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Triumphant

The young engineers, 280 to be precise, changed the dynamics of DRDL. It was a valuable experience for all of us. We were now in a position to develop, through these young teams, a re-entry technology and structure, a millimetric wave radar, a phased array radar, rocket systems and other such equipment. When we first assigned these tasks to the young scientists, they did not fully grasp the importance of their work. Once they did, they felt uneasy under the burden of the tremendous faith placed in them. I still remember one young man telling me, “There is no big shot in our team, how will we be able to break through?” I told him, “A big shot is a little shot who keeps on shooting, so keep trying.” It was astonishing to see how in the young scientific environment, negative attitudes changed to positive and things that were previously thought impractical began happening. Many older scientists were rejuvenated simply by being part of a young team.

It has been my personal experience that the true flavour, the real fun, the continuous excitement of work lie in the process of doing it rather than in having it over and done with. To return to the four basic factors that I am convinced are involved in successful outcomes: goal-setting, positive thinking, visualizing, and believing.

By now, we had gone through an elaborate exercise of goal-setting and enthused the young scientists about these goals. At the review meetings, I would insist that the youngest scientists present their team’s work. That would help them in visualizing the whole system. Gradually, an atmosphere of confidence grew. Young scientists started questioning senior colleagues on solid technical issues. Nothing daunted them, because they feared nothing. If there were doubts, they rose above them. They soon became persons of power. A person with belief never grovels before anyone, whining and whimpering that it’s all too much, that he lacks support, that he is being treated unfairly. Instead, such a person tackles problems head on and then affirms, ‘As a child of God, I am greater than anything that can happen to me’. I tried to keep the work environment lively with a good blend of the experience of the older scientists mixed with the skills of their younger colleagues. This positive dependence between youth and experience had created a very productive work culture at DRDL.

The first launch of the Missile Programme was conducted on 16 September 1985, when Trishul took off from the test range at Sriharikota (SHAR). It was a ballistic flight meant for testing the in-flight performance of the solid propellant rocket motor. Two C-Band radars and Kalidieo-theodolite (KTLs) were used to track the missile from the ground. The test was successful. The launcher, rocket motor and telemetry systems functioned as planned. The aerodynamic drag however was higher than the estimates predicted on the basis of wind tunnel testing. In terms of technology breakthrough or experience enrichment, this test was of little value but the real achievement of this test was to remind my DRDL friends that they could fly missiles without being driven by the brute demands of compliance or reverse engineering. In a swift stroke, the psyche of the DRDL scientists experienced a multi-dimensional expansion.

This was followed by the successful test flight of the Pilotless Target Aircraft (PTA). Our engineers had developed the rocket motor for the PTA designed by the Bangalore-based Aeronautical Development Establishment (ADE). The motor had been type- approved by DTD&P (Air). This was a small but significant step towards developing missile hardware that is not only functional but also acceptable to the user agencies. A private sector firm was engaged to produce a reliable, airworthy, high thrust-to-weight ratio rocket motor with technology input from DRDL. We were slowly graduating from single laboratory projects to multi-laboratory programmes to laboratory-industry exercises. The development of PTA symbolized a great confluence of four different organizations. I felt as if I was standing at a meeting point and looking at the roads coming from ADE, DTD&P (Air) and ISRO. The fourth road was the DRDL, a highway to national self-reliance in missile technology.

Taking our partnership with the academic institutions of the country a step further, Joint Advanced Technology Programmes were started at the Indian Institute of Science (IISc), and Jadavpur University. I have always had a deep regard for academic institutions and reverence for excellent academicians. I value the inputs that academicians can make to development. Formal requests had been placed with these institutions and arrangements arrived at under which expertise from their faculties would be extended to DRDL in pursuance of its projects.

Let me highlight a few contributions of academic institutions to the various missile systems. Prithvi had been designed as an inertially guided missile. To reach the target accurately, the trajectory parameters have to be loaded into its brain—an on-board computer. A team of young engineering graduates at Jadavpur University under the guidance of Prof. Ghoshal developed the required robust guidance algorithm. At the IISc, postgraduate students under the leadership of Prof. IG Sharma developed air defence software for multi-target acquisition by Akash. The re- entry vehicle system design methodology for Agni was developed by a young team at IIT Madras and DRDO scientists. Osmania University's Navigational Electronics Research and Training Unit had developed state-of-the-art signal processing algorithms for Nag. I have only given a few examples of collaborative endeavour. In fact, it would have been very difficult to achieve our advanced technological goals without the active partnership of our academic institutions.

