc. He spent quite some time talking with me and guided me about the instrumentation requirements for the wind

tunnel at IISc. He also suggested a few names of scientists at NAL whom I should be meeting¹.

I was working as a Satellite Instructional Television Experiment (SITE) Resident Representative at the Goddard Space Flight Centre, NASA, USA when Vikram Sarabhai passed away in end December 1971. After his demise, M. G. K. Menon assumed charge as the Chairman of ISRO. It was known that Dhawan would become the Chairman later on his return to India. I met Menon during his visit in March 1972 to USA. I had briefed him about the work that I was carrying out. It was clear that we were headed towards disagreements with NASA regarding the reception and utilization of data from Earth Resources Technology Satellite (ERTS 1). Menon told me about the changes he had planned in ISRO.

I came back to Ahmedabad from USA in August 1972 for the ISRO Seminar on Space Science and Space Applications. Earlier, I met Menon and briefed him about my latest study on INSAT-S, involving five spot beams for television broadcasting and he had approved my presentation. I was not certain about the views of Dhawan regarding the INSAT system. I got the opportunity to meet him again during the ISRO Seminar in Ahmedabad. By that time, he had become Chairman of the Space Commission. I requested him and Yash Pal to be there during my presentation and both of them kindly agreed. After my presentation, we worked overnight to develop an integrated plan for the utilization of the satellite by All India Radio and the Ministry of Communications, Government of India (GoI).

I briefed Dhawan later about my work at NASA and the studies being carried out regarding the INSAT satellite system. I also briefed him about my participation in the first team concerned with remote sensing technology. I told him about the unsuccessful discussions regarding establishment of the ground data reception facility for the ERTS 1 satellite of NASA. I also told him about our unsuccessful plans for placing our engineers at Fairchild Hiller, where the ATS F satellite was being built for NASA. I briefed him about my discussions with Menon regarding the changes in ISRO. As we discussed certain aspects of the INSAT work, he asked me, 'Did we meet earlier?' I said yes and narrated to him about the first meeting at TERLS and later at IISc in 1965. After discussing about my work in USA, he told me to wind up my work at the Goddard Space Flight Centre and return to India. At that time, he indicated his plans for setting up

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the ISRO Headquarters in Bangalore. M. A. Vellodi as Additional Secretary and T. N. Seshan as Joint Secretary had already moved to Bangalore when the new Department of Space (DoS) was formed. I had known and met both of them on many occasions in the Department of Atomic Energy office in Mumbai.

During the ISRO Seminar in Ahmedabad, it was clear that Dhawan was keenly interested in continuing the work that was started by Sarabhai, but he had his own ideas about certain aspects of our work. He enquired about our own personal ideas on certain aims and objectives of the SITE programme.

Some ideas were expressed as to how education and instruction for the rural population could result in stemming the migration from rural areas to urban areas. He opposed pursuing such ideas and made his opposition clear to all of us. He was clear that making opportunities available to the rural population was important and how people use these opportunities should be left to them. He wanted us to pursue our ideas regarding education, improvement of agricultural practices and national integration.

After my return from USA in January 1973, there was uncertainty about where I would be located. All the ISRO units in Ahmedabad were brought together and the Space Applications Centre (SAC) was formed with Yash Pal as the Director. Likewise, all the units in Thiruvananthapuram were brought together as Vikram Sarabhai Space Centre (VSSC) with Brahma Prakash as the Director, and he wanted me to work in VSSC; Yash Pal in SAC, Ahmedabad and Dhawan in Bangalore at the newly formed ISRO Headquarters. After a meeting of all of us, it was decided that I should work in Ahmedabad till the completion of the SITE and as soon as GoI approved the INSAT programme, I should move to Bangalore.

Once Yash Pal, Dhawan and I were discussing the issue of promoting and encouraging 'creativity' in children as part of instructional television programmes being developed for the SITE. Dhawan gave us a fine example. He said: 'Children like to play the board game "Snakes and Ladders" and that can be used to encourage their creativity. To start with, we should give the children a blank board and ask them to draw the squares and number them. Then, give them the freedom to place the ladders and the snakes where they like. This way they could feel empowered to develop the game. They would learn to develop their own rules for the game.' He further suggested that instead of a board we should be using a cloth. This way the game can be packed in a small volume. This led to many such discussions with him regarding the development of the educational television programmes for the SITE.

