

WINGS OF FIRE

An Autobiography

A P J Abdul Kalam with Arun Tiwari

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WINGS OF FIRE AVUL PAKIR JAINULABDEEN ABDUL KALAM has come to personally represent to many of his countrymen the best aspects of Indian life. Born in 1931, the son of a little educated boatowner in Rameswaram, Tamilnadu, he had An Autobiography

an unparalleled career as a defence scientist, culminating in the highest civilian award of India, the Bharat Ratna.

As chief of the country's defence research and development programme, Kalam demonstrated the great potential for dynamism and innovation that existed in seemingly moribund research

establishments. This is the story of Kalam's rise from obscurity and his personal and professional struggles, as well as the story of *Agni*, *Prithvi*, *Akash*, *Trishul* and *Nag* - missiles that have become household names in India and that have raised the nation to the level of a missile power of international recognition.

At the same time as he has helped create India's awesome weaponry, Kalam has maintained the ascetic rigour of his personal life, working 18 hours a day and practicing the veena. With characteristic modesty, Kalam ascribes the greatness of his achievement to the influence of his teachers and mentors. He describes the struggles of his boyhood and youth, bringing alive everyday life in a small town in South India and the inspirational role of educators. He describes the role of visionary Indian scientists, such as Dr Vikram Sarabhai, and of the creation of a coordinated network of research institutions. This is also the saga of independent India's struggle for technological self sufficiency and defensive autonomy – a story as much about politics, domestic and international, as it is about science.

Arun Tiwari worked under Dr APJ Abdul Kalam for over a decade in the Defence Research and Development Laboratory (DRDL), Hyderabad. He is currently Director, Cardiovascular Technology Institute, Hyderabad, where he is pursuing Dr Kalam's vision of developing cost-effective medical devices using indigenous defence technology.

Dr Kalam is now India's President. He was elected to India's office by a huge majority in 2002.

Cover photograph: Courtesy *The Week*, a *Malayala Manorama* Publication Picture by B Jayachandran

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To the memory of my parents

My Mother

Sea waves, golden sand, pilgrims' faith,

Rameswaram Mosque Street, all merge into one, My Mother!

You come to me like heaven's caring arms.

I remember the war days when life was challenge and toil—

Miles to walk, hours before sunrise,

Walking to take lessons from the saintly teacher near the temple.

Contents

Again miles to the Arab teaching school,

Climb sandy hills to Railway Station Road, Collect, distribute newspapers to temple city citizens,
Preface

Few hours after sunrise, going to school.

Acknowledgements

Evening, business time before study at night.

Introduction

All this pain of a young boy,

My Mother you transformed into pious strength ORIENTATION

With kneeling and bowing five times

CREATION

For the Grace of the Almighty only, My Mother.

Your strong piety is your children's strength, PROPITIATION

You always shared your best with whoever needed the most, CONTEMPLATION

You always gave, and gave with faith in Him.

Epilogue

I still remember the day when I was ten,

Sleeping on your lap to the envy of my elder brothers and sisters
It was full moon night, my world only you knew
Mother! My Mother!

When at midnight I woke with tears falling on my knee
You knew the pain of your child, My Mother.

Your caring hands, tenderly removing the pain
Your love, your care, your faith gave me strength
To face the world without fear and with His strength.

We will meet again on the great Judgement Day, My Mother!

APJ Abdul Kalam

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one. He has an intuitive rapport with the humblest and simplest people, an indication of his own simplicity and innate spirituality.

For myself, writing this book has been like a pilgrimage. Through Dr Kalam, I was blessed with the revelation that the real joy of living can be found in only one way—in one's communion with an eternal source of hidden knowledge within oneself—which each individual is bidden to seek and find for himself or herself. Many of you may never

Preface

meet Dr Kalam in person, but I hope you will enjoy his company through this book, and that he will become your spiritual friend.

I have worked under Dr APJ Abdul Kalam for over a decade. I could include in this book only a few incidents among the many This might seem to disqualify me as his biographer, and I certainly narrated to me by Dr Kalam. In fact, this book provides only a thumbnail had no notion of being one. One day, while speaking to him, I sketch of Dr Kalam's life. It is quite possible that certain important asked him if he had a message for young Indians. His message fascinated incidents have been inadvertently dropped and that the contribution of me. Later, I mustered the courage to ask him about his recollections so some individuals to the projects co-ordinated by Dr Kalam has gone that I could pen them down before they were buried irretrievably under unrecorded. Since a quarter-century of professional life separates me the sands of time.

from Dr Kalam, some important issues might also have remained We had a long series of sittings late into the night and early under unrecorded or have been distorted. I am solely responsible for such the fading stars of dawn—all somehow stolen from his very busy shortcomings, which are, of course, completely unintentional.

schedule of eighteen hours a day. The profundity and range of his ideas

Arun Tiwari

mesmerized me. He had tremendous vitality and obviously received immense pleasure from the world of ideas. His conversation was not always easy to follow, but was always fresh and stimulating. There were complexities, subtleties, and intriguing metaphors and subplots in his narrative, but gradually the unfolding of his brilliant mind took the form of a continuous discourse.

When I sat down to write this book, I felt that it required greater skills than I possessed. But realising the importance of this task and regarding it an honour to have been permitted to attempt it, I prayed earnestly for the courage and calibre to complete it.

This book is written for the ordinary people of India for whom Dr Kalam has an immense affection, and of whom Dr Kalam is certainly e e prpersess



Acknowledgements

Introduction

I wish to express my gratitude to all the people involved in the This book is being released at a time when India's technological writing of this book, especially Mr YS Rajan, Mr A Sivathanu endeavours, to assert its sovereignty and strengthen its security, are Pillai, Mr RN Agarwal, Mr Prahlada, Mr KVSS Prasada Rao questioned by many in the world. Historically, people have always fought and Dr SK Salwan, who were very generous in sharing their time and among themselves on one issue or another. Prehistorically, battles were knowledge with me.

fought over food and shelter. With the passage of time, wars were waged over religious and ideological beliefs; and now the dominant I am thankful to Prof. KAV Pandalai and Mr R Swaminathan, for struggle of sophisticated warfare is for economic and technological critical reviews of the text. I thank Dr B Soma Raju for his tangible, but supremacy. Consequently, economic and technological supremacy is always unspoken support, for this project. My sincere thanks go to my equated with political power and world control.

wife and unsparing critic, Dr Anjana Tiwari, for her tough comments, accompanied with her gentle support.

A few nations who have grown very strong technologically, over the past few centuries, have wrested control, for their own purposes. These It has been a pleasure to work with Universities Press, and the co-major powers have become the self-proclaimed leaders of the new operation of the editorial and production staff is much appreciated.

world order. What does a country of one billion people, like India, do There are many fine people, such as the photographer Mr. Prabhu, in such a situation? We have no other option but to be technologically who have selflessly enriched me and this book in ways beyond measure.

strong. But, can India be a leader in the field of technology? My answer I thank them all.

is an emphatic 'Yes'. And let me validate my answer by narrating some And finally, my deepest gratitude to my sons, Aseem and Amol—

incidents from my life.

for their unfailing emotional support during the writing, and because I When I first began the reminiscences that have gone into this book, seek in them that attitude towards life which Dr Kalam admired, and I was uncertain about which of my memories were worth narrating or wanted this work to reflect.

were of any relevance at all. My childhood is precious to me, but would

Arun Tiwari

it be of interest to anyone else? Was it worth the reader's while, I wondered, to know about the tribulations and triumphs of a small-town boy? Of the straitened circumstances of my schooldays, the

odd jobs I did to pay my school fees, and how my decision to become a e e prpersess



vegetarian was partly due to my financial constraints as a college do for him. “Give me your blessings, sir,” he said, “so that I may have student—why should these be of any interest to the general public? In a longer life and can complete at least one of your projects.” the end, I was convinced that these were relevant, if not for anything The young man’s dedication moved me and I prayed for his recovery else but because they tell something of the story of modern India, as all night. The Lord answered my prayers and Tiwari was able to get individual destiny and the social matrix in which it is embedded cannot back to work in a month. He did an excellent job in helping to realise be seen in isolation. Having been persuaded of this, it did seem germane the Akash missile airframe from scratch within the short space of three to include the accounts of my frustrated attempt to become an Air years. He then took up the task of chronicling my story. Over the last Force pilot and of how I became, instead of the Collector my father year, he patiently transcribed the bits and pieces of my story and dreamed I would be, a rocket engineer.

converted them into a fluent narrative. He also went through my personal Finally, I decided to describe the individuals who had a profound library meticulously and selected from among the pieces of poetry those influence on my life. This book is also by way of a submission of thanks, that I had marked while reading, and included them in the text.

therefore, to my parents and immediate family, and to the teachers and This story is an account, I hope, not just of my personal triumphs preceptors I was fortunate to have had, both as a student and in my and tribulations but of the successes and setbacks of the science professional life. It is also a tribute to the unflagging enthusiasm and establishment in modern India, struggling to establish itself in the efforts of my young colleagues who helped to realise our collective technological forefront. It is the story of national aspiration and of co-dreams. The famous words of Isaac Newton about standing on the operative endeavour. And, as I see it, the saga of India’s search for shoulders of giants are valid for every scientist and I certainly owe a scientific self-sufficiency and technological competence is a parable for great debt of knowledge and inspiration to the distinguished lineage of our times.

Indian scientists, that included Vikram Sarabhai, Satish Dhawan and Brahm Prakash. They played major roles in my life and in the story of Each individual creature on this beautiful planet is created by God Indian science.

to fulfil a particular role. Whatever I have achieved in life is through His help, and an expression of His will. He showered His grace on me I completed sixty years of age on 15 October 1991. I had decided through some outstanding teachers and colleagues, and when I pay my to devote my retirement to fulfilling what I saw as my duties in the tributes to these fine persons, I am merely praising His glory. All these sphere of social service. Instead, two things happened simultaneously.

rockets and missiles are His work through a small person called Kalam, First, I agreed to continue in government service for another three years in order to tell the several-million mass of India, to never feel small or and, next, a young colleague, Arun Tiwari, requested me to share my helpless. We are

all born with a divine fire in us. Our efforts should be reminiscences with him, so that he could record them. He was someone to give wings to this fire and fill the world with the glow of its goodness.

who had been working in my laboratory since 1982, but I had never May God bless you!

really known him well until the February of 1987 when I visited him at the Intensive Coronary Care Unit of the Nizam's Institute of Medical

APJ Abdul Kalam

Sciences in Hyderabad. He was a mere 32 years old, but was fighting valiantly for his life. I asked him if there was anything he wanted me to e e prpersess



I

ORIENTATION

[1931 – 1963]

This earth is His, to Him belong those vast and boundless skies; Both seas within Him rest, and yet in that small pool He lies.

ATHARVA VEDA

Book 4, Hymn 16.

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WINGS OF FIRE

ORIENTATION

The famous Shiva temple, which made Rameswaram so sacred to pilgrims, was about a ten-minute walk from our house. Our locality was predominantly Muslim, but there were quite a few Hindu families too, living amicably with their Muslim neighbours. There was a very old 1

mosque in our locality where my father would take me for evening prayers. I had not the faintest idea of the meaning of the Arabic prayers chanted, but I was totally convinced that they reached God. When my father came out of the mosque after the prayers, people of different religions would be sitting outside, waiting for him. Many of them offered bowls of water to my father who would dip his fingertips in them and say a prayer. This water was then carried home for invalids. I also remember people visiting our home to offer thanks after being cured.

I was born into a middle-class Tamil family in the island town of My father always smiled and asked them to thank Allah, the benevolent Rameswaram in the erstwhile Madras state. My father, and merciful.

Jainulabdeen, had neither much formal education nor much wealth; The high priest of Rameswaram temple, Pakshi Lakshmana Sastry, despite these disadvantages, he possessed great innate wisdom and a was a very close friend of my father's. One of the most vivid memories true generosity of spirit. He had an ideal helpmate in my mother, of my early childhood is of the two men, each in his traditional attire, Ashiamma. I do not recall the exact number of people she fed every discussing spiritual matters. When I was old enough to ask questions, I day, but I am quite certain that far more outsiders ate with us than all the asked my father about the relevance of prayer. My father told me there members of our own family put together.

was nothing mysterious about prayer. Rather, prayer made possible a My parents were widely regarded as an ideal couple. My mother's communion of the spirit between people. "When you pray," he said, lineage was the more distinguished, one of her forebears having been

"you transcend your body and become a part of the cosmos, which bestowed the title of 'Bahadur' by the British.

knows no division of wealth, age, caste, or creed." I was one of many children—a short boy with rather undistinguished My father could convey complex spiritual concepts in very simple, down-looks, born to tall and handsome parents. We lived in our ancestral house, to-earth Tamil. He once told me, "In his own time, in his own place, in what which was built in the middle of the 19th century. It was a fairly large he really is, and in the stage he has reached—good or bad—every human pucca house, made of limestone and brick, on the Mosque Street in being is a specific element within the whole of the manifest divine Being. So Rameswaram. My austere father used to avoid all inessential comforts why be afraid of difficulties, sufferings and problems? When troubles come, and luxuries. However, all necessities were provided for, in terms of try to understand the relevance of your sufferings. Adversity always presents food, medicine or clothes. In fact, I would say mine was a very secure opportunities for introspection."

childhood, both materially and emotionally.

"Why don't you say this to the people who come to you for help and I normally ate with my mother, sitting on the floor of the kitchen. She advice?" I asked my father. He put his hands on my shoulders and looked would place a banana leaf before me, on which she then ladled rice and straight into my eyes. For quite some time he said nothing, as if he was aromatic sambhar, a variety of sharp, home-made pickles and a dollop judging my capacity to comprehend his words. Then he answered in a low, of fresh coconut chutney.

deep voice. His answer filled me with a strange energy and enthusiasm: e e prpersess



WINGS OF FIRE

ORIENTATION

Whenever human beings find themselves alone, as a natural reaction, By the time the boat met its untimely end, Ahmed Jallaluddin had they start looking for company. Whenever they are in trouble, they look become a close friend of mine, despite the difference in our ages. He for someone to help them. Whenever they reach an impasse, they look was about 15 years older than I and used to call me Azad. We used to to someone to show them the way out. Every recurrent anguish, longing, go for long walks together every evening. As we started from Mosque and desire finds its own special helper. For the people who come to me Street and made our way towards the sandy shores of the island, in distress, I am but a go-between in their effort to propitiate demonic Jallaluddin and I talked mainly of spiritual matters. The atmosphere of forces with prayers and offerings. This is not a correct approach at all Rameswaram, with its flocking pilgrims, was conducive to such discussion.

and should never be followed. One must understand the difference Our first halt would be at the imposing temple of Lord Shiva. Circling between a fear-ridden vision of destiny and the vision that enables us to around the temple with the same reverence as any pilgrim from a distant seek the enemy of fulfilment within ourselves.

part of the country, we felt a flow of energy pass through us.