Let us consider the example of the Agni payload breakthrough. Agni is a two-stage rocket system and employs re-entry technology developed in the country for the first time. It is boosted by a first-stage solid rocket motor derived from SLV-3 and further accelerated at the second stage with the liquid rocket engines of Prithvi. For the Agni, the payload gets delivered at hypersonic speeds, which calls for the design and development of a re-entry vehicle structure. The payload with guidance electronics is housed in the re-entry vehicle structure, which is meant to protect the payload by keeping the inside temperature within the limit of 40oC, when the outside skin temperature is greater than 2500oC. An inertial guidance system with an on-board computer guides the payload to the required target. For any re-entry missile system, three-dimensional preforms are core material for making the carbon-carbon nose tip that will remain strong even at such high temperatures. Four laboratories of DRDO and the CSIR achieved this in a short span of 18 months—something other countries could do only after a decade of research and development!

Another challenge involved in the Agni payload design was related to the tremendous speed with which it would re-enter the atmosphere. In fact, Agni would re-enter the atmosphere at twelve times the speed of sound (12 Mach, as we call it in science). At this tremendous speed, we had no experience of how to keep the vehicle under control. To carry out a test, we had no wind tunnel to generate that kind of speed. If we sought American help, we would have been seen as aspiring to something they considered their exclusive privilege. Even if they consented to co-operate, they would be certain to quote a price for their wind tunnel greater than our entire project budget. Now, the question was how to beat the system. Prof. SM Deshpande of the IISc found four young, bright scientists working in the field of fluid dynamics and, within six months, developed the software for Computational Fluid Dynamics for Hypersonic Regimes, which is one of its kind in the world.

Another achievement was the development of a missile trajectory simulation software, ANUKALPANA by Prof. IG Sharma of IISc to evaluate multi-target acquisition capabilities of an Akash-type weapon system. No country would have given us this kind of software, but we developed it indigenously.

In yet another example of creating a synergy of scientific talent, Prof. Bharati Bhatt of IIT Delhi, working with the Solid Physics Laboratory (SPL) and Central Electronics Limited (CEL), broke the monopoly of the western countries by developing ferrite phase shifters for use in the multi-function, multi-tasking 3-D Phased Army Radar for surveillence, tracking and guidance of Akash. Prof. Saraf of IIT, Kharagpur, working with BK Mukho-padhyay, my colleague at RCI, made a millimetric wave (MMW) antenna for the Nag Seeker Head in two years, a record even by international standards. The Central Electrical and Electronics Research Institute (CEERI), Pilani developed an Impatt Diode in consortium with the SPL and RCI to overcome technological foreign dependence in creating these components, which are the heart of any MMW device.

As work on the project spread horizontally, performance appraisal became more and more difficult. DRDO has an assessment-linked policy. Leading nearly 500 scientists, I had to finalize their performance appraisals in the form of Annual Confidential Reports (ACRs). These reports would be forwarded to an assessment board comprised of outside specialists for recommendations. Many people viewed this part of my job uncharitably. Missing a promotion was conveniently translated as a dislike I had towards them. Promotions of other colleagues were seen as subjective favours granted by me. Entrusted with the task of performance evaluation, I had to be a fair judge.

To truly understand a judge, you must understand the riddle of the scales; one side heaped high with hope, the other side holding apprehension. When the scales dip, bright optimism turns into silent panic.

When a person looks at himself, he is likely to misjudge what he finds. He sees only his intentions. Most people have good intentions and hence conclude that whatever they are doing is good. It is difficult for an individual to objectively judge his actions, which may be, and often are, contradictory to his good intentions. Most people come to work with the intention of doing it. Many of them do their work in a manner they find convenient and leave for home in the evening with a sense of satisfaction. They do not evaluate their performance, only their intentions. It is assumed that because an individual has worked with the intention of finishing his work in time, if delays occurred, they were due to reasons beyond his control. He had no intention of causing the delay. But if his action or inaction caused that delay, was it not intentional?

Looking back on my days as a young scientist, I am aware that one of the most constant and powerful urges I experienced was my desire to be more than what I was at that moment. I desired to feel more, learn more, express more. I desired to grow, improve, purify, expand. I never used any outside influence to advance my career. All I had was the inner urge to seek more within myself. The key to my motivation has always been to look at how far I had still to go rather than how far I had come. After all, what is life but a mixture of unsolved problems, ambiguous victories, and amorphous defeats?