While working in Ahmedabad, I was visiting the Community Science Centre for teaching children about simple rockets. We made simple rockets using the available fireworks. In order to improve the safety characteris-

tics of the crude rockets, I was looking for a safe propellant for handling by the children. When I met Dhawan, I narrated to him about the model rocket programmes in USA. I also told him about the interest shown by Sarabhai, when NASA had brought some of the model rockets to TERLS. After listening to my ideas regarding the model rockets, he suggested that I should talk to M. R. Kurup (General Manager, Rocket Propellant Plant in VSSC). He also spoke to him and later I discussed some of my ideas with Kurup, he took up the work with keen interest.

Kurup sourced the required propellant from the Defence factory at Aravankadu. A complete project was undertaken at VSSC. The rocket casing was made from extruded plastic and it resembled our RH300 rocket. A simple wire launcher was also developed and the propellant could be ignited by an electrical pulse. A demonstration of the entire system was arranged in TERLS. Dhawan was happy to see the system. The small rocket was named 'Thumbi'. As far as I remember, more than 500 such small rockets were made. These small rockets were safe to be handled by children and the propellant had low ISP and low total impulse. Later V. R. Gowarikar (then Director, VSSC), on my request, sent two engineers with about ten such rockets for demonstration to hearing and speech-impaired children in a school in Bangalore, where my wife was working. These rockets were highly appreciated as an 'educational tool'¹.

Once the INSAT Task Force report was submitted to the Government, a meeting was called by the Planning Commission to discuss about the future plans of ISRO. The time frame was 1974 or early 1975, before the beginning of the SITE. We were surprised that Dhawan had decided to make certain that a large number of senior persons from ISRO were required to be present in the meeting. From ISRO/DoS, Brahma Prakash, Yash Pal, Chitnis, Pant, U. R. Rao, P. R. Pisharoty, Vellodi, T. N. Seshan and I were present in the meeting. The meeting was Chaired by D. P. Dhar, Vice Chairman of the Planning Commission. Mohan Dharia, Minister for Commerce, and Minhas, Member, Planning Commission were also present. A view was expressed by some in the meeting that the awareness created by the television programmes, and advertisements about products and services could lead to dissatisfaction of the people who could not obtain them. This could lead to a revolution. At that time Dhawan countered the argument that such a revolution caused by rising expectations should be always preferred and welcomed compared to revolution caused by rising frustrations.

D. P. Dhar had indicated that the INSAT programme was an ambitious one. The outlays for INSAT satellite could be approved for ISRO, but the outlays for ground segment for television, radio, telecommunications and Meteorology would not be approved by the Government at that time. Dhawan promptly said that it would not be

acceptable to ISRO to have a satellite with no funding provided to the users of the satellite as envisaged. All of us appreciated the stand taken by Dhawan. He told us to continue our work on the INSAT satellites.

I was carrying out various studies regarding the INSAT satellites after completion of the ISRO–MIT (USA) study in June 1970. While all these were technical studies regarding the satellites, the ‘management’ of the satellite project was not addressed adequately. Sarabhai had advocated that the management of the satellite project should be on the lines of the INTELSAT.