I remember my father starting his day at 4 a.m. by reading the namaz Jallaluddin would talk about God as if he had a working partnership before dawn. After the namaz, he used to walk down to a small coconut with Him. He would present all his doubts to God as if He were standing grove we owned, about 4 miles from our home. He would return, with nearby to dispose of them. I would stare at Jallaluddin and then look about a dozen coconuts tied together thrown over his shoulder, and only towards the large groups of pilgrims around the temple, taking holy dips then would he have his breakfast. This remained his routine even when in the sea, performing rituals and reciting prayers with a sense of respect he was in his late sixties.

towards the same Unknown, whom we treat as the formless Almighty.

I have throughout my life tried to emulate my father in my own world I never doubted that the prayers in the temple reached the same of science and technology. I have endeavoured to understand the destination as the ones offered in our mosque. I only wondered whether fundamental truths revealed to me by my father, and feel convinced that Jallaluddin had any other special connection to God. Jallaluddin's schooling there exists a divine power that can lift one up from confusion, misery, had been limited, principally because of his family's straitened melancholy and failure, and guide one to one's true place. And once an circumstances. This may have been the reason why he always encouraged individual severs his emotional and physical bondage, he is on the road me to excel in my studies and enjoyed my success vicariously. Never to freedom, happiness and peace of mind.

did I find the slightest trace of resentment in Jallaluddin for his deprivation.

Rather, he was always full of gratitude for whatever life had chosen to I was about six years old

when my father embarked on the project of give him.

building a wooden sailboat to take pilgrims from Rameswaram to Dhanuskodi, (also called Sethukkarai), and back. He worked at building Incidentally, at the time I speak of, he was the only person on the the boat on the seashore, with the help of a relative, Ahmed Jallaluddin, entire island who could write English. He wrote letters for almost anybody who later married my sister, Zohara. I watched the boat take shape.

in need, be they letters of application or otherwise. Nobody of my The wooden hull and bulkheads were seasoned with the heat from wood acquaintance, either in my family or in the neighbourhood even had fires. My father was doing good business with the boat when, one day, Jallaluddin's level of education or any links of consequence with the a cyclone bringing winds of over 100 miles per hour carried away our outside world. Jallaluddin always spoke to me about educated people, of boat, along with some of the landmass of Sethukkarai. The Pamban scientific discoveries, of contemporary literature, and of the achievements Bridge collapsed with a train full of passengers on it. Until then, I had of medical science. It was he who made me aware of a "brave, new only seen the beauty of the sea, now its uncontrollable energy came as world" beyond our narrow confines.

a revelation to me.

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2



WINGS OF FIRE

ORIENTATION

In the humble environs of my boyhood, books were a scarce wages. Half a century later, I can still feel the surge of pride in earning commodity. By local standards, however, the personal library of STR

my own money for the first time.

Manickam, a former 'revolutionary' or militant nationalist, was sizeable.

Every child is born, with some inherited characteristics, into a specific He encouraged me to read all I could and I often visited his home to socio-economic and emotional environment, and trained in certain ways borrow books.

by figures of authority. I inherited honesty and self-discipline from my Another person who greatly influenced my boyhood was my first father; from my mother, I inherited faith in goodness and deep kindness cousin, Samsuddin. He was the sole distributor for newspapers in and so did my three brothers and sister. But it was the time I spent with Rameswaram. The newspapers would arrive at Rameswaram station Jallaluddin and Samsuddin that perhaps contributed most to the uniqueness by

the morning train from Pamban. Samsuddin's newspaper agency of my childhood and made all the difference in my later life. There was a one-man organization catering to the reading demands of the unschooled wisdom of Jallaluddin and Samsuddin was so intuitive and 1,000-strong literate population of Rameswaram town. These responsive to non-verbal messages, that I can unhesitatingly attribute newspapers were mainly bought to keep abreast of current developments my subsequently manifested creativity to their company in my childhood.

in the National Independence Movement, for astrological reference or I had three close friends in my childhood—Ramanadha Sastry, to check the bullion rates prevailing in Madras. A few readers with a Aravindan, and Sivaprakasan. All these boys were from orthodox Hindu more cosmopolitan outlook would discuss Hitler, Mahatma Gandhi and Brahmin families. As children, none of us ever felt any difference amongst Jinnah; almost all would finally flow into the mighty political current of ourselves because of our religious differences and upbringing. In fact, Periyar EV Ramaswamy's movement against high caste Hindus.

Ramanadha Sastry was the son of Pakshi Lakshmana Sastry, the high Dinamani was the most sought after newspaper. Since reading the printed priest of the Rameswaram temple. Later, he took over the priesthood of matter was beyond my capability, I had to satisfy myself with glancing the Rameswaram temple from his father; Aravindan went into the business at the pictures in the newspaper before Samsuddin delivered them to his of arranging transport for visiting pilgrims; and Sivaprakasan became a customers.

catering contractor for the Southern Railways.

The Second World War broke out in 1939, when I was eight years. During the annual Shri Sita Rama Kalyanam ceremony, our family old. For reasons I have never been able to understand, a sudden demand used to arrange boats with a special platform for carrying idols of the for tamarind seeds erupted in the market. I used to collect the seeds and Lord from the temple to the marriage site, situated in the middle of the sell them to a provision shop on Mosque Street. A day's collection would pond called Rama Tirtha which was near our house. Events from the fetch me the princely sum of one anna. Jallaluddin would tell me stories Ramayana and from the life of the Prophet were the bedtime stories my about the war which I would later attempt to trace in the headlines in mother and grandmother would tell the children in our family.

Dinamani. Our area, being isolated, was completely unaffected by the war. But soon India was forced to join the Allied Forces and something. One day when I was in the fifth standard at the Rameswaram like a state of emergency was declared. The first casualty came in the Elementary School, a new teacher came to our class. I used to wear a form of the suspension of the train halt at Rameswaram station. The cap which marked me as a Muslim, and I always sat in the front row newspapers now had to be bundled and thrown out from the moving next to Ramanadha Sastry, who wore a sacred thread. The new teacher train on the Rameswaram Road between Rameswaram and Dhanuskodi.

could not stomach a Hindu priest's son sitting with a Muslim boy. In That forced Samsuddin to look for a helping hand to catch the bundles accordance with our social ranking as the new teacher saw it, I was and, as if naturally, I filled the slot. Samsuddin helped me earn my first asked to go and sit on the back bench. I felt very sad, and so did e e prpersess



WINGS OF FIRE

ORIENTATION

Ramanadha Sastry. He looked utterly downcast as I shifted to my seat father's permission to leave Rameswaram and study at the district in the last row. The image of him weeping when I shifted to the last row headquarters in Ramanathapuram.

left a lasting impression on me.

He told me as if thinking aloud, "Abul! I know you have to go away After school, we went home and told our respective parents about to grow. Does the seagull not fly across the Sun, alone and without a the incident. Lakshmana Sastry summoned the teacher, and in our nest? You must forego your longing for the land of your memories to presence, told the teacher that he should not spread the poison of social move into the dwelling place of your greater desires; our love will not inequality and communal intolerance in the minds of innocent children.

bind you nor will our needs hold you." He quoted Khalil Gibran to my He bluntly asked the teacher to either apologize or quit the school and hesitant mother, "Your children are not your children. They are the sons the island. Not only did the teacher regret his behaviour, but the strong and daughters of Life's longing for itself. They come through you but sense of conviction Lakshmana Sastry conveyed ultimately reformed not from you. You may give them your love but not your thoughts. For this young teacher.

they have their own thoughts."

On the whole, the small society of Rameswaram was highly stratified He took me and my three brothers to the mosque and recited the and very rigid in terms of the segregation of different social groups.

prayer All Fatiha from the Holy Qur'an. As he put me on the train at However, my science teacher Sivasubramania Iyer, though an orthodox Rameswaram station he said, "This island may be housing your body Brahmin with a very conservative wife, was something of a rebel. He but not your soul. Your soul dwells in the house of tomorrow which none did his best to break social barriers so that people from varying of us at Rameswaram can visit, not even in our dreams. May God bless backgrounds could mingle easily. He used to spend hours with me and you, my child!"

would say, "Kalam, I want you to develop so that you are on par with Samsuddin and Ahmed Jallaluddin travelled with me to the highly educated people of the big cities." Ramanathapuram to enrol me in Schwartz High School, and to arrange One day, he invited me to his home for a meal. His wife was horrified for my boarding there. Somehow, I did not take to the new setting. The at the idea of a Muslim boy being invited to dine in her ritually pure town of Ramanathapuram was a thriving,

factionous town of some fifty kitchen. She refused to serve me in her kitchen. Sivasubramania Iyer thousand people, but the coherence and harmony of Rameswaram was was not perturbed, nor did he get angry with his wife, but instead, served absent. I missed my home and grabbed every opportunity to visit me with his own hands and sat down beside me to eat his meal. His wife Rameswaram. The pull of educational opportunities at Ramanathapuram watched us from behind the kitchen door. I wondered whether she had was not strong enough to nullify the attraction of poli, a South Indian observed any difference in the way I ate rice, drank water or cleaned sweet my mother made. In fact, she used to prepare twelve distinctly the floor after the meal. When I was leaving his house, Sivasubramania different varieties of it, bringing out the flavour of every single ingredient Iyer invited me to join him for dinner again the next weekend. Observing used in the best possible combinations.

my hesitation, he told me not to get upset, saying, “Once you decide to Despite my homesickness, I was determined to come to terms with change the system, such problems have to be confronted.” When I visited the new environment because I knew my father had invested great his house the next week, Sivasubramania Iyer’s wife took me inside her hopes in my success. My father visualized me as a Collector in the kitchen and served me food with her own hands.

making and I thought it my duty to realise my father’s dream, although I Then the Second World War was over and India’s freedom was desperately missed the familiarity, security and comforts of imminent. “Indians will build their own India,” declared Gandhiji. The Rameswaram.

whole country was filled with an unprecedented optimism. I asked my e e prpersess

4



WINGS OF FIRE

ORIENTATION

Jallaluddin used to speak to me about the power of positive thinking and I often recalled his words when I felt homesick or dejected. I tried hard to do as he said, which was to strive to control my thoughts and my mind and, through these, to influence my destiny. Ironically, that destiny did not lead me back to Rameswaram, but rather, swept me farther away from the home of my childhood.

* * *

2

Once I settled down at the Schwartz High School, Ramanathapuram, the enthusiastic fifteen-year-old within me re-emerged. My teacher, Iyadurai Solomon, was an ideal guide for an eager young mind that was yet uncertain of the possibilities and alternatives that lay before it. He made his students feel very comfortable in class with his warm and open-minded attitude. He used to say that a good student could learn more from a bad teacher than a poor student from even a skilled teacher.

During my stay at Ramanathapuram, my relationship with him grew beyond that of teacher and pupil. In his company, I learnt that one could exercise enormous influence over the events of one's own life. Iyadurai Solomon used to say, "To succeed in life and achieve results, you must understand and master three mighty forces— desire, belief, and expectation." Iyadurai Solomon, who later became a Reverend, taught me that before anything I wanted could happen, I had to desire it intensely and be absolutely certain it would happen. To take an example from my own life, I had been fascinated by the mysteries of the sky and the flight of birds from early childhood. I used to watch cranes and seagulls soar into flight and longed to fly. Simple, provincial boy though I was, I was convinced that one day I, too, would soar up into the skies. Indeed, I was the first child from Rameswaram to fly.

Iyadurai Solomon was a great teacher because he instilled in all the children a sense of their own worth. Solomon raised my self-esteem to e e prpersess

5



WINGS OF FIRE

ORIENTATION

a high point and convinced me, the son of parents who had not had the were about a hundred boys living in the three-storeyed hostel building.

benefits of education, that I too could aspire to become whatever I Rev. Father used to visit each boy every night with a Bible in his hand.

wished. "With faith, you can change your destiny," he would say.

His energy and patience was amazing. He was a very considerate person One day, when I was in the fourth form, my mathematics teacher, who took care of even the most minute requirements of his students. On Ramakrishna Iyer, was teaching another class. Inadvertently, I wandered Deepavali, on his instructions, the Brother in charge of the hostel and into that classroom and in the manner of an old-fashioned despot, the mess volunteers would visit each room and distribute good gingelly Ramakrishna Iyer caught me by the neck and caned me in front of the oill for the ritual bath.

whole class. Many months later, when I scored full marks in mathematics, I stayed on the St. Joseph's campus for four years and shared my he narrated the incident to the entire school at morning assembly.

room with two others. One was an orthodox Iyengar from Srirangam

"Whomsoever I cane becomes a great man! Take my word, this boy is and the other a Syrian Christian from Kerala. The three of us had a going to bring glory to his school and to his teachers." His praise quite wonderful time together. When I was made secretary of the vegetarian made up for the earlier humiliation!

mess during my third year in the hostel, we invited the Rector, Rev.

By the time I completed my education at Schwartz, I was a self-Father Kalathil, over for lunch one Sunday. Our menu included the confident boy determined to succeed. The decision to go in for further choicest preparations from our diverse backgrounds. The result was education was taken without a second thought. To us, in those days, the rather unexpected, but Rev. Father was lavish in his praise of our efforts.

awareness of the possibilities for a professional education did not exist; We enjoyed every moment with Rev. Father Kalathil, who participated higher education simply meant going to college. The nearest college in our unsophisticated conversation with childlike enthusiasm. It was a was at Tiruchchirappalli, spelled Trichinopoly those days, and called Trichi memorable event for us all.

for short.

My teachers at St. Joseph were the true followers of Kanchi In 1950, I arrived at St. Joseph's College, Trichi, to study for the Paramacharya, who evoked people to "enjoy the action of giving". The Intermediate examination. I was not a bright student in terms of vivid memory of our mathematics teachers, Prof. Thothathri Iyengar examination grades but, thanks to my two buddies back in Rameswaram, and Prof. Suryanarayana Sastry, walking together on the campus inspires I had acquired a practical bent of mind.

me to this day.