The trouble is that we often merely analyse life instead of dealing with it. People dissect their failures for causes and effects, but seldom deal with them and gain experience to master them and thereby avoid their recurrence. This is my belief: that through difficulties and problems God gives us the opportunity to grow. So when your hopes and dreams and goals are dashed, search among the wreckage, you may find a golden opportunity hidden in the ruins.

To motivate people to enhance their performance and deal with depression is always a challenge for a leader. I have observed an analogy between a force field equilibrium and resistance to change in organizations. Let us imagine change to be a coiled spring in a field of opposing forces, such that some forces support change and others resist it. By increasing the supportive forces such as supervisory pressure, prospects of career growth and monetary benefits or decreasing the resisting forces such as group norms, social rewards, and work avoidance, the situation can be directed towards the desired result—but for a short time only, and that too only to a certain extent. After a while the resisting forces push back with greater force as they are compressed even more tightly. Therefore, a better approach would be to decrease the resisting force in such a manner that there is no concomittant increase in the supporting forces. In this way, less energy will be needed to bring about and maintain change.

The result of the forces I mentioned above, is motive. It is a force which is internal to the individual and forms the basis of his behaviour in the work environment. In my experience, most people possess a strong inner drive for growth, competence, and self- actualization. The problem, however, has been the lack of a work environment that stimulates and permits them to give full expression to this drive. Leaders can create a high productivity level by providing the appropriate organizational structure and job design, and by acknowledging and appreciating hard work.

I first attempted to build up such a supportive environment in 1983, while launching IGMDP. The projects were in the design phase at that time. The re-organization resulted in at least forty per cent to fifty per cent increase in the level of activity. Now that the multiple projects were entering into the development and flight-testing stage, the major and minor milestones reached gave the programme visibility and continuous commitment. With the absorption of a young team of scientists, the average age had been brought down from 42 to 33 years. I felt it was time for a second re-organization. But how should I go about it? I took stock of the motivational inventory available at that time—let me explain to you what I mean by this term. The motivational inventory of a leader is made up of three types of understanding: an understanding of the needs that people expect to satisfy in their jobs, an understanding of the effect that job design has on motivation, and an understanding of the power of positive reinforcement in influencing people's behaviour.

The 1983 re-organization was done with the objective of renewal: it was indeed a very complex exercise handled deftly by AV Ranga Rao and Col R Swaminathan. We created a team of newly-joined young scientists with just one experienced person and gave them the challenge of building the strap-down inertial guidance system, an on-board computer and a ram rocket in propulsion system. These exercises were being attempted for the first time in the country, and the technology involved was comparable with world-class systems. The guidance technology is centred around the gyro and accelerometer package, and electronics, to process the sensor output. The on-board computer carries the mission computations and flight sequencing. A ram rocket system breathes air to sustain its high velocity for long durations after it is put through a booster rocket. The young teams not only designed these systems but also developed them into operational equipment. Later Prithvi and then Agni used similar guidance systems, with excellent results. The effort of these young teams made the country self-reliant in the area of protected technologies. It was a good demonstration of the 'renewal factor'. Our intellectual capacity was renewed through contact with enthusiastic young minds and had achieved these outstanding results.

Now, besides the renewal of manpower, emphasis had to be laid on augmenting the strength of project groups. Often people seek to satisfy their social, egoistic, and self-actualization needs at their workplaces. A good leader must identify two different sets of environmental features. One, which satisfies a person's needs and the other, which creates dissatisfaction with his work. We have already observed that people look for those characteristics in their work that relate to the values and goals which they consider important as giving meaning to their lives. If a job meets the employees' need for achievement, recognition, responsibility, growth and advancement, they will work hard to achieve goals.

Once the work is satisfying, a person then looks at the environment and circumstances in the workplace. He observes the policies of the administration, qualities of his leader, security, status and working conditions. Then, he correlates these factors to the inter-personal relations he has with his peers and examines his personal life in the light of these factors. It is the agglomerate of all these aspects that decides the degree and quality of a person's effort and performance.