The INSAT Task Force under the chairmanship of Menon had thought about the INSAT Authority. Dhawan had different ideas regarding the management of the INSAT programme. Right from the beginning, he had indicated that such a large project would not be part of any ISRO Centre, but that it would be handled directly by DoS. In 1976, it became clear that we were going ahead with the INSAT satellite project and the Advance Publication of Information (API) was filed for registering our frequencies with the International Telecommunications Union (ITU). Thereafter we had many discussions regarding the organization and management of the INSAT satellite system and its utilization. In 1977, I was named as the Project Director, INSAT 1 Space Segment Project and moved to Bangalore from Ahmedabad. It was set up as an independent project of DoS. There was a Project Management Board, but I was required to report directly to Dhawan, who was Secretary, DoS. This was a major responsibility given to me and Dhawan supported me by giving the necessary administrative and financial powers. He was specific about making our large Projects as inter-centre projects. He shared his thoughts clearly on the management of such projects. Under his guidance I was able to organize the INSAT 1 Space Segment Project. He gave a free hand to certain Project Directors and expected results from them. He allowed me to select the necessary persons from various ISRO Centres. I prepared a list of about 70 persons and I was looking to get about 10 persons in consultation with Brahma Prakash, Yash Pal and U. R. Rao. Dhawan clearly told me that he had chosen two persons to work on the project: S. Vasantha, an expert in aeronautics from VSSC and S. Vaidyanathan, Internal Financial Advisor at VSSC. His choice was excellent.

In 1977, after the INSAT 1 project was approved, we had to achieve full frequency coordination with INTELSAT. This was crucial for ensuring the 74° East orbital location for the INSAT satellite. As the coordination was not progressing by correspondence, Dhawan decided that a series of meetings should be held in Washington DC, USA, for achieving coordination with INTELSAT. He assured us full support of the Government. In order to make certain that our coordination goals were achieved, he decided to back us up with his presence in the background. He also ensured that Vellodi (Secretary, Ministry of External Affairs, GoI) and S. M.

Agarwal (Secretary, Ministry of Communications, GoI) were also present. Dhawan, Vellodi and Agarwal were present in their hotel rooms when negotiations with INTELSAT were progressing and were kept fully in the picture. T. V. Srirangan (Wireless Advisor) was leading the team. Jai Singh and I were representing ISRO. Rawal and John Francis were from the Ministry of Communications, GoI. When it became known to INTELSAT that the three most important persons concerned and capable of taking the necessary decisions on behalf of GoI were present in Washington DC, the negotiations progressed smoothly and within three days we achieved the necessary coordination.

In the INSAT study carried out jointly by ISRO and MIT in 1970, we specifically identified the need for developing a dedicated control facility for the INSAT satellites. We identified that such a facility should be located near the place where satellite development would be taking place. At that time, we identified Thiruvananthapuram as the site. By 1973–74, it was clear that the satellite development activities would take place in and around Bangalore. The ISRO Headquarters and DoS were also in the same city. The logical step then was to locate the INSAT-1 Space Segment Project Office in Bangalore. When we had gone ahead with the filing of API with the International Telecommunications Union for the frequencies to be used for the INSAT satellites, it was clear that we would have to use the frequencies in the C-band for the Telemetry, Tracking and Command (TT&C) System. We also had to plan for locating the INSAT-1 Master Control Facility (MCF) in the vicinity of Bangalore².

The first-cut computations indicated that if we wanted to locate our control Earth stations such that no other country could object to our radiating high radio frequency power in the C-band for commanding our satellite, we would have to locate the Earth station such that it was to be at least 500 km away from the nearest location of the ground microwave communication system in that country. Thus, we had to locate the Earth station about 500 km away from Jaffna, Sri Lanka. We also wanted the location to be reachable within a few hours from Bangalore and at a distance less than 200 km. The INSAT-1 Space Segment Project Office was set up in Bangalore by November 1977 and search for the INSAT-1 MCF location started in February 1978. After a long search, we short-listed two places: Hassan in Karnataka and Anantapur in Andhra Pradesh. Considering the availability of Government land and the scope for future expansion, we finally chose Hassan. I was initially looking for about 10 acres of land. The land offered by the Karnataka Government was about 30 acres. The DoS administration was more concerned about the cost of fencing, land development, water requirements and maintenance. I wanted the entire land to be acquired, and Dhawan agreed with me and advised us to proceed with it. This site was selected and work on planning for the building and other infrastructure

was taken up immediately. It was decided that while the equipment for the Satellite Control Centre would be imported as part of the deliverables by the spacecraft contractor, the necessary satellite control Earth stations and power systems would be provided by DoS. A new project, INSAT Satellite Control Earth Stations (ISCES), was taken up by SAC.

