A. P. J. Abdul Kalam (1931–2015)

Avul Pakir Jainulabdeen Abdul Kalam, a distinguished aerospace technologist who led the development of the country's first satellite launch vehicle as well as the first indigenous operational missiles, then went on to become first the Scientific Adviser to the Defence Minister and later the Principal Scientific Adviser to the Government of India, and finally entered national politics as the 11th President of the Republic, passed away on 27 July 2015 as he had just begun to address students at the Indian Institute of Management at Shillong. His death has taken away one of the most remarkable and charismatic figures, not only in Indian science and technology but also in Government, politics and public life.

Kalam was born in Rameswaram (Tamil Nadu) on 15 October 1931 to Jainulabdeen and Ashiamma, parents of modest means whose income Kalam supported by selling newspapers when he was a young boy. After schooling in the neighbourhood, he went to Tiruchirappalli in 1950, and obtained a B Sc in Physics from St Joseph's College in 1954. He found physics was not his cup of tea, and furthermore jobs for physicists were scarce. So during the next three years he studied aeronautical engineering at the Madras Institute of Technology, where he obtained a Diploma (equivalent to a Bachelor's degree, DMIT), and went to HAL Bangalore for shop-floor training. He wanted to be a pilot, but just missed being selected by IAF. However he got a position at the Directorate of Technical Development and Production (DTD&P (Air)) at Delhi in 1955, and three years later was posted to the Aeronautical Development Establishment (ADE) at Bangalore. Here he designed and operated the country's first ground effect machine or hovercraft, which attracted a great deal of technical and political attention as it could be a useful transport vehicle in an otherwise difficult terrain like the Rann of Kutch or any river delta. Although a flying prototype won excited praise from Defence Minister V. K. Krishna Menon, the project was inexplicably shelved – it was Kalam's first experience with the harsh realities of public decision-making. Fortunately M. G. K. Menon (Director of TIFR at the time), visiting ADE, was quick to recognize Kalam's unusual abilities, drive and passion; this led to Vikram Sarabhai (who was then heading the Indian National Committee for Space Research) hiring Kalam in 1964 as a Rocket Engineer at the Thumba Equatorial Rocket Launching Station (TERLS) near Thiruvananthapuram (Trivandrum). Here Kalam led a series of programmes including fibre-reinforced plastic technology development, and was Chief Designer for a Rocket-Assisted Take-Off system for aircraft. At that time the programme conceived by Sarabhai was still in its initial stages; its assets, including Kalam and some of his sounding rockets and equipment, were housed in an ancient church building that had been generously handed over by the Bishop of Trivandrum for use in Sarabhai's projects. During some of the visits I made there at that time, both guests and hosts, including Kalam and his colleagues, stayed at what was called the Rocket Club in the City and ate at the Railway Station: Kalam was a vegetarian, spoke only Tamil and English and was already a popular figure among the engineers working there, who affectionately called him 'Kalam Iyer'.

Kalam with a Mysore turban.

In 1963 Kalam was sent to the US for a six-month training programme on sounding rocket launching techniques. Years later the amusing suggestion was made that Kalam had learnt his space technology during that visit, but what attracted Kalam most was a painting at the Wallops Island facility, depicting Tipu Sultan's soldiers using rockets against the British during the 18th century Anglo-Mysore wars (– incidentally a subject in which both of us have had a long-standing shared interest).

After the successful launches of sounding rockets at TERLS, Sarabhai began conceptualizing an Indian Satellite Launch Vehicle (SLV). As a space programme began getting formulated and the Space Science and Technology Centre (later named VSSC after Vikram Sarabhai) came up at Veli Hill, I got to work with Kalam more closely. Among these projects were one on rarefied gas dynamics (with S. M. Deshpande), developing Monte Carlo codes for solving the Boltzmann equation on problems such as determination of satellite drag, and another on high-velocity flows (with N. M. Reddy) on heat transfer on nose cones and in nozzles. This and a variety of technical reviews took some of us to Trivandrum every now and then. Meanwhile in 1972, following the untimely passing away of Vikram Sarabhai the previous year when he was only 52, Satish Dhawan had taken over as Chairman of a reorganized ISRO and heading the newly established Space Commission and Department of Space.