Whenever I returned to Rameswaram from Schwartz, my elder When I was in the final year at St. Joseph's, I acquired a taste for brother Mustafa Kamal, who ran a provision store on the railway station English literature. I began to read the great classics, Tolstoy, Scott and road, would call me in to give him a little help and then vanish for hours Hardy being special favourites despite their exotic settings, and then I together leaving the shop in my charge. I sold oil, onions, rice and moved on to some works in Philosophy. It was around this time that I everything else. The fastest moving items, I found, were cigarettes and developed a great interest in Physics.

bidis. I used to wonder what made poor people smoke away their hard-The lessons on subatomic physics at St. Joseph's by my physics earned money. When spared by Mustafa, I would be put in charge of his teachers, Prof. Chinna Durai and Prof. Krishnamurthy, introduced me kiosk by my younger brother, Kasim Mohammed. There I sold novelties to the concept of the half-life period and matters related to the radioactive made of seashells.

decay of substances. Sivasubramania Iyer, my science teacher at At St. Joseph's, I was lucky to find a teacher like the Rev. Father Rameswaram, had never taught me that most subatomic particles are TN Sequeira. He taught us English and was also our hostel warden. We unstable and that they disintegrate after a certain time into other particles.

All this I was learning for the first time. But when he taught me to strive e e prpersess



WINGS OF FIRE

ORIENTATION

with diligence because decay is inherent in all compounded things, was aspect. Everything solid, thus, contains much empty space within and he not talking of the same thing? I wonder why some people tend to see everything stationary contains great movement within. It is as though science as something which takes man away from God. As I look at it, the great dance of Shiva is being performed on earth during every moment the path of science can always wind through the heart. For me, science of our existence.

has always been the path to spiritual enrichment and self-realisation.

When I joined the B.Sc. degree course at St. Joseph's, I was unaware Even the rational thought-matrices of science have been home to of any other option for higher education. Nor did I have any information fairy tales. I am an avid reader of books on cosmology and enjoy reading about career opportunities available to a student of science. Only after about celestial bodies. Many friends, while asking me questions related obtaining a B.Sc. did I realise that physics was not my subject. I had to to space flights, sometimes slip into astrology. Quite honestly, I have go into engineering to realise my dreams. I could have joined the never really understood the reason behind the great importance attached Engineering course long ago, right after finishing my Intermediate course.

by people to the faraway planets in our solar system. As an art, I have Better late than never, I told myself as I made the detour, applying for nothing against astrology, but if it seeks acceptance under the guise of admission into the Madras Institute of Technology (MIT), regarded as science, I reject it. I do not know how these myths evolved about planets, the crown jewel of technical education in South India at that time.

star constellations, and even satellites—that they can exercise power I managed to be on the list of selected candidates, but admission to on human beings. The highly complicated calculations manipulated around this prestigious institution was an expensive affair. Around a thousand the precise movements of celestial bodies, to derive highly subjective rupees was required, and my father could not spare that much money.

conclusions appear illogical to me. As I see it, the Earth is the most At that time, my sister, Zohara, stood behind me, mortgaging her gold powerful and energetic planet. As John Milton puts it so beautifully in bangles and chain. I was deeply touched by her determination to see me Paradise Lost, Book VIII:

educated and by her faith in my abilities. I vowed to release her bangles

. . . *What if the Sun*

from mortgage with my own earnings. The only way before me to earn *Be centre to the World, and*

other stars

money at that point of time was to study hard and get a scholarship. I *The planet earth, so steadfast though she seem*, went ahead at full steam.

In sensibly three different motions move?

What fascinated me most at MIT was the sight of two. Wherever you go on this planet, there is movement and life. Even decommissioned aircraft displayed there for the demonstration of the apparently inanimate things like rocks, metal, timber, clay are full of various subsystems of flying machines. I felt a strange attraction towards intrinsic movement—with electrons dancing around each nucleus. This then, and would sit near them long after other students had gone back motion originates in their response to the confinement imposed on them to the hostel, admiring man's will to fly free in the sky, like a bird. After by the nucleus, by means of electric forces which try to hold them as completing my first year, when I had to opt for a specific branch, I chose as possible. Electrons, just like any individual with a certain amount almost spontaneously chose aeronautical engineering. The goal was very of energy, detest confinement. The tighter the electrons are held by the clear in my mind now; I was going to fly aircraft. I was convinced of nucleus, the higher their orbital velocity will be: in fact, the confinement this, despite being aware of my lack of assertiveness, which probably of electrons in an atom results in enormous velocities of about 1000 km came about because of my humble background. Around this time, I per second! These high velocities make the atom appear a rigid sphere, made special efforts to try and communicate with different kinds of just as a fast-moving fan appears like a disc. It is very difficult to people. There were setbacks, disappointments and distractions, but my compress atoms more strongly—thus giving matter its familiar solid father's inspiring words anchored me in those periods of nebulous drift.

e e prpersess

7





(b)



WINGS OF FIRE

ORIENTATION

Plate 1 (a) My father Jainulabdeen was not formally educated, but was a man of great wisdom and kindness. (b) Pakshi Lakshmana Sastry, a close friend of my father and the head priest of the Rameswaram Temple.

e e prpersess

8



(a)



(b)



WINGS OF FIRE

ORIENTATION

Plate 2 The locality in which I grew up: (a) My house on Mosque Street. (b) Thousands of pilgrims from great distances descend on the ancient temple of Lord Shiva. I often assisted my brother Kasim Mohamed in his shop selling artifacts on this street.

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WINGS OF FIRE

ORIENTATION

Plate 3 The old mosque in our locality where my father would take me and my brothers every evening to offer prayers.

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WINGS OF FIRE

ORIENTATION

Plate 4 My brother pointing at the T–square I used while studying engineering.

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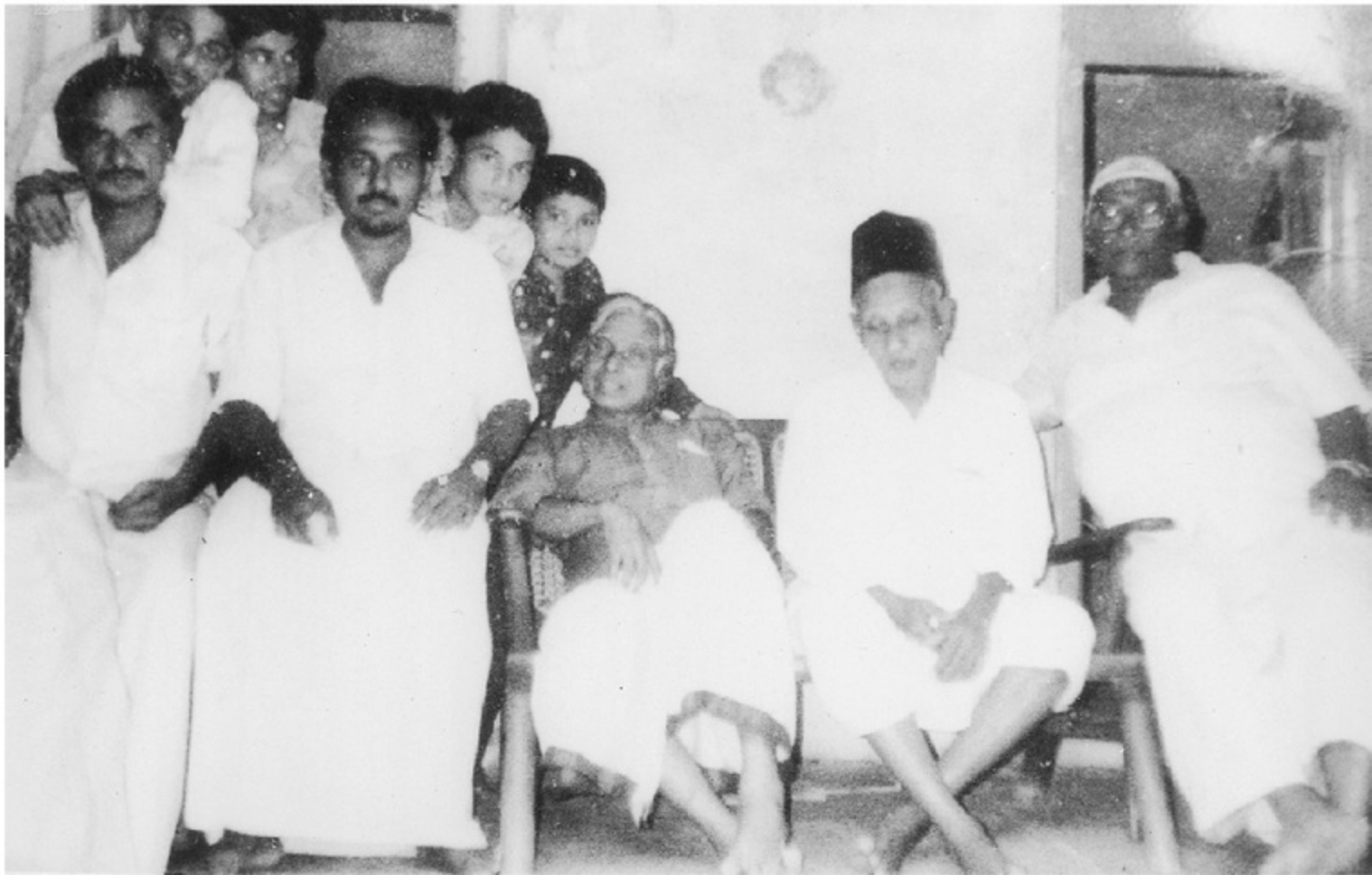


WINGS OF FIRE

ORIENTATION

Plate 5 STR Manickam (inset), a friend of my brother Mustafa Kamal, had a large collection of books. This is his house, from where I would borrow books while at Rameswaram.

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WINGS OF FIRE

ORIENTATION

Plate 6 A family get-together.

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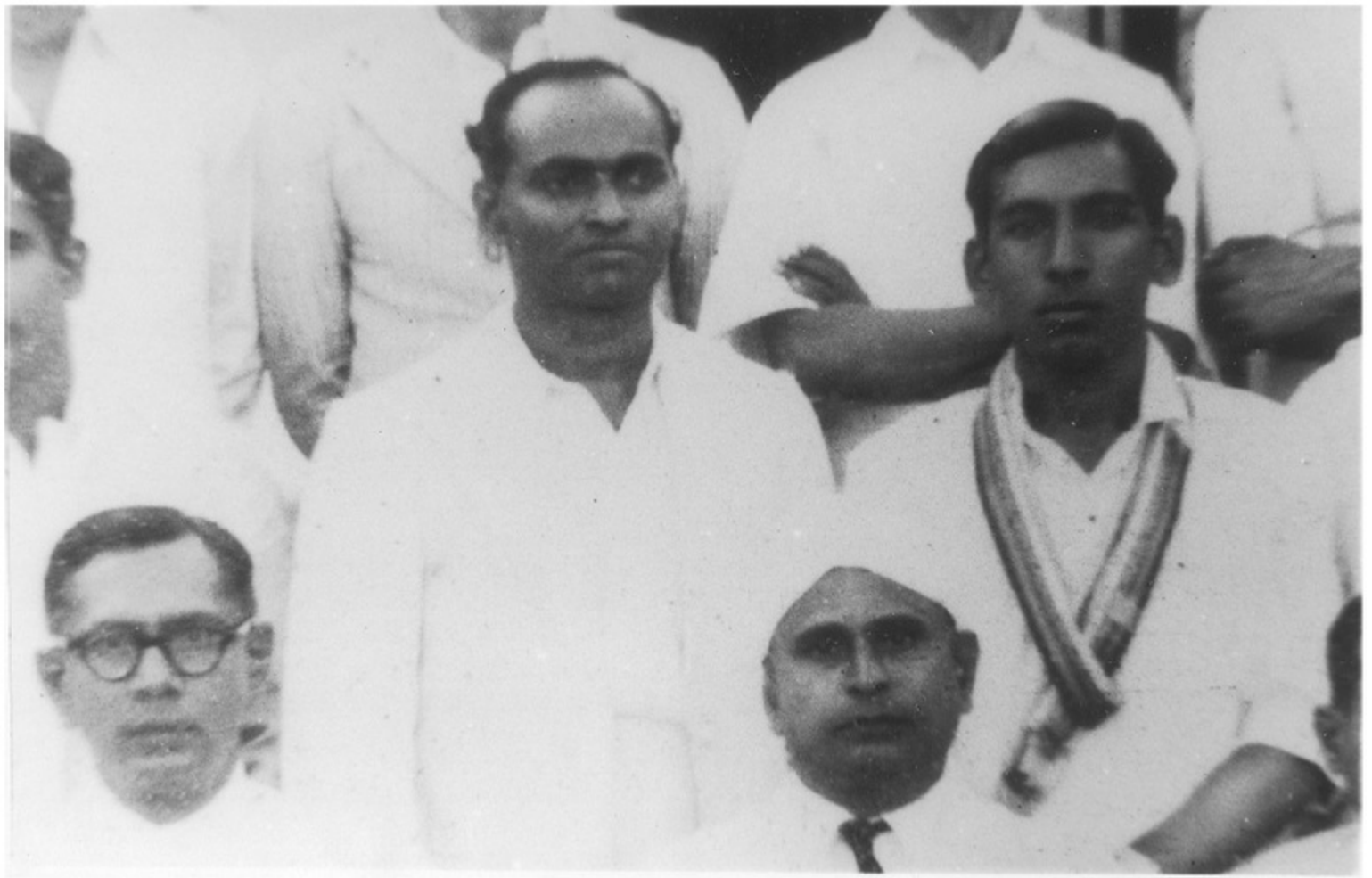
WINGS OF FIRE

ORIENTATION

Plate 7 The simple surroundings of Schwartz High School, Ramanathapuram.

The words on the plaque read "Let not thy winged days be spent in vain. When once gone no gold can buy them back again."

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WINGS OF FIRE

ORIENTATION

Plate 8 My teachers at Schwartz High School—Iyadurai Solomon (standing, left) and Ramakrishna Iyer (sitting, right). They are the best examples of small-town Indian teachers committed to nurturing talent.

e e prpersess

15



WINGS OF FIRE

ORIENTATION

“He who knows others is learned, but the wise one is the one who consider is whether the choice articulates their inner feelings and knows himself. Learning without wisdom is of no use.” aspirations.