I had to present the financial outlay at a meeting of the Space Commission. Apart from plans of the building, the architect had prepared a good model and I was supposed to use that. I knew that once the satellite became operational, we would not have a chance to expand the building. Therefore, we had prepared the full plan of the building. Many of my colleagues advised me to be prepared for massive cuts and accept it without too much of a discussion. The meeting was chaired by Dhawan and attended by Brahma Prakash and Manmohan Singh (Secretary, Ministry of Finance, GoI and Member (Finance), Space Commission). After the presentation was over, Manmohan Singh asked me: 'Is this building going to be sufficient for the next few years?' I said yes. There was not much discussion and the proposals were approved without any cut².

Immediately after the launch of the INSAT-1A satellite in April 1982, there were problems with it. It had reached the geosynchronous orbit and it completely failed in less than six months. Throughout that time, Dhawan had fully supported us. The INSAT-1B satellite was launched in 1983 using the NASA Space Shuttle orbiter Challenger. The satellite had some initial problems, but it functioned well beyond its operational design life of seven years.

The SLV-3 project was initiated during the time Sarabhai was the Chairman of ISRO. He had already foreseen the need for a launch vehicle capable of launching satellites in geosynchronous orbits. The need for a smaller versatile launch vehicle capable of launching satellites in polar sun synchronous orbits was felt once we started using data from remote-sensing satellites. Such a vehicle could also inject small communication satellites in geosynchronous transfer orbits. During the time Dhawan was the Chairman of ISRO, definition and design of augmented satellite launch vehicle (ASLV) and polar satellite launch vehicle (PSLV) had taken place. These vehicles were flown after Dhawan retired. The first two flights of ASLV in 1987 and 1988 respectively were failures. The next two flights ASLV D3 in 1992 and ASLV D4 in 1994 were successful. The first flight of PSLV on 20 September 1993 was a failure, but having understood the reasons for it we were able to correct the necessary hardware. The second flight of PSLV on 15 October 1994 was successful. These flight failures and successes resulted in our getting large amounts of data needed for future vehicles. Both the successful flights of the ASLV D4 and PSLV D2 took place in a short time when I was the Director of VSSC. So far, a total 50 flights of PSLV have taken place and out of which 48 were successful.

The PSLV has been a versatile vehicle. It has been used for the polar orbit, geosynchronous transfer orbit, lunar orbit and Mars Orbiter Mission.

The development of the pressure fed liquid propulsion technology was started during Sarabhai's time, but the liquid propulsion technology was firmly established during Dhawan's time. An agreement with Société d'Etudes pour la Propulsion par Reaction or Jet Propulsion Studies Company France (SEP), France was signed in 1974. According to it, a large number of our engineers will work with SEP and contribute from India to the development of the Viking engine. This arrangement resulted in our acquisition of the necessary pump-fed technology for liquid propulsion vehicles. The second stages of PSLV and GSLV use the VIKAS engine. The arrangement of using the ISRO workforce for the necessary technology transfer was unique. According to this arrangement, ISRO also manufactured a large number of high-quality pressure transducers and supplied them to SEP³.

During the time Dhawan was the Chairman of ISRO, scientific cooperation between ISRO and DLR of Germany as well as between ISRO and CNES, France developed rapidly. While the relationship with NASA was cordial during the SITE, after its conclusion the relationship became more commercial and contractual in nature.

Dhawan wholeheartedly supported the Ariane Passenger Payload Experiment (APPLE) satellite project. This project provided a unique opportunity of free flight on the third experimental flight of the Ariane vehicle. We were able to use the fourth stage of SLV-3 vehicle as the apogee boost motor for the APPLE satellite. This resulted in successful development of our first indigenous geosynchronous communication satellite. He also fully supported the Satellite Telecommunications Experimental Project (STEP). In this project we were able to use the Symphonie satellite developed jointly by France and Germany. During the SITE we used a satellite in our national television network. The STEP project paved the way for integration and utilization of space communications in our domestic telecommunications. We were able to use the satellite in our domestic telecommunications overcoming the problems of delays in the Subscriber Trunk Dialling (STD) as well as echo cancellation. Both these projects resulted in strengthening our scientific relationships with CNES, France; DLR, Germany; the European Space Agency (ESA) and aerospace industry in Europe.