The development of an Indian SLV that could put a small 40 kg class Indian satellite into low-earth orbit quickly became the most ambitious project on the ISRO agenda. Kalam was appointed Project Manager of the SLV-3 mission (as the vehicle got to be designated). This was a somewhat surprising appointment, and there were members of the scientific community who were skeptical about the project's chances of success, both within and outside ISRO, and the adequacy of Kalam for the task. However Dhawan had seen enough of Kalam in operation to conclude that he was one person who had delivered on what he had promised, because of his remarkable ability to work in teams and lead them. When the first launch failed in 1979 the fears of the pessimists seemed confirmed. However the second one launched a year later succeeded, and placed a 35 kg *Rohini* satellite in a 400 km orbit. The story of what happened immediately after these two events is well known: after the failure, Kalam wanted to resign, but Dhawan, who persuaded him to stay, faced the press answering the inevitable awkward questions. After a long internal meeting analysing the causes of the failure, Kalam formally took responsibility for it, an admission that was followed by com-

plete silence in the meeting, till Dhawan concluded it saying 'I am going to put Kalam in orbit!'. After the success of the second launch Dhawan chose to remain in the background and asked Kalam to go talk to the press.

In many ways the SLV-3 was a turning point in the history of the Indian space programme. Success changed perceptions, within ISRO and outside, about what Indian S&T could do. The engineers who had taken part in the project and Satish Dhawan, Brahm Prakash (Director of VSSC), and Kalam himself saw the success as confirmation of the validity of the elaborate technology management system that had been set up to monitor the project. The system worked through a variety of technical reviews by teams that included experts from outside, methods for putting together teams of scientists from different divisions within VSSC and other ISRO centres, and a variety of coordination mechanisms for ensuring smooth progress in the project. Failure of the first launch began to be seen as the first step to success. The outlook of the organization as a whole about their own capabilities became much more confident, and made it possible for them to dream of bigger enterprises. In short, what later became famous as 'ISRO culture' was born.

As SLV development was completed, Kalam went on to become Director of ISRO Launch Vehicles/Systems and moved to Headquarters in Bangalore. With Kalam in Bangalore interaction was closer and more frequent, and with IISc scientists it was facilitated by a Space Technology Cell on the campus sponsored by ISRO. Using this association with IISc, Kalam wanted to write a full account of the SLV-3 project, and work towards a Ph D. On the latter he asked me whether I would agree to be his guide, but I told him in all sincerity that a man like him did not need a Ph D. Any way Kalam was restless with paper work, and was itching for projects that led to new hardware. This came when DRDO sought Kalam from ISRO to head the Defence Research and Development Laboratories (DRDL) at Hyderabad, to take forward a nascent missile development programme that had till then been making rather slow progress. Dhawan reluctantly agreed to let him go, and with some proactive encouragement from Defence Minister R. Venkataraman, Kalam and V. S. Arunachalm (Scientific Adviser at the time) made ambitious plans for a 'quiver' of five missiles. This must have been an exciting prospect for Kalam, for he now had a whole programme to implement as Chief Executive Officer of an Integrated Guided Missile Development project, which included *Prithvi*, *Akash*, *Trishul*, *Nag* and *Agni*. As with the SLV-3 the first flights of *Prithvi* and *Agni* were both failures, and revived once again the generally pessimistic view that still prevailed in spite of the SLV-3. But *Prithvi* was quickly fixed and had a successful launch only a few weeks later. *Agni* took a little longer but it also succeeded. Kalam had confirmed the reputation that he already had acquired regarding his ability to deliver on what had been promised.

Kalam and his 'guru' Satish Dhawan.