In the course of my education at MIT, three teachers shaped my Prof. KAV Pandalai taught me aero-structure design and analysis.

thinking. Their combined contributions formed the foundation on which He was a cheerful, friendly and enthusiastic teacher, who brought a I later built my professional career. These three teachers were Prof.

fresh approach to every year's teaching course. It was Professor Sponder, Prof. KAV Pandalai and Prof. Narasingha Rao. Each one of Pandalai who opened up the secrets of structural engineering to us.

them had very distinct personalities, but they shared a common impulse—

Even today I believe that everyone who has been taught by Prof. Pandalai the capacity to feed their students' intellectual hunger by sheer brilliance would agree that he was a man of great intellectual integrity and untiring zeal.

scholarship—but with no trace of arrogance. His students were free to Prof. Sponder taught me technical aerodynamics. He was an Austrian disagree with him on several points in the classroom.

with rich practical experience in aeronautical engineering. During the Prof. Narasingha Rao was a mathematician, who taught us theoretical Second World War, he had been captured by the Nazis and imprisoned aerodynamics. I still remember his method of teaching fluid dynamics.

in a concentration camp. Understandably, he had developed a very strong After attending his classes, I began to prefer mathematical physics to dislike for Germans. Inciden- tally, the aeronautical department was any other subject. Often, I have been told I carry a “surgical knife” to headed by a German, Prof. Walter Repenthin. Another well-known aeronautical design reviews. If it had not been for Prof. Rao's kind and professor, Dr Kurt Tank, was a distinguished aeronautical engineer who persistent advice on picking up proofs to equations of aerodynamic flow, had designed the German Focke–Wulf FW 190 single-seater fighter I would not have acquired this metaphorical tool.

plane, an outstanding combat aircraft of the Second World War. Dr Aeronautics is a fascinating subject, containing within it the promise Tank later joined the Hindustan Aeronautics Limited (HAL) in Bangalore of freedom. The great difference between freedom and escape, between and was responsible for the design of India's first jet fighter, the HF-24

motion and movement, between slide and flow are the secrets of this Marut.

science. My teachers revealed these truths to me. Through their Notwithstanding these irritants, Prof. Sponder preserved his meticulous teaching, they created within me an excitement about individuality and maintained high professional standards. He was always aeronautics. Their intellectual fervour, clarity of thought and passion for calm, energetic and in total control of himself. He kept abreast of the perfection helped me to launch into a serious study of fluid dynamics-latest technologies and expected his students to do the same. I consulted modes of compressible medium motion, development of shock waves him before opting for aeronautical engineering. He told me that one and shock, induced flow separation at increasing speeds, shock stall and should never worry about one's

future prospects: instead, it was more shock-wave drag.

important to lay sound foundations, to have sufficient enthusiasm and an Slowly, a great amalgamation of information took place in my mind.

accompanying passion for one's chosen field of study. The trouble with The structural features of aeroplanes began to gain new meanings—

Indians, Prof. Sponder used to observe, was not that they lacked biplanes, monoplanes, tailless planes, canard configured planes, delta-educational opportunities or industrial infrastructure—the trouble was in wing planes, all these began to assume increasing significance for me.

their failure to discriminate between disciplines and to rationalise their The three teachers, all of them authorities in their different fields, helped choices. Why aeronautics? Why not electrical engineering? Why not me to mould a composite knowledge.

mechanical engineering? I myself would like to tell all novitiate engineering students that when they choose their specialization, the essential point to e e prpersess

16



WINGS OF FIRE

ORIENTATION

My third and last year at MIT was a year of transition and was to and patted my back in appreciation. He said, “I knew I was putting you have a great impact on my later life. In those days, a new climate of under stress and asking you to meet an impossible deadline. I never political enlightenment and industrial effort was sweeping across the expected you to perform so well.”

country. I had to test my belief in God and see if it could fit into the During the rest of the period of the project, I participated in an essay matrix of scientific thinking. The accepted view was that a belief in competition organized by the MIT Tamil Sangam (Literary Society).

scientific methods was the only valid approach to knowledge. If so, I Tamil is my mother tongue and I am proud of its origins, which have wondered, was matter alone the ultimate reality and were spiritual been traced back to Sage Agastya in the pre-Ramayana period; its phenomena but a manifestation of matter? Were all ethical values relative, literature dates back to the fifth century BC. It is said to be a language and was sensory perception the only source of knowledge and truth? I moulded by lawyers and grammarians and is internationally acclaimed wondered about these issues, attempting to sort out the vexing question for its clear-cut logic. I was very enthusiastic about ensuring that science of “scientific temper” and my own spiritual interests. The value system did not remain outside the purview of this wonderful language. I wrote in which I had been nurtured was profoundly religious. I had been taught an article entitled “Let Us Make Our Own Aircraft” in Tamil. The article that true reality lay beyond the material world in the spiritual realm, and evoked much interest and I

won the competition, taking the first prize that knowledge could be obtained only through inner experience.

from 'Devan', the editor of the popular Tamil weekly, Ananda Vikatan.

Meanwhile, when I had finished my course work, I was assigned a My most touching memory of MIT is related to Prof. Sponder. We project to design a low-level attack aircraft together with four other were posing for a group photograph as part of a farewell ritual. All the colleagues. I had taken up the responsibility of preparing and drawing graduating students had lined up in three rows with the professors seated the aerodynamic design. My team mates distributed among themselves in the front. Suddenly, Prof. Sponder got up and looked for me. I was the tasks of designing the propulsion, structure, control and standing in the third row. "Come and sit with me in the front," he said. I instrumentation of the aircraft. One day, my design teacher, Prof.

was taken aback by Prof. Sponder's invitation. "You are my best student Srinivasan, then the Director of the MIT, reviewed my progress and and hard work will help you bring a great name for your teachers in declared it dismal and disappointing. I offered a dozen excuses for the future." Embarrassed by the praise but honoured by the recognition, I delay, but none of them impressed Prof. Srinivasan. I finally pleaded for sat with Prof. Sponder for the photograph. "Let God be your hope, your a month's time to complete the task. The Professor looked at me for stay, your guide and provide the lantern for your feet in your journey into some time and said, "Look, young man, today is Friday afternoon. I give the future," said the introverted genius, bidding me adieu.

you three days' time. If by Monday morning I don't get the configuration drawing, your scholarship will be stopped." I was dumbstruck. The From MIT, I went to Hindustan Aeronautics Limited (HAL) at scholarship was my lifeline and I would be quite helpless if it was Bangalore as a trainee. There I worked on engine overhauling as part of withdrawn. I could see no other way out but to finish the task as I had a team. Hands-on work on aircraft engine overhauling was very been instructed. That night, I remained at the drawing board, skipping educative. When a principle learnt in the classroom is borne out by dinner. Next morning, I took only an hour's break to freshen up and eat practical experience, it creates a strange sense of excitement—akin to a little food. On Sunday morning, I was very near completion, when unexpectedly running into an old friend among a crowd of strangers. At suddenly I felt someone else's presence in the room. Prof. Srinivasan HAL, I worked on the overhauling of both piston and turbine engines.

was watching me from a distance. Coming straight from the gymkhana, The hazy concepts of gas dynamics and diffusion processes in the he was still in his tennis outfit and had dropped in to see my progress.

working principle of after burning came into sharper focus in my mind.

After examining my work, Prof. Srinivasan hugged me affectionately I was also trained in radial engine-cum-drum operations.

e e prpersess



WINGS OF FIRE

ORIENTATION

I learned how to check a crankshaft for wear and tear, and a connecting rod and crankshaft for twist. I did calibrations of a fixed-pitch fan fitted to a super-charged engine. I opened up pressure and acceleration-cum-speed control systems, and air starter supply systems of turbo-engines. Getting to understand feathering, un-feathering and reversing of propeller engines was very interesting. The demonstration of the delicate art of beta (blade angle control) by HALL technicians still 3

lingers in my memory. They had neither studied in major universities, nor were they merely implementing what their engineer-in-charge was suggesting. They had been working hands-on for years and this had given them something like an intuitive feel for the work.

Two alternative opportunities for employment, both close to my long-standing dream of flying, presented themselves before me when I came Through the window of the compartment, I watched the countryside slip past. From a distance, the men in the fields in out of HALL as a graduate aeronautical engineer. One was a career in their white dhotis and turbans, and the womenfolk in bright the Air Force and another was a job at the Directorate of Technical splashes of colour against the green background of paddy fields, seemed Development and Production, DTD&P(Air), at the Ministry of Defence.

to inhabit some beautiful painting. I sat glued to the window. Almost I applied for both. The interview calls arrived from both the places almost everywhere, people were engaged in some activity which had a rhythm simultaneously. I was asked to reach Dehra Dun by the Air Force and tranquillity about it—men driving cattle, women fetching water from recruitment authorities and Delhi by DTD&P(Air). The boy from the streams. Occasionally, a child would appear and wave at the train.

Coromandel Coast took a train to the North of India. My destination was more than 2000 km away, and was to be my first encounter with It is astonishing how the landscape changes as one moves northwards.

the vastness of my motherland.

The rich and fertile plains of the river Ganga and its numerous tributaries have invited invasion, turmoil, and change. Around 1500 BC, fair-skinned

* * *

Aryans swept in through the mountain passes from the far north-west.

The tenth century brought Muslims, who later mingled with the local people and became an integral part of this country. One empire gave way to another. Religious conquests continued. All this time, the

part of India south of the Tropic of Cancer remained largely untouched, safe behind the shield of the Vindhya and Satpura mountain ranges. The Narmada, Tapti, Mahanadi, Godavari, and Krishna rivers had woven a net of almost unassailable protection for the tapering Indian peninsula.

To bring me to Delhi, my train had crossed all these geographical impediments through the power of scientific advancement.

I halted for a week in Delhi, the city of the great Sufi Saint Hazrat Nizamuddin, and appeared for the interview at DTD&P(Air). I did well at the interview. The questions were of a routine nature, and did not perplex me.

18



WINGS OF FIRE

ORIENTATION

challenge my knowledge of the subject. Then I proceeded to Dehra as you can rely upon the eternally unbroken promise of sunrise... and of Dun for my interview at the Air Force Selection Board. At the Selection Spring.

Board, the emphasis was more on “personality” than on intelligence.

When the student is ready, the teacher will appear—How true! Here Perhaps they were looking for physical fitness and an articulate manner.

was the teacher to show the way to a student who had nearly gone I was excited but nervous, determined but anxious, confident but tense.

astray! “Accept your destiny and go ahead with your life. You are not I could only finish ninth in the batch of 25 examined to select eight destined to become an Air Force pilot. What you are destined to become officers for commissioning in the Air Force. I was deeply disappointed.

is not revealed now but it is predetermined. Forget this failure, as it was It took me some time to comprehend that the opportunity to join the Air essential to lead you to your destined path. Search, instead, for the true Force had just slipped through my fingers. I dragged myself out of the purpose of your existence. Become one with yourself, my son! Surrender Selection Board and stood at the edge of a cliff. There was a lake far yourself to the wish of God,” Swamiji said.

below. I knew that the days ahead would be difficult. There were questions to be answered and a plan of action to be prepared. I trekked I returned to Delhi and enquired at the DTD&P(Air) about the down to Rishikesh.

outcome of my interview. In response, I was handed my appointment letter. I joined the next day as Senior Scientific Assistant on a basic I bathed in the Ganga and revelled in the purity of its water.

Then, I salary of Rs 250/- per month. If this was to be my destiny, I thought, let walked to the Sivananda Ashram situated a little way up the hill. I could it be so. Finally, I was filled with mental peace. No more did I feel any feel intense vibrations when I entered. I saw a large number of sadhus bitterness or resentment at my failure to enter the Air Force. All this seated all around in a state of trance. I had read that sadhus were psychic was in 1958.

people—people who know things intuitively and, in my dejected mood, I sought answers to the doubts that troubled me.

At the Directorate, I was posted at the Technical Centre (Civil Aviation). If I was not flying aeroplanes, I was at least helping to make I met Swami Sivananda—a man who looked like a Buddha, wearing them airworthy. During my first year in the Directorate, I carried out a a snow-white dhoti and wooden slippers. He had an olive complexion design assignment on supersonic target aircraft with the help of the and black, piercing eyes. I was struck by his irresistible, almost child-officer-in-charge, R Varadharajan, and won a word of praise from the like smile and gracious manner. I introduced myself to the Swamiji. My Director, Dr Neelakantan. To gain shop-floor exposure to aircraft Muslim name aroused no reaction in him. Before I could speak any maintenance, I was sent to the Aircraft and Armament Testing Unit further, he inquired about the source of my sorrow. He offered no (A&ATU) at Kanpur. At that time, they were involved in a tropical explanation of how he knew that I was sad and I did not ask.

evaluation of Gnat Mk I aircraft. I participated in the performance I told him about my unsuccessful attempt to join the Indian Air Force assessment of its operation systems.

and my long-cherished desire to fly. He smiled, washing away all my Even in those days, Kanpur was a very populous city. It was my first anxiety almost instantly. Then he said in a feeble, but very deep voice, experience of living in an industrial town. The cold weather, crowds, Desire, when it stems from the heart and spirit, when it is pure and noise and smoke were in total contrast to what I was used to in intense, possesses awesome electromagnetic energy. This energy is Rameswaram. I was particularly troubled by the ubiquitous presence of released into the ether each night, as the mind falls into the sleep state.

potatoes on the dining table, right from breakfast to dinner. To me, it Each morning it returns to the conscious state reinforced with the cosmic seemed that a feeling of loneliness pervaded the city. The people on the currents. That which has been imaged will surely and certainly be streets had all come from their villages in search of jobs in factories, manifested. You can rely, young man, upon this ageless promise as surely leaving behind the smell of their soil and the protection of their families.

e e prpersess



ORIENTATION

On my return to Delhi, I was informed that the design of a DART

available to begin with. All we knew was that we had to make a successful target had been taken up at the DTD&P (Air) and that I had been heavier-than-air flying machine. We tried to read as much literature as included in the design team. I completed this task with the other team we could find on hovercrafts, but there was not much available. We members. Then, I undertook a preliminary design study on a Human tried to consult people knowledgeable in this area, but could find none.