The matrix organization evolved in 1983 proved excellent in meeting all these requirements. So, while retaining this structure of the laboratory, we undertook a task-design exercise. The scientists working in technology directorates were made system managers to interact exclusively with one project. An external fabrication wing was formed under PK Biswas, a developmental fabrication technologist of long standing, to deal with the public sector undertakings (PSUs) and private sector firms associated with the development of the missile hardware. This reduced pressure on the in-house fabrication facilities and enabled them to concentrate on jobs which could not be undertaken outside, which in fact occupied all the three shifts.

Work on Prithvi was nearing completion when we entered 1988. For the first time in the country, clustered Liquid Propellant (LP) rocket engines with programmable total impulse were going to be used in a missile system to attain flexibility in payload range combination. Now, besides the scope and quality of the policy decisions Sundaram and I were providing to the Prithvi team, the project's success depended on creative ideas being converted into workable products and the quality and thoroughness of the team members' contribution. Saraswat with Y Gyaneshwar and P Venugopalan did a commendable job in this regard. They instilled in their team a sense of pride and achievement. The importance of these rocket engines was not restricted to the Prithvi project—it was a national achievement. Under their collective leadership, a large number of engineers and technicians understood and committed themselves to the team goals, as well as the specific goals which each one of them was committed to accomplish personally. Their entire team worked under a self-evident sort of direction. Working together with the Ordnance Factory, Kirkee, they also completely eliminated the import content in the propellant for these engines.

Leaving the vehicle development in the safe and efficient hands of Sundaram and Saraswat, I started looking at the mission's vulnerable areas. Meticulous planning had gone into the development of the launch release mechanism (LRM) for the smooth lift-off of the missile. The joint development of explosive bolts to hold the LRM prior to the launch by DRDL and Explosive Research and Development Laboratory (ERDL) was an excellent example of multi- work centre coordination.

While flying, drifting into spells of contemplation and looking down at the landscape below has always been my favourite preoccupation. It is so beautiful, so harmonious, so peaceful from a distance that I wonder where all those boundaries are which separate district from district, state from state, and country from country. Maybe such a sense of distance and detachment is required in dealing with all the activities of our life.

Since the Interim Test Range at Balasore was still at least a year away from completion, we had set up special facilities at SHAR for the launch of Prithvi. These included a launch pad, block house, control consoles and mobile telemetry stations. I had a happy reunion with my old friend MR Kurup who was the Director, SHAR Centre by then. Working with Kurup on the Prithvi launch campaign gave me great satisfaction. Kurup worked for Prithvi as a team member, ignoring the boundary lines that divide DRDO and ISRO, DRDL and SHAR. Kurup used to spend a lot of time with us at the launch pad. He complemented us with his experience in range testing and range safety and worked with great enthusiasm in propellant filling, making the maiden Prithvi launch campaign a memorable experience.

Prithvi was launched at 11:23 hrs on 25 February 1988. It was an epoch-making event in the history of rocketry in the country. Prithvi was not merely a surface-to-surface missile with a capability of delivering a 1000 kg conventional warhead to a distance of 150 km with an accuracy of 50 meter CEP; it was in fact the basic module for all future guided missiles in the country. It already had the provision for modification from a long-range surface to an air missile system, and could also be deployed on a ship.

The accuracy of a missile is expressed in terms of its Circular Error Probable (CEP). This measures the radius of a circle within which 50 per cent of the missiles fired will impact. In other words, if a missile has a CEP of 1 km (such as the Iraqi Scud missiles fired in the Gulf War), this means that half of them should impact within 1 km of their target. A missile with a conventional high-explosive warhead and a CEP of 1 km would not normally be expected to destroy or disable fixed military targets such as a Command and Control Facility or an Air Base. It would however be effective against an undefined target such as a city.

The German V-2 missiles fired at London between September 1944 and March 1945 had a conventional high-explosive warhead and a very large CEP of some 17 km. Yet the 500 V-2s which hit London succeeded in causing more than 21,000 casualties and destroying about 200,000 homes.

When the West were crying themselves hoarse over the NPT, we stressed upon building competence in core guidance and control technologies to achieve a CEP as precise as 50 m. With the success of the Prithvi trials, the cold reality of a possible strategic strike even without a nuclear warhead had silenced the critics to whispers about a possible technology-conspiracy theory.

The launch of Prithvi sent shock waves across the unfriendly neighbouring countries. The response of the Western bloc was initially one of shock and then of anger. A seven-nation technology embargo was clamped, making it impossible for India to buy anything even remotely connected with the development of guided missiles. The emergence of India as a self-reliant country in the field of guided missiles upset all the developed nations of the world.

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