The Kalam style of technology management and leadership had now become very clear. At DRDL he refused to occupy a spacious Director's bungalow, preferring a room in the Guest House; and would talk shop with anybody he met on after-dinner walks, sometimes past midnight. He made it clear that the project was more important than any member of the team – including himself. He had set up a nationwide network of scientists and engineers who could help tackle the challenges faced by any project. If a bright young man somewhere could help solve his problem, Kalam himself would go there to meet him. Kalam's personal charm and humility, his obvious sincerity and commitment to the project and its goals, and his track record of success made it very difficult for anybody who had been asked for help to say No. Sivaraj Ramaseshan used to say that Kalam could milk a tiger [or tigress?]! I recall vividly an instance where a facility abroad that had promised to make some essential high-speed tests for him withdrew the offer at the last minute, upsetting project schedules. Kalam by then had a healthy respect for what software (in the form of computational fluid dynamics, CFD) could do for hardware, and asked me at that time (around 1988/89?) whether we would take on that task at NAL (which I was then heading), with the help of scientists from IISc and DRDL. The attraction of NAL was that my NAL colleague U. N. Sinha had already designed and built some parallel computers which at that time were the most powerful available in the country. With S. M. Deshpande from IISc, a few scientists from NAL and a few more from DRDL worked round the clock, and came up with an answer in about three months. That answer was enough for Kalam to make his decision, and he immediately cleared the launch. It turned out to be successful and he was delighted (and incidentally confirmed the CFD estimate). When he came shortly thereafter to talk about the project at NAL, the auditorium was packed and overflowing, not only with NAL scientists but many other staff as well.

With *Prithvi* entering production the missile programme was gradually maturing, and Kalam became 'the Missile Man' to the media. In 1992 Kalam was

appointed Scientific Adviser to the Defence Minister and Director General of DRDO. The aeronautical community was then very busy with the LCA programme, and there were long discussions with Kalam about some of the challenges. Three of the major ones were being tackled by National Teams, composed of scientists and engineers from the Defence labs, NAL and many academic institutions. Kalam was at first rather skeptical about how the National Teams would work out, but as the LCA carbon fibre wings were manufactured and tested, and the flight control system for the unstable LCA had begun to work very well on flight simulators, Kalam seemed converted to the idea.

To academic groups that had contributed significantly to his projects, Kalam gave considerable support. For example IISc could, with such support, set up a joint Advanced Technology Programme and a Centre of Excellence in CFD, and get substantial grants for the High Speed Aerodynamics Laboratory.

After I retired from NAL in 1993, my direct involvement in the LCA diminished, but our paths crossed again on Kalam's 'India 2020' project. This was done through the Technology Information Forecasting and Assessment Council (TIFAC), of which Kalam was Chairman. As a member of the Project Group, I could see at close quarters that Kalam's plans and thinking were not limited to rockets, aircraft and strategic industries, but covered the whole spectrum, ranging from food and agriculture, health, education and infrastructure to materials, chemicals and manufacturing. But his approach was the same: what *projects* – doable, affordable – will achieve his goal of development by 2020? His philosophy seems to have been that absence of projects was a sign of woolly thinking at the top, and so project-speak became his third language. Thus specific projects were formulated in 17 areas, and 25 reports were prepared by the Group. A summary of all this work appeared in the very readable book *India 2020: A Vision for the New Millennium*, written by Kalam along with Y. S. Rajan. It starts with a dedication to a 10-year old girl who, in answer to Kalam's question 'What is your ambition?', replied 'I want to live in a developed India'. So the theme was development – all round and inclusive. The logic of Kalam's thinking starts with Amartya Sen and is inspired by Buddha, Mahatma Gandhi, Jawaharlal Nehru and others – all Indian minds.

Apart from detailed discussions of technical and economic issues, Kalam was keenly sensitive to the fact that most Indians are pessimistic (if not cynical) about the possible benefits of big programmes. He was however convinced (from his own experience in ISRO and DRDO) that, given the right leadership, the country was fully capable of taking on ambitious goals – such as being a developed country by 2020. He realized however that such a national mission needs a change in the general mindset, and that can only happen with a new generation. It was therefore extremely important that young people today must be given the confidence to think that they *can* build a better future for themselves and their nation. It was perhaps this thought-process that made Kalam so keen to talk with the young all across the nation. He had always been an informal leader, and with young people he became very open and quickly mastered the art of giving answers that were at one and the same time simple, amusing, convincing and practical, urging them all the time to dream and to chase their dreams.