Centrifuge. I later carried out the design and development of a Vertical One day, I simply took the decision to proceed with the limited information Takeoff and Landing Platform. I was also associated with the and resources available.

development and construction of the Hot Cockpit. Three years passed.

This endeavour to produce a wingless, light, swift machine opened Then the Aeronautical Development Establishment (ADE) was born in the windows of my mind. I was quick to see at least a metaphorical Bangalore and I was posted to the new establishment.

connection between a hovercraft and an aircraft. After all, the Wright Bangalore as a city was in direct contrast to Kanpur. In fact, I feel Brothers made the first aeroplane after fixing bicycles for seven years!

our country has an uncanny way of bringing out extremes in her people.

I saw in the GEM project great opportunities for ingenuity and growth.

I suppose, it is because Indians have been both afflicted and enriched by We went straight into hardware development after spending a few centuries of migrations. Loyalty to different rulers has dulled our capacity months on the drawing board.

for a single allegiance. Instead, we have developed an extraordinary There is always the danger that a person with my kind of background—

ability to be compassionate and cruel, sensitive and callous, deep and rural or small-town, middle-class, whose parents had limited education—

fickle, all at the same time. To the untrained eye, we may appear colourful will retreat into a corner and remain there struggling for bare existence, and picturesque; to the critical eye, we are but shoddy imitations of our unless some great turn of circumstance propels him into a more various masters. In Kanpur, I saw paan-chewing imitations of Wajid Ali favourable environment. I knew I had to create my own opportunities.

Shah, and in Bangalore it was replaced by dog-walking sahibs. Here too, I longed for the depth and calmness of Rameswaram. The Part by part, subsystem by subsystem, stage by stage, things started relationship between the heart and the head of an earthy Indian has moving. Working on this project, I

learned that once your mind stretches been eroded by the divided sensibilities of our cities. I spent my evenings to a new level it never goes back to its original dimension.

exploring the gardens and shopping plazas of Bangalore.

At that time VK Krishna Menon was the Defence Minister. He was The workload at ADE during the first year of its inception was quite keenly interested in the progress of our small project, which he envisioned light. In fact, I had to generate work for myself at first, until the tempo as the beginning of the indigenous development of India's defence gradually built up. Based on my preliminary studies on ground-handling equipment. Whenever he was in Bangalore, he always found some time equipment, a project team was formed to design and develop an to review the progress of our project. His confidence in our ability ignited indigenous hovercraft prototype as a ground equipment machine (GEM).

our enthusiasm. I would enter the assembly shop leaving my other The team was a small working group, comprising four persons at the problems outside, just as my father used to enter the mosque for prayer, level of Scientific Assistant. Dr OP Mediratta, Director of the ADE, leaving his shoes outside.

asked me to lead the team. We were given three years to launch the But not everyone accepted Krishna Menon's opinion about GEM.

engineering model.

Our experiments with the available parts and components did not exactly The project was, by any standards, bigger than our collective delight my senior colleagues. Many even called us a group of eccentric capabilities. None of us had any experience in building a machine, let inventors in pursuit of an impossible dream. I, being the leader of the alone a flying machine. There were no designs or standard components

“navvies”, was a particularly inviting target. I was regarded as yet another e e prpersess

20



WINGS OF FIRE

ORIENTATION

country bumpkin who believed that riding the air was his domain. The

“You have demonstrated that the basic problems of hovercraft weight of opinion against us buttressed my ever-optimistic mind. The development are solved. Go for a more powerful prime mover and call comments of some of the senior scientists at ADE made me recall John me for a second ride,” Krishna Menon told me. The skeptical Group Trowbridge's famous satirical poem on the Wright Brothers, published Captain (now Air Marshall) Golay, later became a good friend of mine.

in 1896:

We completed the project ahead of schedule. We had a working

. . . . with thimble and thread

hovercraft with us, moving on an air cushion of about 40mm with a load *And wax and hammer, and buckles and screws*, of 550kg, including the tare weight. Dr Mediratta was visibly pleased *And all such things as geniuses use*; —

with the achievement. But by this time, Krishna Menon was out of office *Two bats for patterns, curious fellows!*

and could not take his promised second ride. In the new order, not many *A charcoal-pot and a pair of bellows*.

people shared his dream with regard to military applications of an When the project was about a year old, Defence Minister Krishna indigenous hovercraft. In fact, even today, we import hovercrafts. The Menon made one of his routine visits to ADE. I escorted him into our project was mired in controversies and was finally shelved. It was a assembly shop. Inside, on a table lay the GEM model broken down into new experience for me. So far, I had believed that the sky was the limit, sub-assemblies. The model represented the culmination of one year's but now it appeared that the limits were much closer. There are boundaries untiring efforts to develop a practical hovercraft for battlefield that dictate life: you can only lift so much weight; you can only learn so applications. The minister fired one question after another at me, fast; you can only work so hard; you can only go so far!

determined to ensure that the prototype would go into test flight within I was unwilling to face reality. I had put my heart and soul into Nandi.

the coming year. He told Dr Mediratta, “GEM flight is possible with the That it would not be used was something beyond my comprehension. I gadgets Kalam now possesses”.

was disappointed and disillusioned. In this period of confusion and The hovercraft was christened Nandi, after the bull ridden by Lord uncertainty, memories from my childhood came back to me and I Shiva. For a prototype, its form, fit and finish was beyond our expectation, discovered new meanings in them.

given the rudimentary infrastructure we possessed. I told my colleagues, Pakshi Sastry used to say, “Seek the truth, and the truth shall set you

“Here is a flying machine, not constructed by a bunch of cranks but by free.” As the Bible says, “Ask and you shall receive.” It did not happen engineers of ability. Don't look at it—it is not made to look at, but to fly immediately, but it happened nevertheless. One day, Dr Mediratta called with.”

me. He inquired about the state of our hovercraft. When told that it was Defence Minister Krishna Menon flew in the Nandi, overruling the in perfect condition to be flown, he asked me to organize a

demonstration accompanying officials' concern for his safety. A Group Captain in the for an important visitor the next day. No VIP was scheduled to visit the minister's troupe, who had logged in many thousands of flying hours, laboratory during the next week as far as I knew. However, I even offered to fly the machine to save the minister from the potential communicated Dr Mediratta's instructions to my colleagues and we felt danger of flying with an inexperienced civilian pilot like myself and a new surge of hope.

gestured to me to come out of the machine. I was sure about my The next day Dr Mediratta brought a visitor to our hovercraft—a competence in flying the machine I had made, and therefore shook my tall, handsome, bearded man. He asked me several questions about the head in negation. Observing this wordless communication, Krishna machine. I was struck by the objectivity and clarity of his thinking. “Can Menon dismissed the insulting suggestion of the Group Captain with a you give me a ride in the machine?” he enquired. His request filled me laugh and signalled to me to start the machine. He was very happy.

with joy. Finally, here was someone who was interested in my work.

e e prpersess

21



WINGS OF FIRE

ORIENTATION

We took a ten-minute ride in the hovercraft, a few centimetres above I was advised to stay back for a couple of days. However, the next the ground. We were not flying, but were definitely floating in the air.

evening I was told about my selection. I was to be absorbed as a rocket The visitor asked me a few questions about myself, thanked me for the engineer at INCOSPAR. This was a breakthrough a young man like ride and departed. But not before introducing himself—he was Prof.

myself dreamed of.

MGK Menon, Director of the Tata Institute of Fundamental Research My work at INCOSPAR commenced with a familiarization course (TIFR). After a week, I received a call from the Indian Committee for at the TIFR Computer Centre. The atmosphere here was remarkably Space Research (INCOSPAR), to attend an interview for the post of different from that at DTD&P (AIR). Labels mattered very little. There Rocket Engineer. All I knew about INCOSPAR at that time was that it was not need for anyone to justify his position or to be at the receiving was formed out of the TIFR talent pool at Bombay (now Mumbai) to end of the others' hostility.

organize space research in India.

Some time in the latter half of 1962, INCOSPAR took the decision to I went to Bombay to attend the interview. I was unsure about the set up the Equatorial Rocket Launching Station at Thumba, a sleepy type of questions I would have to face at the interview. There was fishing village near Trivandrum (now Thiruvananthapuram) in Kerala.

hardly any time to read up or talk to any experienced person. Lakshmana Dr Chitnis of the Physical Research Laboratory, Ahmedabad had spotted Sastry's voice quoting from the Bhagawad Gita echoed in my ears: it as a suitable location as it was very close to the earth's magnetic *All beings are born to delusion . . . overcome by the equator*. This was the quiet beginning of modern rocket-based research *dualities which arise from wish and hate But those* in India. The site selected at Thumba lay between the railway line and *men of virtuous deeds in whom sin has come to an end*, the sea coast, covering a distance of about two and a half km and *freed from the delusion of dualities, worship Me* measuring about 600 acres. Within this area, stood a large church, whose *steadfast in their vows*.

site had to be acquired. Land acquisition from private parties is always I reminded myself that the best way to win was to not need to win.

a difficult and time-consuming process, especially in densely populated The best performances are accomplished when you are relaxed and places like Kerala. In addition, there was the delicate matter of acquiring free of doubt. I decided to take things as they came. Since neither Prof.

a site of religious significance. The Collector of Trivandrum then, K

MGK Menon's visit nor the call for an interview had been of my making, Madhavan Nair, executed this task in a most tactful, peaceful and I decided this was the best attitude to take.

expeditious manner, with the blessings and cooperation of Right Rev. Dr Dereira, who was the Bishop of Trivandrum in 1962. Soon RD John, the I was interviewed by Dr Vikram Sarabhai along with Prof. MGK

executive engineer of the Central Public Works Department (CPWD), Menon and Mr Saraf, then the Deputy Secretary of the Atomic Energy had transformed the entire area. The St. Mary Magdalene church housed Commission. As I entered the room, I sensed their warmth and the first office of the Thumba Space Centre. The prayer room was my friendliness. I was almost immediately struck by Dr Sarabhai's warmth.

first laboratory, the Bishop's room was my design and drawing office.

There was none of the arrogance or the patronising attitudes which To this day, the church is maintained in its full glory and, at present, interviewers usually display when talking to a young and vulnerable houses the Indian Space Museum.

candidate. Dr Sarabhai's questions did not probe my existing knowledge or skills; rather they were an exploration of the possibilities I was filled Very soon after this, I was asked to proceed to America for a six-with. He was looking at me as if in reference to a larger whole. The month training programme on sounding rocket launching techniques, at entire encounter seemed to me a total moment

of truth, in which my the National Aeronautics and Space Administration (NASA) work dream was enveloped by the larger dream of a bigger person.

centres. I took some time off before going abroad and went to e e prpersess

22



WINGS OF FIRE

ORIENTATION

Rameswaram. My father was very pleased to learn about the opportunity that had come my way. He took me to the mosque and organized a special namaz in thanksgiving. I could feel the power of God flowing in a circuit through my father to me and back to God; we were all under the spell of the prayer.

One of the important functions of prayer, I believe, is to act as a stimulus to creative ideas. Within the mind are all the resources required for successful living. Ideas are present in the consciousness, which when released and given scope to grow and take shape, can lead to successful events. God, our Creator, has stored within our minds and personalities, great potential strength and ability. Prayer helps us to tap and develop these powers.

Ahmed Jallaluddin and Samsuddin came to see me off at Bombay airport. It was their first exposure to a big city like Bombay, just as I myself was about to have my first exposure to a mega city like New York. Jallaluddin and Samsuddin were self-reliant, positive, optimistic men who undertook their work with the assurance of success. It is from these two persons that I drew the core creative power of my mind. My sentiments could not be contained, and I could feel the mist of tears in my eyes. Then, Jallaluddin said, “Azad, we have always loved you, and we believe in you. We shall always be proud of you”. The intensity and purity of their faith in my capabilities broke my last defences, and tears welled up in my eyes.

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23



WINGS OF FIRE

ORIENTATION - 1

II

CREATION

[1963 – 1980]

ee prpersess

24



WINGS OF FIRE

ORIENTATION - 1

ACHIEVERS

My impression of the American people can be summarized by a quotation from Benjamin Franklin, “Those things that hurt instruct!” I realised that people in this part of the world meet their problems head 4

on. They attempt to get out of them rather than suffer them.

My mother had once narrated an incident from the Holy Book—

after God created man, he asked the angels to prostrate themselves before Adam. Everybody prostrated themselves except Iblis, or Satan, who refused. “Why did you not prostrate yourself?” Allah asked. “You created me of fire and him of clay. Does not that make me nobler than Achievers

Adam?” Satan contended. God said, “Be gone from paradise! This is no place for your contemptuous pride.” Satan obeyed, but not before cursing I

Adam with the same fate. Soon Adam followed suit by becoming a started my work at NASA at the Langley Research Centre (LRC) transgressor after eating the forbidden fruit. Allah said, “Go hence and in Hampton, Virginia. This is primarily an R&D centre for may your descendants live a life of doubt and mistrust.” advanced aerospace technology. One of my most vivid memories What makes life in Indian organizations difficult is the widespread of LRC is of a piece of sculpture depicting a charioteer driving two prevalence of this very contemptuous pride. It stops us from listening to horses, one representing scientific research and the other technological our juniors, subordinates and people down the line. You cannot expect a development, metaphorically encapsulating the interconnection between person to deliver results if you humiliate him, nor can you expect him to research and development.

be creative if you abuse him or despise him. The line between firmness From LRC I went to the Goddard Space Flight Centre (GSFC) at and harshness, between strong leadership and bullying, between discipline Greenbelt, Maryland. This Centre develops and manages most of NASA’s and vindictiveness is very fine, but it has to be drawn. Unfortunately, the earth-orbiting science and applications satellites. It operates NASA’s only line prominently drawn in our country today is

between the ‘heroes’

tracking networks for all space missions. Towards the end of my visit, I and the ‘zeros’. On one side are a few hundred ‘heroes’ keeping nine went to the Wallops Flight Facility at Wallops Island in East Coast, Virginia.

hundred and fifty million people down on the other side. This situation This place was the base for NASA’s sounding rocket programme. Here, has to be changed.