While the first scientific satellite of ISRO, Aryabhata was being made, work on the designing of the second satellite, Bhaskara had started. This was to be the satellite with remote-sensing capability. Dhawan was keenly interested in developments in the field of Earth observations for meteorological purposes and remote sensing of Earth resources. The initial development work regarding remote sensing had begun in ISRO under the leadership of Pisharoty. Historically remote sensing was part of

aerial surveys and aerial photography. This was the function taken up by the Survey of India.

The National Remote Sensing Agency (NRSA) was established as a registered society on 2 September 1974 by the Department of Science and Technology, GoI. Many of us were unhappy about this development. However Dhawan fully supported the formation of NRSA and K. R. Rao was its first Director. NRSA started functioning in Secunderabad, Andhra Pradesh from middle of April 1975. The administrative control of NRSA was transferred later to DoS in the early 1980s. With the growth of indigenous efforts in space-borne remote sensing, NRSA played a major role in the ground segment under the Indian Remote Sensing Programme. Now NRSA has been transformed as the National Remote Sensing Centre (NRSC); a Centre of ISRO. The Indian Institute of Remote Sensing, Dehradun has now developed as a premier institution for education in remote sensing. Dhawan had taken the lead to form the National Natural Resources Management System (NNRMS).

In many of the discussions with Dhawan, it became clear to us that he was much concerned about the impact of our activities on the environment whenever any plans for new buildings were discussed. He was concerned about the environment at Sriharikota Island, particularly after seeing the impact of the cyclone in 1977. He was concerned about the situation of the Yenadi population there. Dhawan gave clear directions about the environmental conservation for the land at Mahendragiri, where we had developed the liquid propulsion testing facilities. When we acquired the land for the INSAT-1 Master Control Facility at Hassan, there was just one palm tree. In our discussions regarding planting trees on this land, S. D. Sharma, the architect and I came up with a plan. We developed a master plan for the buildings and technical activities. Taking that into account, we started planting trees even before the construction activities were taken up. I also indicated to Dhawan that we will make the land there full of trees, and that in all our remote sensing images it will stand out as the greenest spot in that area. By the time we became operational, Dhawan appreciated the way we developed greenery and the Housing Colony in Hassan.

Earlier we did not have 'standard atmosphere' defined for TERLS or SHAR. For quite some time we were using the NASA standard atmosphere developed for the Wallops Island, VA, USA. Dhawan insisted on our defining and developing the standard atmosphere model for TERLS and SHAR. He explained to us the influence of the land-ocean-atmosphere interfaces on the surface wind conditions. He also discussed the effects of trees and hills nearby on the winds. It was fascinating and I was reminded of listening to Sarabhai explaining to us about the solar wind.

Dhawan was highly respected wherever he visited and I had seen this first hand. Whenever we visited any indus-

try in India, we would come across many scientists, engineers and managers who were students at IISc. As soon as they recognized Dhawan, they would come forward to pay their respects. After that our work would proceed rapidly. He recognized that we had to have full support and participation of the industry in our efforts. The systems for industrial participation developed for the SLV-3 project and the SITE during his time are responsible for ISRO being able to deliver such a large number of operational space systems and services.

At Dhawan's insistence a large number of small, 3-in aperture refracting telescopes were developed and produced at the Central Scientific Instruments Organization, Chandigarh. These telescopes were distributed to many schools. I was able to get four such telescopes for the Central Schools supported by the DoS at Ahmedabad, Hassan and Bangalore.

Any discussion with Dhawan used to be intellectually satisfying. His insights into the design principles were guiding factors for us. After Dhawan had retired as the Chairman of ISRO, he was once visiting SAC. I requested him to give us a lecture on his recent work on the subject of 'bird flight'. He agreed as we had the right kind of film projection equipment and an auditorium with a large screen. He showed in the lecture the compilation of the moving pictures of birds in flight. It was not only intellectual, but also a fantastic visual treat. After listening to his lecture, I read the book; it inspired me to study the subject of remotely piloted vehicles.