If he could 'ignite' young people's minds there would be an army of project assistants 'more powerful than thermonuclear energy', he said. And young people loved him for those informal interactions and for the opportunity they had to ask the President of the Republic any question they could frame. Kalam in fact became a phenomenally successful communicator, and spoke with equal ease to young and old, to rich and poor, to the weak and the powerful, to the illiterate and the scholarly, and to a peasant or a president. This Kalam charm was enhanced by an austere life-style, an enormous capacity for hard work and a strong commitment to use of technology for the benefit of man (e.g. using carbon fibre for polio calipers and designing and making inexpensive stents – he was a frugal innovator long before those words became popular). And there was his interest in the arts, in particular a fascination with the veena and Karnatak music, that gave his personality an almost universal appeal across the nation. And he had the classical Indic ability to condense a whole way of thinking or doing into some pithy sutra, sukti or maxim, even as he quoted from the *Thirukkural*, the *Gita*, the *Koran* and the *Bible*.

He did not lack critics. At almost every stage of his life there were people who doubted his abilities. He was very loyal to the institutions he worked for – so much so that outsiders sometimes felt he did not give them enough credit. I hope my colleagues in science will pardon me if I say that the bulk of the scientific community was often confused by him. A CV of his made in the early 80s lists all the technology projects that he had handled successfully but there was no list of publications. To a community that is used, understandably, to assessing colleagues in the profession by the papers they write, the question was how to evaluate a person often called scientist but without a publication record. This confusion manifested itself when his name came up for election to the academies of science. On one occasion I remember that although the engineers had recommended his election, the Council had a long and inconclusive discussion about it. Satish Dhawan, who had sat silently through all of that discussion, was finally asked by the Chairman why he had not said a word and what his view was. Dhawan just said 'The old man [C. V. Raman] would have taken him'. That ended the discussion and Kalam was elected.

Kalam himself made a clear distinction between science and technology, and between research and development. Indeed, he 'cautioned [his] team against becoming scientists' – to discourage open-ended thinking and emphasize the discipline that is essential for a project to deliver on time and within budget. This is perhaps understandable in a developing country where a space programme had to justify itself (almost endlessly), and was forced to be risk-averse if it had to be successful and acceptable. In retrospect, I am impressed by the unanimity of judgement of most leading scientists in India of the time – M. G. K. Menon, Vikram Sarabhai, Raja Ramanna and Satish Dhawan – who often saw the spark in Kalam right from the time he had only just graduated with a DMIT from Madras, whereas some of his colleagues could not – even after years of working together. His later record fully justified the confidence that these perceptive leaders had reposed in him from the very beginning, in part because of his natural ability to work with and inspire small or large teams. When Kalam was picked as the Project Director for the

SLV-3 by Dhawan some of his scientist friends wrote or spoke to him expressing their reservations. Remarkably however, neither Dhawan nor Brahm Prakash had any doubts that they had made the best choice for the job. I should add to that list Atal Bihari Vajpayee, who saw that another brahmachari like himself, who helped weaponize a nuclear device and could easily have passed for just a technology freak, would in fact make a wonderful President for the Republic – one who knew that strength respects strength but thought of missiles as 'weapons of peace'.

The vast majority of the people of India, from every walk of life, have however been mesmerized by the tangible achievements, charisma, simplicity, humanity and dedication that characterized Kalam, and they went on to shower their affection, love and respect on him, irrespective of caste, religion, gender or political persuasion. His autobiography *Wings of Fire* (1999) became an inspiring national classic. He was honoured widely and received the *Bharat Ratna* in 1997 when he was still Scientific Adviser to the Defence Minister. He won the von Karman Wings Award of the Aerospace History Society in 2009 at the California Institute of Technology. The citation called him 'an international leader and humanitarian who is honoured and admired by the next generation'. (Characteristically, the cash award he received at the time was donated by Kalam to Caltech, for a Kalam Prize to be awarded every year to the best student in the Master's course.) He also won the Von Braun Award for excellence in management and leadership of space projects from the (US) National Space Society.