I saw a painting prominently displayed in the reception lobby. It depicted As the process of confronting and solving problems often requires a battle scene with a few rockets flying in the background. A painting hard work and is painful, we have endless procrastination. Actually, with this theme should be the most commonplace thing at a Flight Facility, problems can be the cutting edge that actually distinguish between but the painting caught my eye because the soldiers on the side launching success and failure. They draw out innate courage and wisdom.

the rockets were not white, but dark-skinned, with the racial features of people found in South Asia. One day, my curiosity got the better of me, As soon as I returned from NASA, India’s first rocket launch took drawing me towards the painting. It turned out to be Tipu Sultan’s army place on 21 November 1963. It was a sounding rocket, called Nike-fighting the British. The painting depicted a fact forgotten in Tipu’s own Apache, made at NASA. The rocket was assembled in the church country but commemorated here on the other side of the planet. I was building I have referred to earlier. The only equipment available to happy to see an Indian glorified by NASA as a hero of warfare rocketry.

transport the rocket was a truck and a manually operated hydraulic e e prpersess

25



WINGS OF FIRE

ORIENTATION - 1

ACHIEVERS

crane. The assembled rocket was to be shifted from the church building training, but Prof. Sarabhai’s faith in our capabilities. After the successful to the launch pad by truck. When the rocket was lifted by the crane and launch of Nike-Apache, he chose to share with us his dream of an was about to be placed on the launcher, it started tilting, indicating a leak Indian Satellite Launch Vehicle.

in the hydraulic system of the crane. As we were fast approaching the Prof. Sarabhai’s optimism was highly contagious. The very news of launch time, 6 p.m., any repairs to the crane had to be ruled out.

his coming to Thumba would electrify people and all laboratories, Fortunately, the leak was not large and we managed to lift the rocket workshops and design offices would hum with unceasing activity. People manually, using our collective muscle power and finally placing it on the would work

virtually round the clock because of their enthusiasm to launcher.

show Prof. Sarabhai something new, something that had not been done In the maiden Nike-Apache launch, I was in charge of rocket before in our country—be it a new design or a new method of fabrication integration and safety. Two of my colleagues who played a very or even an out-of-the-way administrative procedure. Prof. Sarabhai active and crucial role in this launch were D Easwardas and R

would often assign multiple tasks to a single person or a group. Though Aravamudan. Easwardas undertook the rocket assembly and arranged some of those tasks would appear totally unrelated in the beginning, the launch. Aravamudan, whom we called Dan, was in charge of radar, they would, at a later stage, emerge as deeply interconnected. When telemetry and ground support. The launch was smooth and problem-Prof. Sarabhai was talking to us about the Satellite Launch Vehicle (SLV), free. We obtained excellent flight data and returned with a sense of he asked me, almost in the same breath, to take up studies on a rocket-pride and accomplishment.

assisted take-off system (RATO) for military aircraft. The two things When we were relaxing the next evening at the dinner table, we had no apparent connection except in the mind of this great visionary. I received news of the assassination of President John F Kennedy in knew that all I had to do was to remain alert and focussed on my purpose, Dallas, Texas. We were appalled. The Kennedy years were a significant and sooner or later, an opportunity to do a challenging job would enter era in America, when young men were at the helm of affairs. I used to my laboratory.

read with interest about Kennedy's moves in the missile crisis of late Prof. Sarabhai was ever-willing to try out novel approaches and liked 1962. The Soviet Union built missile sites in Cuba, from which it would to draw in young people. He had the wisdom and judgement which have been possible to launch attacks on American cities. Kennedy enabled him to realise not only if something was well done, but also imposed a blockade or 'quarantine', barring the introduction of any when it was time to stop. In my opinion, he was an ideal experimenter offensive missiles to Cuba. America also threatened to respond to any and innovator. When there were alternative courses of action before us, Soviet nuclear attack from Cuba on any country in the Western whose outcome was difficult to predict, or to reconcile varying Hemisphere by retaliating against the USSR. After fourteen days of perspectives, Prof. Sarabhai would resort to experimentation to resolve intense drama, the crisis was resolved by the Soviet Premier Khrushchev the issue. This was precisely the situation at INCOSPAR in 1963. A ordering that the Cuban bases be dismantled and the missiles returned bunch of young, inexperienced, but nevertheless energetic and to Russia.

enthusiastic persons were given the task of fleshing out the spirit of self-The next day, Prof. Sarabhai had a detailed discussion with us on reliance in the field of science and technology in general, and of space future plans. He was creating a new frontier in the field of science and research in particular. It was a great example of leadership by trust.

technology in India. A new generation, scientists and engineers in their The rocket launch site later blossomed into the Thumba Equatorial 30s and early 40s, was being charged with an unprecedented dynamism.

Rocket Launch Station (TERLS). TERLS was established through active Our biggest qualifications at INCOSPAR were not our degrees and collaboration with France, USA and USSR. The leader of the Indian e e prpersess

26



WINGS OF FIRE

ORIENTATION - 1

ACHIEVERS

space programme—Prof. Vikram Sarabhai—had comprehended the full operational sounding rockets were developed. These rockets had wide implications of the challenge and had not balked at taking it on. Right ranging capabilities, and to date several hundreds of these rockets have from the day INCOSPAR was formed, he was aware of the need to been launched for various scientific and technological studies.

organize an integrated national space programme, with the equipment I still remember that the first Rohini rocket consisted of a single solid for the manufacture of rockets and launch facilities developed and propulsion motor weighing a mere 32 kg. It lifted a nominal 7 kg payload produced indigenously.

to an altitude of about 10 km. It was soon followed by another, to which With this in view, a wide-ranging programme for scientific and one more solid propellant stage was added to dispatch multi-experiment technological development in rocket fuels, propulsion systems, payloads weighing nearly 100 kg to an altitude of over 350 km.

aeronautics, aerospace materials, advanced fabrication techniques, rocket The development of these rockets had resulted in a fully indigenous motor instrumentation, control and guidance systems, telemetry, tracking capability in the production of sounding rockets as well as their propellants.

systems and scientific instruments for experimentation in space were This programme had brought into the country technology for the launched at the Space Science and Technology Centre and the Physical production of very high-performance solid propellants, like those based Research Laboratory at Ahmedabad. Incidentally, this laboratory has on polyurethane and polybutane polymer. It later resulted in the setting produced a large number of Indian space scientists of extremely high up of a Propellant Fuel Complex (PFC) to manufacture strategic calibre over the years.

chemicals required for rocket engines, and a Rocket Propellant Plant The real journey of the Indian aerospace programme, however, had (RPP) to produce propellants.

begun with the Rohini Sounding Rocket (RSR) Programme. What is it The development of Indian rockets in the twentieth century can be that distinguishes a sounding rocket from a Satellite Launch

Vehicle seen as a revival of the eighteenth century dream of Tipu Sultan. When (SLV) and from a missile? In fact, they are three different kinds of Tipu Sultan was killed, the British captured more than 700 rockets and rockets. Sounding rockets are normally used for probing the near-earth subsystems of 900 rockets in the battle of Turukhanahally in 1799. His environment, including the upper regions of the atmosphere. While they army had 27 brigades, called Kushoons, and each brigade had a company can carry a variety of scientific payloads to a range of altitudes, they of rocket men, called Jourks. These rockets had been taken to England cannot impart the final velocity needed to orbit the payload. On the by William Congreve and were subjected by the British to what we call other hand, a launch vehicle is designed to inject into orbit a technological

‘reverse engineering’ today. There were, of course, no GATT, IPR Act, payload or satellite. The final stage of a launch vehicle provides the or patent regime. With the death of Tipu, Indian rocketry also met its necessary velocity for a satellite to enter an orbit. This is a complex demise—at least for 150 years.

operation requiring on-board guidance and control systems. A missile, though belonging to the same family, is a still more complex system. In Meanwhile, rocket technology made great strides abroad. Konstantin addition to the large terminal velocity and onboard guidance and control, Tsiolkovsky in Russia (1903), Robert Goddard in USA (1914) and it must have the capability to home onto targets. When the targets are Hermann Oberth in Germany (1923) gave rocketry new dimensions. In fast-moving and capable of manoeuvring, a missile is also required to Nazi Germany, Wernher von Braun’s group produced V-2 short range carry out target-tracking functions.

ballistic missiles and showered fire on the Allied Forces. After the war, both the USA and the USSR captured their share of German rocket The RSR programme was responsible for the development and technology and rocket engineers. With this booty, they started to run fabrication of sounding rockets and their associated on-board systems their deadly arms race with missiles and warheads.

for scientific investigations in India. Under this programme, a family of e e prpersess

27



WINGS OF FIRE

ORIENTATION - 1

DREAMERS

Rocketry was reborn in India thanks to the technological vision of Prime Minister Jawaharlal Nehru. Prof. Sarabhai took the challenge of giving physical dimensions to this dream. Very many individuals with myopic vision questioned the relevance of space activities in a newly independent nation which was finding it difficult to feed its population.

But neither Prime Minister Nehru nor Prof. Sarabhai had any ambiguity of purpose. Their vision was

very clear: if Indians were to play a meaningful role in the community of nations, they must be second to 5

none in the application of advanced technologies to their real-life problems. They had no intention of using it merely as a means to display our might.

* * *

Dreamers

During his frequent visits to Thumba, Prof. Sarabhai would openly review the progress of work with the entire team.

He never gave directions. Rather, through a free exchange of views, he led us forward into new terrain which often revealed an unforeseen solution. Perhaps he was aware that though a particular goal might be clear to himself, and he could give adequate directions for its accomplishment, his team members might have resisted working towards a goal that made no sense to them. He considered the collective understanding of the problem the main attribute of effective leadership.

He once told me, “Look, my job is to make decisions; but it is equally important to see to it that these decisions are accepted by my team members.”

In fact, Prof. Sarabhai took a series of decisions that were to become the life-mission of many. We would make our own rockets, our own Satellite Launch Vehicles (SLVs) and our own satellites. And this would not be done one-by-one but concurrently, in a multi-dimensional fashion.

In the development of payloads for the sounding rockets, instead of getting a certain payload and then engineering it to fit into the rocket, we discussed the matter threadbare with the payload scientists working in different organizations and at different locations. I may even say that the most significant achievement of the sounding rocket programme was to establish and maintain nation-wide mutual trust.

e e prpersess

28



WINGS OF FIRE

ORIENTATION - 1

DREAMERS

Perhaps realising that I preferred to persuade people to do as they by Prof. UR Rao, would be engineered by my team to fit into the nose were told rather than use my legitimate authority, Prof. Sarabhai assigned cone of the Rohini Rocket. At an altitude of 150 km, the nose cone me the task of

providing interface support to payload scientists. Almost would be separated by explosion of pyros triggered by an electronic all physical laboratories in India were involved in the sounding rocket timer. With this, the X-ray sensors would be exposed to space for programme, each having its own mission, its own objective and its own collecting the required information about the emissions from stars.

payload. These payloads were required to be integrated to the rocket Together, Prof. Oda and Prof. Rao were a unique blend of intellect and structure so as to ensure their proper functioning and endurance under dedication, which one rarely sees. One day, when I was working on the flight conditions. We had X-ray payloads to look at stars; payloads fitted integration for Prof. Oda's payload with my timer devices, he insisted with radio frequency mass spectrometers to analyse the gas composition on using the timers he had brought from Japan. To me they looked flimsy, of the upper atmosphere; sodium payloads to find out wind conditions, but Prof. Oda stuck to his stand that the Indian timers be replaced by its direction and velocity. We also had ionospheric payloads to explore the Japanese ones. I yielded to his suggestion and replaced the timers.

different layers of the atmosphere. I not only had to interact with scientists The rocket took off elegantly and attained the intended altitude. But the from TIFR, National Physical Laboratory (NPL), and Physical Research telemetry signal reported mission failure on account of timer malfunction.

Laboratory (PRL), but also with payload scientists from USA, USSR, Prof. Oda was so upset that tears welled up in his eyes. I was stunned France, Germany and Japan.

by the emotional intensity of Prof. Oda's response. He had clearly put I often read Khalil Gibran, and always find his words full of wisdom.

his heart and soul into his work.

"Bread baked without love is a bitter bread that feeds but half a man's Sudhakar was my colleague in the Payload Preparation Laboratory.

hunger,"—those who cannot work with their hearts achieve but a hollow, As part of the pre-launch schedule, we were filling and remotely pressing half-hearted success that breeds bitterness all around. If you are a writer the hazardous sodium and thermite mix. As usual, it was a hot and humid who would secretly prefer to be a lawyer or a doctor, your written words day at Thumba. After the sixth such operation, Sudhakar and I went into will feed but half the hunger of your readers; if you are a teacher who the payload room to confirm the proper filling of the mix. Suddenly, a would rather be a businessman, your instructions will meet but half the drop of sweat from his forehead fell onto the sodium, and before we need for knowledge of your students; if you are a scientist who hates knew what was happening, there was a violent explosion which shook science, your performance will satisfy but half the needs of your mission.

the room. For a few paralysed seconds, I did not know what to do. The The personal unhappiness and failure to achieve results that comes from fire was spreading, and water would not extinguish the sodium fire.

being a round peg in a square hole is not, by any means, new. But there Trapped in this inferno, Sudhakar, however, did not lose his presence of are exceptions to this like Prof. Oda and Sudhakar, who bring to their mind. He broke the glass window with his bare hands and literally threw work a personal touch of magic based upon their individual character, me out to safety before jumping out himself. I touched Sudhakar's personality, inner motives, and perhaps the dreams crystallized within bleeding hands in gratitude, he was smiling through his pain. Sudhakar their hearts. They become so emotionally involved with their work that spent many weeks in the hospital recuperating from the severe burns he any dilution of the success of their effort fills them with grief.

had received.

Prof. Oda was an X-ray payload scientist from the Institute of At TERLS, I was involved with rocket preparation activities, payload Space and Aeronautical Sciences (ISAS), Japan. I remember him as a assembly, testing and evaluation besides building subsystems like payload diminutive man with a towering personality and eyes that radiated housing and jettisonable nose cones. Working with the nose cones led intelligence. His dedication to his work was exemplary. He would bring me, as a natural consequence, into the field of composite materials.