In the monograph *Bird Flight* Dhawan states: 'Since time immemorial man has been fascinated and intrigued by the beauty, grace and intricacies of the bird flights. There is perfect harmony of form and function. It is equally exhilarating to attempt to understand how the physiology and performance of birds are related to scientific principles.'⁴

A. P. J. Abdul Kalam in his book *Wings of fire* writes about Dhawan as follows: 'Prof. Dhawan was a man with mission. He would effortlessly pull together all the loose ends to make work move smoothly. At VSSC the review meetings presided by Prof. Dhawan used to be considered major events. He was a true captain of ISRO ship – a commander, navigator, housekeeper, all rolled into one. Yet he never pretended to know more than he did. Instead; when something appeared ambiguous, he would ask questions and discuss his doubts frankly.'⁵

I was impressed by the meticulous way Dhawan used to prepare for any meeting. He would come fully prepared for the discussion topics. In the very first budget review meeting held in 1974, he asked us to follow the zero-base budgeting (ZBB) principles. That resulted in setting our priorities and discontinuation of many small Technology Development Projects in ISRO.

When we were preparing the budget for the INSAT-1 Space Segment Project, it became clear that the outlays required were very large. The inclusion of these in the

ISRO budget could have skewed it. He opined that the outlays for the operational systems should be separately budgeted and that they should not be part of the science and technology-related budget. This was accepted by the Planning Commission and the Finance Ministry. For the INSAT-1 project, we had a separate budget code and that was part of the Transport and Communications Sector. I wish we had followed that system in the later projects.

In one of the meetings in Delhi, I did not agree with Dhawan on a point. Many members from other ministries asked me how I could disagree with the Chairman of ISRO? I explained that we had the freedom to express our opinions and Dhawan did not mind that. Once he had taken the decision, he had made up his mind, we would accept that and take actions necessary according to the organizational discipline.

Abdul Kalam also wrote about Dhawan in his book; *Wings of Fire*: 'His mind used to be very firm once it had been decided on any issue. But before taking a decision; it used to be like clay, open to impressions until the final moulding. Then the decisions would be popped into the potter's oven for glazing; never failing to emerge hard and tough, resistant and enduring.'⁵

Dhawan was concerned about the problems faced by the working people everywhere. In most organizations, the management generally viewed labour union leaders as adversaries. Dhawan recognized that the workers are partners in the nation-building endeavour. He wanted to have a proper dialogue with the people working in ISRO or DoS. He had clear views about this⁶: 'By the time India became free, you had the Trade Union Act, which was a part of the Constitution of India. Constitution gave the right to freedom of association. So, the formation of a trade union was looked down upon by the intellectuals and it is still so to some extent. Of course, they have gone through complete ups and downs too. They became bottlenecks of a kind in the name of freedom of association. In any case, the principle remained that in VSSC there were a large number of trade unions, both technical as well as for the clerical staff, and they had rivalries between them. That's not how the Government of India runs. Government procedure ends with the administrative procedures at the Cabinet Secretary. He is the boss of all the representative guardians and he is the Advisor to the Cabinet. So, I went up to Delhi and saw him. He just happened to be Rao Saheb, an extraordinary man, you know. He became a member of the Space Commission. Incidentally, there was another interesting thing. In the Government of India rules of business, in any meeting – I don't know whether it still exists or not, but that is what I learnt at Delhi – any meeting of Secretaries or group of people from the Government where a Cabinet Secretary is present, he is automatically the Chairman of the meeting. So, I had gone to ask him about this Joint Consultative Machinery that I must set up. Scientific departments don't have any. They are running around. I said, "Look at

what P&T is doing, what all the other departments are doing. This is not what we are going to do. DOS and ISRO must have a formal standing group where the employees are present in their own right. And we must set up a system in which we can talk regularly to each other. Problems will come and they will help solve those problems." So, he said, "Very good idea. You go ahead and set it out." Seshan worked very hard at the job. I have forgotten the names of the two workmen from Thumba ... Ramdas was one. There was another chap who was ... very smart. They worked hard with Seshan, and Seshan of course used to lose his temper every now and then. On the other hand, he was bottled up to see that this was a very important thing to do. So, we set up the Joint Consultative Machinery (JCM) where the requirement was that the Chairman, ISRO, has to preside. No one else will do.'