In summary, he was an outstanding technological manager and leader, but he was also much more than that: a sensitive human being with a big and soft heart, a karma yogi with a desi genius for understanding his countrymen, a rock star, a great Indian citizen and a true patriot – all in one.

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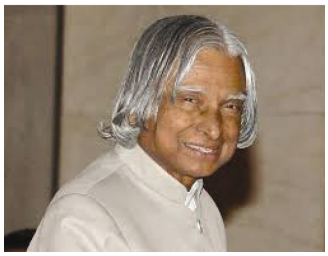

A. P. J. Abdul Kalam was born in 1931 in the fishing island of Rameshwaram, Tamil Nadu, India. His parents were from a middle-class family with high ethical standards. He went to vernacular schools nearby. He did his collegiate education in one of the good colleges in Tamil Nadu, St Joseph's College in Tiruchirappalli.

While at school he was highly influenced by his teachers. That inculcated a habit of trying to ask questions to understand nature, to enjoy it and to be one with it. His quest to understand the flight of the birds gave him the Wings of Fire, the urge to become a pilot and to fly. This attracted him to the study of aeronautical engineering at the Madras Institute of Technology.

He learnt compassion from his mother and strict discipline from his brother, who was nearly sixteen years elder to him. His father set an example for him to follow and practice religious tolerance and societal integration. The recipe for success was well engrained in him at the very initial stage of his life through his teachers and family.

As a traditionally trained aeronautical engineer, his initial assignments were in aeronautical establishments, starting his career as a trainee and moving on to the design of a hovercraft, which was possibly one of the first flying machines designed and developed in India. The doyens of Indian science and technology at that time never failed to notice the work of a committed young man who gave all his time to his work than to any other pleasures of life, including setting up of a nest of his own. They were very impressed by his hard work, passion and knowledge and it enabled him to get a passport to work on the first Satellite Launch Vehicle programme of the country. The success of SLV-3, preceded by its own dose of failure, was perhaps the first nationally successful project wherein India's capabilities in using science and technology base came to the fore. This was perhaps the first time the scientists gained a certain level of credibility for their usefulness to the nation in the eyes of the public, media and the politicians.

Kalam subsequently moved over to head the Integrated Guided Missile Development Programme (IGMDP). This programme was conceived to address a large spectrum of the missile requirements of the country and was way ahead of the technological capabilities available in India and perhaps in the world. Until Kalam joined Defence Research Development Organization (DRDO), defence research was shrouded in secrecy and was mostly inward looking. He first established several design review teams with experts from the academia and the industry and ensured that everyone was exposed to and contributed to the goals of DRDO. He also established joint research centres with generous core and project-specific funding in all major educational institutions and the industry network. Thus he brought in the ISRO culture to DRDO. He was present in all the design review meetings, which often stretched well beyond dinner time. The fact that Kalam was a great listener and a learner became very evident in these review meetings. He effectively used the design review meetings to have a whole army of academics and researchers from other organizations and the industry to think and contribute to the missile development programme of DRDO. He was also singularly responsible for an enormous increase in open research leading to several doctoral degrees in IISc and IITs that directly addressed the unsolved problems in aerospace and related areas. This was almost the first experiment in India of directed and locally relevant research. He was personally in touch with every scientist and never hesitated to approach anyone who could make a contribution to his vision and mission. He was also extremely generous in acknowledging everyone's contribution in the public. He did this by name with poise in the books that he wrote later and in his well-publicized talks. He did this attribution not only to his mentors like Vikram Sarabhai, Satish Dhawan, Brahm Prakash, Raja Ramanna and others, but also his peers and juniors. He was a great integrator and motivator of people. This art of management of large projects through inclusive participation and generous appreciation was the key ingredient in the success of all his work – a trait that he learnt from his mentors Vikram