X-ray payloads from ISAS, which along with the X-ray payloads made e e prpersess

29



WINGS OF FIRE

ORIENTATION - 1

DREAMERS

It is interesting to know that the bows found, during archaeological When we were at the drawing board, he would bring someone from the excavations at different sites in the country, reveal that Indians used developed world for a technical collaboration. That was his subtle way composite bows made of wood, sinew, and horn as early as the eleventh of challenging each one of us to stretch our capabilities.

century, at least 500 years before such bows were made in medieval At the same time, even if we failed to meet certain objectives, he Europe. The versatility of composites, in the sense that they possess would praise whatever we had accomplished. Whenever he found any very desirable structural, thermal, electrical, chemical and mechanical one of us going over his head and attempting a task for which he did not properties, fascinated me. I was so enthused with these man-made have the capability or skill, Prof. Sarabhai would reassign activity in materials that I was in a hurry to know everything about them almost such a way so as to lower pressure and permit better quality work to be overnight. I used to read up everything available on related topics. I was performed. By the time the first Rohini-75 rocket was launched from particularly interested in the glass and carbon Fibre Reinforced Plastic TERLS on 20 November 1967, almost each one of us was in his own (FRP)

composites.

groove.

An FRP composite is composed of an inorganic fibre woven into a matrix that encloses it and gives the component its bulk form. In February 1969, Prime Minister Indira Gandhi visited Thumba to dedicate TERLS

By now I was accustomed to Prof. Sarabhai's working methods. He wanted to see me urgently in Delhi.

was always full of enthusiasm and optimism. In such a state of mind, to the International Space Science Community. On this occasion, she sudden flashes of inspiration were almost natural. On reaching Delhi, I commissioned the country's first filament winding machine in our contacted Prof. Sarabhai's secretary for an appointment and was asked laboratory. This event brought my team, which included CR Satya, PN

to meet him at 3.30 a.m. at Hotel Ashoka. Delhi being a slightly unfamiliar Subramanian and MN Satyanarayana, great satisfaction. We made high-place, with an unfriendly climate for someone like me, conditioned to the strength glass cloth laminates to build non-magnetic payload housings warm and humid climate of South India, I decided to wait in the hotel and flew them in two-stage sounding rockets. We also wound and test lounge after finishing my dinner.

flew rocket motor casings of up to 360 mm diameter.

I have always been a religious person in the sense that I maintain a Slowly, but surely, two Indian rockets were born at Thumba. They working partnership with God. I was aware that the best work required were christened Rohini and Menaka, after the two mythological dancers more ability than I possessed and therefore I needed help that only God in the court of Indra, the king of the sky. The Indian payloads no longer could give me. I made a true estimate of my own ability, then raised it by needed to be launched by French rockets. Could this have been done 50 per cent and put myself in God's hands. In this partnership, I have but for the atmosphere of trust and commitment which Prof. Sarabhai always received all the power I needed, and in fact have actually felt it had created at INCOSPAR? He brought into use each person's flowing through me. Today, I can affirm that the kingdom of God is knowledge and skills. He made every man feel directly involved in problem within you in the form of this power, to help achieve your goals and solving. By the very fact of the team members' participation, the solutions realise your dreams.

became genuine and earned the trust of the entire team resulting in total commitment towards implementation.

There are many different types and levels of experience that turn this internal power reaction critical. Sometimes, when we are ready, the Prof. Sarabhai was matter-of-fact and never tried to hide his gentlest of contacts with Him fills us with insight and wisdom. This disappointment. He used to talk with us in an honest and objective manner.

could come from an encounter with another person, from a word, a Sometimes I found him making things look more positive than they actually question, a gesture or even a look. Many a time, it could come even were, and then charming us by his almost magical powers of persuasion.

through a book, a conversation, some phrase, even a line from a poem e e prpersess

30



WINGS OF FIRE

ORIENTATION - 1

DREAMERS

or the mere sight of a picture. Without the slightest warning, something nevertheless in a successful manner.

new breaks into your life and a secret decision is taken, a decision that Suddenly, I became aware of another man who came and sat down you may be completely unconscious of, to start with.

on the sofa opposite mine. He was a well-built person with an intelligent I looked around the elegant lounge. Somebody had left a book on a look and refined posture. Unlike me—always disorderly in my dress—

nearby sofa. As if to fill the small hours of that cold night with some this man was wearing elegant clothes. Notwithstanding the odd hours, warm thoughts, I picked up the book and started browsing. I must have he was alert and vivacious.

turned only a few pages of the book, about which I do not remember a There was a strange magnetism about him which derailed the train thing today.

of my thoughts on innovation. And before I could get back to the book, It was some popular book related to business management. I was I was informed that Prof. Sarabhai was ready to receive me. I left the not really reading it, only skimming over paragraphs and turning pages.

book on the nearby sofa from where I had picked it up. I was surprised Suddenly, my eyes fell on a passage in the book, it was a quotation from when the man sitting on the opposite sofa was also asked to come inside.

George Bernard Shaw. The gist of the quote was that all reasonable Who was he? It was not long before my question was answered. Even men adapt themselves to the world. Only a few unreasonable ones persist before we sat down, Prof. Sarabhai introduced us to each other. He in trying to adapt the world to themselves. All progress in the world was Group Captain VS Narayanan from Air Headquarters.

depends on these unreasonable men and their innovative and often non-Prof. Sarabhai ordered coffee for both of us and unfolded his plan of conformist actions.

developing a rocket-assisted take-off system (RATO) for military aircraft.

I started reading the book from the Bernard Shaw passage onwards.

This would help our warplanes to take off from short runways in the The author was describing certain myths woven around the concept Himalayas. Hot coffee was served over small talk. It was totally and the process of innovation in industry and business. I read about the uncharacteristic of Prof. Sarabhai. But as soon as we finished the coffee, myth of strategic planning. It is generally believed that substantial Prof. Sarabhai rose and asked us to accompany him to Tilpat Range on strategic and technological planning greatly increases the odds of a ‘no the outskirts of Delhi. As we were passing through the lobby, I threw a surprises’ outcome. The author was of the opinion that it is essential for cursory glance at the sofa where I had left the book. It was not there.

a project manager to learn to live with uncertainty and ambiguity. He It was about an hour’s drive to the Range. Prof. Sarabhai showed us felt that it was a myth to hold that the key to economic success is a Russian RATO. “If I get you the motors of this system from Russia, computability. A quotation from General George Patton was given as a could you do it in eighteen months time?” Prof. Sarabhai asked us. “Yes, counterpoint to this myth—that a good plan violently executed right now we can!” Both Gp Capt VS Narayanan and I spoke almost simultaneously.

is far better than a perfect plan executed next week. It is a myth that to Prof. Sarabhai’s face beamed, reflecting our fascination. I recalled what win big one must strive to optimize, the author felt. Optimization wins I had read, “He will bestow on you a light to walk in.” only on paper, but would invariably lose later in the real world, the book said.

After dropping us back at the Hotel Ashoka, Prof. Sarabhai went to the Prime Minister’s house for a breakfast meeting. By that evening, Waiting in the hotel lobby at 1 a.m. for an appointment two hours the news of India taking up the indigenous development of a device to later was certainly not a reasonable proposition, neither for me nor for help short run take-offs by high performance military aircraft, with myself Prof. Sarabhai. But then, Prof. Sarabhai had always exhibited a strong heading the project, was made public. I was filled with many emotions—

component of unorthodoxy in his character. He was running the show happiness, gratitude, a sense of fulfilment and these lines from a little-of space research in the country—under-staffed, overworked—

known poet of the nineteenth-century crossed my mind: e e prpersess



DREAMERS

For all your days prepare

The active international cooperation dominant in the early years was *And meet them ever alike* virtually eased out in this plan and the emphasis was on self-reliance *When you are the anvil, bear –* and indigenous technologies. The plan talked about the realisation of a *When you are the hammer, strike.*

SLV for injecting lightweight satellites into a low earth orbit, upgrading RATO motors were mounted on aircraft to provide the additional of Indian satellites from laboratory models to space entities and thrust required during the take-off run under certain adverse operating development of a wide range of spacecraft subsystems like the apogee conditions like partially bombed-out runways, high altitude airfields, more and booster motors, momentum wheel, and solar panel deployment than the prescribed load, or very high ambient temperatures. The Air mechanism. It also promised a wide range of technological spin-offs Force was in dire need of a large number of RATO motors for their Slike the gyros, various types of transducers, telemetry, adhesives, and 22 and HF-24 aircraft.

polymers for non-space applications. Over and above, there was the dream of an adequate infrastructure that would be capable of supporting The Russian RATO motor shown to us at the Tilpat Range was R&D in a variety of engineering and scientific disciplines.

capable of generating a 3000 kg thrust with a total impulse of 24500 kg-seconds. It weighed 220 kg and had a double base propellant encased in The second development was the formation of a Missile Panel in the steel. The development work was to be carried out at the Space Science Ministry of Defence. Both Narayanan and I were inducted as members.

and Technology Centre with the assistance of the Defence Research The idea of making missiles in our own country was exciting, and we and Development Organization (DRDO), HAL, DTD&P(Air) and Air spent hours on end studying the missiles of various advanced countries.

Headquarters.

The distinction between a tactical missile and a strategic missile is After a detailed analysis of the available options, I chose a fibreglass often a fine one. Generally, by ‘strategic’, it is understood that the missile motor casing. We decided in favour of a composite propellant which will fly thousands of kilometres. However, in warfare, this term is used gives a higher specific impulse and aimed at a longer burning time to to denote the kind of target rather than its distance from missile launch.

utilize it completely. I also decided to take additional safety measures by Strategic missiles are those that strike at the enemy’s heartland, either incorporating a diaphragm which would rupture if the chamber pressure in counter-force attacks on their strategic forces or in counter-value for some reason exceeded twice the operating pressure. Two significant attacks on the society, which in

essence means his cities. Tactical developments occurred during the work on RATO. The first was the weapons are those that influence a battle, and the battle may be by land, release of a ten-year profile for space research in the country, prepared sea or air, or on all three together. This categorization now appears by Prof. Sarabhai. This profile was not merely an activity plan laid down nonsensical, as the US Air Force's ground-launched Tomahawk is used by the top man for his team to comply with, it was a theme paper meant in a tactical role, notwithstanding its range of some 3000 km. In those for open discussions, to be later transformed into a programme. In fact, days, however, strategic missiles were synonymous with intermediate I found it was the romantic manifesto of a person deeply in love with the range ballistic missiles (IRBMs) with ranges in the order of 1500 nautical space research programme in his country.

miles or 2780 km and inter-continental ballistic missiles (ICBMs) with a capability of going even further.

The plan mainly centred around the early ideas which had been born at INCOSPAR; it included utilization of satellites for television and Gp Capt Narayanan had an ineffable enthusiasm for indigenous guided developmental education, meteorological observations and remote sensing missiles. He was a great admirer of the strong arm approach of the Russian for management of natural resources. To this had been added the Missile Development Programme. "When it could be done there, why not development and launch of satellite launch vehicles.

here, where space research has already prepared the soil for a bonanza of missile technology?" Narayanan used to needle me.

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32



WINGS OF FIRE

ORIENTATION - 1

DREAMERS

The bitter lessons of the two wars in 1962 and 1965 had left the a while, and then asked for time until the next evening to do some Indian leadership with little choice in the matter of achieving self-reliance homework before answering my question.

in military hardware and weapon systems. A large number of Surface-The next evening, Babu came to me before the appointed time. His to-Air Missiles (SAMs) were obtained from the USSR to guard strategic face was beaming with promise. "We can do it, sir! The RATO system locations. Gp Capt Narayanan passionately advocated the development can be made without imports. The only hurdle is the inherent inelasticity of these missiles in the country.

in the approach of the organization towards procurement and sub-While working together on RATO motors and on the Missile Panel, contracting, which would be the two major thrust areas to avoid imports.” Narayanan and I played the roles of student and teacher interchangeably He gave me seven points, or, rather, asked for seven liberties—financial wherever required. He was very eager to learn about rocketry and I approval by a single person instead of an entire hierarchy, air travel for was very curious to know about airborne weapon systems. The depth all people on work irrespective of their entitlement, accountability to of Narayanan’s conviction and his force of application were inspiring.

only one person, lifting of goods by air-cargo, sub-contracting to the Right from the day of our pre-dawn visit to the Tilpat Range with Prof.

private sector, placement of orders on the basis of technical competence, Sarabhai, Narayanan was always busy with his RATO motor. He had and expeditious accounting procedures.

arranged everything that was required before being asked. He obtained These demands were unheard of in government establishments, which funding of Rs 75 lakhs with a further commitment towards any tend to be conservative, yet I could see the soundness of his proposition.

unforeseen costs. “You name the thing and I will get it for you, but do The RATO project was a new game and there was nothing wrong if it not ask for time,” he said. At times, I often laughed at his impatience, was to be played with a new set of rules. I weighed all the pros and cons and read for him these lines from T.S. Eliot’s Hollow Men: of Babu’s suggestions for a whole night and finally decided to present *Between the conception*

them to Prof. Sarabhai. Hearing my plea for administrative liberalization *And the creation*

and seeing the merits behind it, Prof. Sarabhai approved the proposals *Between the emotion*

without a second thought.

And the response

Through his suggestions, Babu had highlighted the importance of *Falls the Shadow*.

business acumen in developmental work with high stakes. To make things Defence R&D at that time was heavily dependent on imported move faster within existing work parameters, you have to pump in more equipment. Virtually nothing indigenous was available. Together, we made people, more material and more money. If you can’t do that, change a long shopping list and drew up an import plan. But this made me your parameters! Instinctive businessman that he was, Babu did not unhappy—was there no remedy or alternative? Was this nation doomed remain long with us and left ISRO for greener pastures in Nigeria. I to live with screwdriver technology? Could a poor country like India could never forget Babu’s common sense in financial matters.

afford this kind of development?

We had opted for a composite structure for the RATO motor casing One day, while working late in the office, which was quite routine using filament fibre glass/epoxy. We had also gone in for a high

energy after I took up the RATO projects, I saw a young colleague, Jaya Chandra composite propellant and an event-based ignition and jettisoning system in Babu going home. Babu had joined us a few months ago and the only real-time. A canted nozzle was designed to deflect the jet away from the thing I knew about him was that he had a very positive attitude and was aircraft. We conducted the first static test of RATO in the twelfth month articulate. I called him into my office and did a bit of loud thinking. “Do of the project initiation. Within the next four months, we conducted 64

you have any suggestions?” I then asked him. Babu remained silent for static tests. And we were just about 20 engineers working on the project!

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33



WINGS OF FIRE

ORIENTATION - 1

MOVERS

been chosen to be a project leader. Prof. Sarabhai gave me the additional responsibility of designing the fourth stage of the SLV. Dr VR Gowarikar, MR Kurup and AE Muthunayagam were given the tasks of designing the other three stages.