Dhawan introduced systematic reviews for performance appraisals in ISRO. He involved academic professors as well as experts from industries as external members in the review process. This made the process highly transparent and it had started and is continued even now.

Dhawan's views on the subject of reviews of personnel, were⁶: 'So, it was essential for ISRO to develop its own methodology. We couldn't copy anything from BARC, except the fact that we have to review and then there was this principle that people have to be reviewed. The principle was in the pattern rather than the implementation. That when a person is reviewed, he or she can be promoted without having a vacancy being created any longer. In fact, I made a little arithmetic. This I had done in IISc earlier. And the principle is simply that a person is rigorously – that is important – evaluated and the evaluation has to be done by not only within your own organisation. There was a little tremor about that in ISRO. But as you look back on it, you can see, I think the ball has gone the full circle, people from academic and the world of research outside ISRO are all in our committees, whether they are committees of the staff, technical projects or the rest of it. A sampling of those constitutes a very good peer group for reviewing. It costs a great deal of difficulty. I know even now it is a great deal of difficulty to collect such people, people are busy, good men particularly. But there was no other way to go. The Space Commission approved it. In fact, when we went up to the government and proposed this, it was objected to that this whole system of appointment and selection should be done by the Union Public Service Commission (UPSC). UPSC objected to it and a question came before Parliament and I had to write an answer which the Prime Minister replied. The PM used to ask K. C. Pant who was not Minister for Space but was assisting the PM in all matters dealing with Space. We had many discussions with him and he reported that we would remain out of UPSC. Then quickly other departments also followed.'

U. R. Rao, who succeeded Satish Dhawan in 1984 writes about the management systems developed by the latter in his book, *India's Rise as a Space Power* – ‘With the approval of Mrs. Gandhi, a high level INSAT coordination committee ICC was created which included all the Secretaries of the concerned departments under the chairmanship of Prof. Dhawan, Secretary Department of Space – DoS. DoS as the nodal agency had complete responsibility for the space segment. The formation of such a unique inter agency and inter departmental committee of all the major stakeholders to oversee the INSAT program implementation from the design of the spacecraft to the establishment of ground infrastructure and final utilization was a significant departure from the past. The new structure not only ensured compatibility and coordination between various activities and different departments, thus ensuring the total success of the program; but also became a shining example worthy of emulation for similar multiagency programs that were launched in the future. ...Encouraged by the success of ICC, Prof. Dhawan had called a meeting of all user departments such as agriculture, forestry, water resources, mines and minerals, environment, ocean development, meteorology and science and technology at Hyderabad in 1980 with a view to develop an orchestrated strategy for evolving a national remote sensing program. This had culminated in the decision to constitute the National Natural Resources Management System (NNRMS) involving the representatives of all the concerned user departments with the department of space acting as the nodal agency. Prof. Dhawan was responsible for building a strong foundation by promoting a number of experimental programs carefully chosen to help in the advancement of our space program to achieve the stated goals. He brought in a new culture of working together on inter-centre projects without compromising on the accountability and responsibility of each centre. He established new organizational structures both within and outside the space department to ensure the ultimate utilization of our space capability, cutting across the traditional boundaries that existed between different ministries. He instituted rigorous reviews of our space program, enabling the program to develop cost, quality and schedule consciousness, which is a rare commodity in India. He brought in a new culture of management by blending the horizontal management style of Vikram with the traditional vertical management strategy, which enabled ISRO to carry out a given task with authority without losing the flexibility of getting fresh inputs and ideas. Above all, he conducted himself with such dignity and farsightedness that he became an outstanding example for all of his colleagues.’⁷

Roddam Narasimha writes about the management style of Dhawan in his obituary on Dhawan³: ‘The principles that Dhawan formulated and applied (but, characteristically never stated) in running the country’s space program can be easily inferred from the way he operat-

ed.....He had supreme confidence in the Indian engineers and scientists, even when they did not have degrees from IITs or foreign universities. ...His methods of management at institute were very different from those he developed for ISRO: he fully understood that different kinds of organizations needed different cultures.... But what specially distinguished Dhawan from many other eminent scientists and engineers were his extraordinary qualities as a leader and a human being, his great personal charm, and his keen social conscience.’

When we were conducting the SITE, we wanted to perform a technical exercise, which would be useful for the future of the INSAT system. The idea was to receive the instructional TV signals from the ATS-6 satellite and broadcast the same using a low power TV Transmitter (LPT). We had thought that we could do this as a controlled exercise involving our own housing colony at the Sriharikota Island. The receiving system, a solid-state low power TV transmitter and the necessary antenna were developed at SAC for this purpose. Dhawan enthusiastically supported this idea as the community on the Sriharikota island was quite isolated. We had successfully carried out the exercise.

Later when INSAT system became operational and LPTs were being deployed, we realized that Hassan would not qualify for such an LPT to be installed there since its population was below 100,000. We requested Dhawan to make a special request and get such systems installed at Hassan. He agreed with our request and made a special request for Hassan and SHAR, which GoI accepted.

Arvind Vellodi⁸ writes about Dhawan in his book *Around the world in eighty years*. ‘He was the fittest person to take on Sarabhai’s mantle and he gave his all to further the development of space technology in India. ... If Vikram Sarabhai was the father of space research in India, the credit for taking the technology forward into the area of advanced launch vehicles and the associated technology; culminating in the Chandrayaan mission must go fully to the vision and dedication of Satish Dhawan. ...Prof. Dhawan was a wonderful human being – one of the best I have ever met – so very gentle and placid.’

After I moved to Bangalore; Dhawan introduced me to Amulya Reddy at IISc, who had a programme called ASTRA. I had many discussions with him regarding energy systems – Solar, wind and biogas for rural areas as well as sun-dried bricks as construction material. Since we had established the INSAT Master Control Facility at Hassan, essentially a rural town, I was looking forward to taking up development work which would be useful in improving life in rural areas. After studying the region, we had taken up development of a simple vertical turbine – the modified Savonius rotor – windmill, not for generation of electricity but for lifting water from a surface well for delivery to a tank at a height of 4 m.

The design was simple and wind-mill components could be manufactured in a small workshop. I had a detailed discussion with Dhawan regarding the safety of the structure. After developing and installing it in Mulabagalu, a village about 90 km away from Bangalore; I invited Dhawan to see it in operation. He made it a point to invite U. R. Rao, Chitnis and many other scientists from the ISRO Headquarters. He had a good interaction with the farmers there. He encouraged G. R. Hatwar; Mechanical Engineer at MCF to refine the design and make a proper report. That report was made and technology was transferred to three entities at no cost as decided by Dhawan.

In the lecture 'Whither Space & Astronautics' delivered by Dhawan at the Astronautical Society of India; Bangalore on 6 September 1996, he concluded by asking a relevant question – 'Collectively can mankind enhance its capabilities to evolve a civilization on Earth which is more humane, sensitive and harmonious not only to humans but to all forms of life? If yes. Then – we go into Space to understand and resolve problems of life on Earth.' I am certain that we will be able to say confidently 'yes', because we have learnt from him to be socially conscious.

Let me conclude on a personal note. During my visits to Bangalore from Ahmedabad for work, many a times I used to stay at the guest house of IISc. Compared to Ahmedabad, Bangalore as a city was lush green. The residence of Dhawan was just next to the guest house and I met his wife Nalini many a times during my walks on the

campus. I used to admire the beautiful gardens on the campus and I remember discussing with her about the lifespan of various flowering trees. After I moved to Bangalore, I was trying to get school admission for my daughters. Since we had moved to Bangalore in November 1977, getting admission in the middle of the academic year was difficult. When I mentioned this to Mrs Dhawan, she immediately offered to help. She accompanied us Bishop Cotton Girls School. Her presence and help made it possible to get admission there.

I am certain that almost all ISRO colleagues will always remember Satish Dhawan as a helpful, gentle, warm and pleasant person.

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doi: 10.18520/cs/v119/i9/1461-1468