What made Prof. Sarabhai pick a few of us for this great mission?

6

One reason seemed to be our professional background. Dr Gowarikar was doing outstanding work in the field of composite propellants. MR

Kurup had established an excellent laboratory for propellants, propulsion and pyrotechnics. Muthunayagam had proved himself in the field of high energy propellants. The fourth stage was to be a composite structure and called for a large number of innovations in fabrication technology; Movers perhaps that was why I was brought in.

I laid the foundation for Stage IV on two rocks—sensible The future satellite launch vehicle (SLV) had also been conceived approximation and unawed support. I have always considered the price by this time. Recognising the immense socio- economic benefits of space of perfection prohibitive and allowed mistakes as a part of the learning technology, Prof. Sarabhai decided in 1969, to go full-steam ahead with process. I prefer a dash of daring and persistence to perfection. I have the task of establishing indigenous capability in building and launching always supported learning on the part of

my team members by paying our own satellites. He personally participated in an aerial survey of the vigilant attention to each of their attempts, be they successful or east coast for a possible site for launching satellite launch vehicles and unsuccessful.

large rockets.

In my group, progress was recognized and reinforced at every tiny Prof. Sarabhai was concentrating on the east coast in order to let the step. Although I provided access to all the information that my co-workers launch vehicle take full advantage of the earth's west to east rotation.

in Stage IV needed, I found I could not spend enough time to be a useful He finally selected the Sriharikota island, 100 km north of Madras (now facilitator and a source of support. I wondered if there was something Chennai), and thus the SHAR Rocket Launch Station was born. The wrong with the way in which I managed my time. At this stage, Prof.

crescent-shaped island has a maximum width of 8 km and lies alongside Sarabhai brought a French visitor to our work centre to point out the the coastline. The island is as big as Madras city. The Buckingham problem to me. This gentleman was Prof. Curien, President of CNES

Canal and the Pulicat lake form its western boundary.

(Centre Nationale de Etudes Spatiales), our counterpart in France. They were then developing the Diamont launch vehicles. Prof. Curien was a In 1968, we had formed the Indian Rocket Society. Soon after, the thorough professional. Together, Prof. Sarabhai and Prof. Curien helped INCOSPAR was reconstituted as an advisory body under the Indian me set a target. While they discussed the means by which I could reach National Science Academy (INSA) and the Indian Space Research it, they also cautioned me about the possibilities of failure. While I arrived Organization (ISRO) was created under the Department of Atomic at a better awareness of Stage IV problems through the supportive Energy (DAE) to conduct space research in the country.

counselling of Prof. Curien, Prof. Sarabhai's catalytic intervention led By this time, Prof. Sarabhai had already hand-picked a team to give Prof. Curien to reinterpret his own progress in the Diamont programme.

form to his dream of an Indian SLV. I consider myself fortunate to have e e prpersess

34



WINGS OF FIRE

ORIENTATION - 1

MOVERS

Prof. Curien advised Prof. Sarabhai to relieve me of all the minor cancelled their Diamont BC

programme. They told us that they did not jobs which posed little challenge and to give me more opportunities for need our Stage IV anymore. It was a great shock, making me re-live achievement. He was so impressed by our well-planned efforts that he the earlier disappointments at Dehra Dun, when I failed to get into the inquired if we could make the Diamont's fourth stage. I recall how this Air Force, and at Bangalore, when the Nandi project was aborted at brought a subtle smile to Prof. Sarabhai's face.

ADE.

As a matter of fact, the Diamont and SLV airframes were I had invested great hope and effort in the fourth stage, so that it incompatible. The diameters were quite different and to attain could be flown with a Diamont rocket. The other three stages of SLV, interchangeability, some radical innovations were required. I wondered involving enormous work in the area of rocket propulsion were at least where I should start. I decided to look around for solutions among my five years away. However, it did not take me long to shelve the own colleagues. I used to carefully observe my colleagues to see if their disappointment of Diamont BC Stage IV. After all, I had thoroughly daily routine reflected their desire to constantly experiment. I also started enjoyed working on this project. In time, RATO filled the vacuum created asking and listening to anyone who showed the slightest promise. Some in me by the Diamont BC Stage.

of my friends cautioned me about what they termed as my naivete. I When the RATO project was underway, the SLV project slowly started made it an unfailing routine to make notes on individual suggestions and taking shape. Competence for all major systems of a launch vehicle had gave handwritten notes to colleagues in engineering and design, requesting been established in Thumba by now. Through their outstanding efforts, concrete follow-up action within five or ten days.

Vasant Gowariker, MR Kurup and Muthunayagam prepared TERLS

This method worked wonderfully well. Prof. Curien testified, while for a big leap in rocketry.

reviewing our progress, that we had achieved in a year's time what our Prof. Sarabhai was an exemplar in the art of team-building. On one counterparts in Europe could barely manage in three years. Our plus occasion, he had to identify a person who could be given the responsibility point, he noted, was that each of us worked with those below and above for developing a telecommand system for the SLV. Two men were in the hierarchy. I made it a point to have the team meet at least once competent to carry out this task—one was the seasoned and sophisticated every week. Though it took up time and energy, I considered it essential.

UR Rao and the other was a relatively unknown experimenter, G

How good is a leader? No better than his people and their commitment Madhavan Nair. Although I was deeply impressed by Madhavan Nair's and participation in the project as full partners! The fact that I got them dedication and abilities, I did not rate his chances as very good. During all together to share whatever little development had been achieved—

one of Prof. Sarabhai's routine visits, Madhavan Nair boldly demonstrated results, experiences,

small successes, and the like—seemed to me worth his improvised but highly reliable telecommand system. Prof. Sarabhai putting all my energy and time into. It was a very small price to pay for did not take much time to back the young experimenter in preference to that commitment and sense of teamwork, which could in fact be called an established expert. Madhavan Nair not only lived up to the trust. Within my own small group of people I found leaders, and learned expectations of his leader but even went beyond them. He was to later that leaders exist at every level. This was another important aspect of become the project director of the Polar Satellite Launch Vehicle (PSLV).

management that I learned.

SLVs and missiles can be called first cousins: they are different in We had modified the existing SLV-IV Stage design to suit the Diamant concept and purpose, but come from the same bloodline of rocketry. A airframe. It was reconfigured and upgraded from a 250 kg, 400 mm massive missile development project had been taken up by DRDO at diameter stage to a 600 kg, 650 mm diameter stage. After two years'

the Defence Research & Development Laboratory (DRDL), Hyderabad.

effort, when we were about to deliver it to CNES, the French suddenly As the pace of this surface-to-air missile development project increased, e e prpersess

35



WINGS OF FIRE

ORIENTATION - 1

MOVERS

the frequency of the Missile Panel meetings and my interaction with Gp effort to bring together the disparate work on electrical and mechanical Capt Narayanan also increased.

integration. Prof. Sarabhai spent the next hour in re-defining our tasks, In 1968, Prof. Sarabhai came to Thumba on one of his routine visits.

and, in the small hours of the morning, the decision to set up a Rocket He was shown the operation of the nose-cone jettisoning mechanism.

Engineering Section was taken.

As always, we were all anxious to share the results of our work with Mistakes can delay or prevent the proper achievement of the Prof. Sarabhai. We requested Prof. Sarabhai to formally activate the objectives of individuals and organizations, but a visionary like Prof.

pyro system through a timer circuit. Prof. Sarabhai smiled, and pressed Sarabhai can use errors as

opportunities to promote innovation and the the button. To our horror, nothing happened. We were dumbstruck. I development of new ideas. He was not especially concerned with the looked at Pramod Kale, who had designed and integrated the timer circuit.

mistake in the timer circuit, least of all with pinning the blame for it.

In a flash each of us mentally went through an anlysis of the failure. We Prof. Sarabhai's approach to mistakes rested on the assumption that requested Prof. Sarabhai to wait for a few minutes, then we detached they were inevitable but generally manageable. It was in the handling of the timer device, giving direct connection to the pyros. Prof. Sarabhai the crises that arose as a consequence that talent could often be revealed.

pressed the button again. The pyros were fired and the nose cone was I later realised by experience, that the best way to prevent errors was to jettisoned. Prof. Sarabhai congratulated Kale and me; but his expression anticipate them. But this time, by a strange twist of fate, the failure of suggested that his thoughts were elsewhere. We could not guess what the timer circuit led to the birth of a rocket engineering laboratory.

was on his mind. The suspense did not last for long and I got a call from It was my usual practice to brief Prof. Sarabhai after every Missile Prof. Sarabhai's secretary to meet him after dinner for an important Panel Meeting. After attending one such meeting in Delhi on 30

discussion.

December 1971, I was returning to Trivandrum. Prof. Sarabhai was Prof. Sarabhai was staying at the Kovalam Palace Hotel, his usual visiting Thumba that very day to review the SLV design. I spoke to him home whenever he was in Trivandrum. I was slightly perplexed by the on the telephone from the airport lounge about the salient points that had summons. Prof. Sarabhai greeted me with his customary warmth. He emerged at the panel meeting. He instructed me to wait at Trivandrum talked of the rocket launching station, envisaging facilities like launch Airport after disembarking from the Delhi flight, and to meet him there pads, block houses, radar, telemetry and so on—things which are taken before his departure for Bombay the same night.

for granted in Indian space research today. Then he brought up the When I reached Trivandrum, a pall of gloom hung in the air. The incident that had occurred that morning. This was exactly what I had aircraft ladder operator Kutty told me in a choked voice that Prof.

feared. My apprehension of a reproach from my leader, however, was Sarabhai was no more. He had passed away a few hours ago, following unfounded. Prof. Sarabhai did not conclude that the failure of the pyro a cardiac arrest. I was shocked to the core; it had happened within an timer circuit was the outcome of insufficient knowledge and lack of skill hour of our conversation. It was a great blow to me and a huge loss to on the part of his people or of faulty understanding at the direction stage.

Indian science. That night passed in preparations for airlifting Prof.

He asked me instead, if we were unenthused by a job that did not pose Sarabhai's body for the

cremation in Ahmedabad.

sufficient challenge. He also asked me to consider if my work was possibly being affected by any problem of which I was hitherto unaware.

For five years, between 1966 to 1971, about 22 scientists and engineers He finally put his finger on the key issue. We lacked a single roof to had worked closely with Prof. Sarabhai. All of them were later to take carry out system integration of all our rocket stages and rocket systems.

charge of important scientific projects. Not only was Prof. Sarabhai a Electrical and mechanical integration work was going on with a great scientist, but also a great leader. I still remember him reviewing significant phase difference—both in time and in space. There was little the bi-monthly progress of the design projects of SLV-3 in June 1970.

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36



WINGS OF FIRE

ORIENTATION - 1

MOVERS

Presentations on Stages I to IV were arranged. The first three Before taking up the responsibility of organizing space research in presentations went through smoothly. Mine was the last presentation. I India and becoming the chairman of INCOSPAR, Prof. Sarabhai had introduced five of my team members who had contributed in various established a number of successful industrial enterprises. He was aware ways to the design. To everybody's surprise, each of them presented his that scientific research could not survive in isolation, away from industry.

portion of the work with authority and confidence. The presentations Prof. Sarabhai founded Sarabhai Chemicals, Sarabhai Glass, Sarabhai were discussed at length and the conclusion was that satisfactory Geigy Limited, Sarabhai Merck Limited, and the Sarabhai Engineering progress had been made.

Group. His Swastik Oil Mills did pioneering work in the extraction of oil Suddenly, a senior scientist who worked closely with Prof. Sarabhai from oilseeds, manufacture of synthetic detergents and of cosmetics.

turned to me and enquired, "Well, the presentations for your project He geared Standard Pharmaceuticals Limited to enable large-scale were made by your team members based on their work. But what did manufacture of penicillin, which was imported from abroad at you do for the project?" That was the first time I saw Prof. Sarabhai astronomical costs at that time. Now with the indigenization of RATO, really annoyed. He told his colleague, "You ought to know what project his

mission had acquired a new dimension—independence in the management is all about. We just witnessed an excellent example. Its manufacture of military hardware and the potential saving of crores of rupees was an outstanding demonstration of team work. I have always seen a rupee in foreign exchange. I recalled this on the day of the successful project leader as an integrator of people and that is precisely what Kalam tried of the RATO system. Including trial expenses, we spent less than is.” I consider Prof. Sarabhai as the Mahatma Gandhi of Indian science. Rs. 25 lakhs on the entire project. The Indian RATO could be produced

—generating leadership qualities in his team and inspiring them through at Rs.17,000 apiece, and it replaced the imported RATO, which cost Rs.

both ideas and example.

33,000.

After an interim arrangement with Prof. MGK Menon at the helm, At the Vikram Sarabhai Space Centre, work on the SLV went on at Prof. Satish Dhawan was given the responsibility of heading ISRO. The full swing. All the subsystems had been designed, technologies identified, whole complex at Thumba, which included TERLS, the Space Science processes established, work centres selected, manpower earmarked and Technology Centre (SSTC), the RPP, the Rocket Fabrication Facility schedules drawn. The only hitch was the lack of a management structure (RFF), and the Propellant Fuel Complex (PFC) were merged together to effectively handle this mega-project and coordinate activities which to form an integrated space centre and christened the Vikram Sarabhai were spread over a large number of work centres with their own ways Space Centre (VSSC) as a tribute to the man to whom it owed its working and management.

existence. The renowned metallurgist, Dr Brahm Prakash, took over as Prof. Dhawan, in consultation with Dr Brahm Prakash, picked me the first Director of VSSC.

for this job. I was appointed the Project Manager—SLV, and reported The RATO system was successfully tested on 8 October 1972 at directly to the Director, VSSC. My first task was to work out a project Bareilly Air Force station in Uttar Pradesh, when a high performance management plan. I wondered why I was selected for this task when Sukhoi-16 jet aircraft became airborne after a short run of 1200 m, as there were stalwarts like Gowardkar, Muthunayagam, and Kurup around.

against its usual run of 2 km. We used the 66th RATO motor in the test.

With organizers like Easwardas, Aravamudan, and SC Gupta available, The demonstration was watched by Air Marshall Shivdev Singh and Dr how would I do better? I articulated my doubts to Dr Brahm Prakash.

BD Nag Chaudhury, then the Scientific Adviser to the Defence Minister.

He told me not to focus on what I saw as other people’s strengths This effort was said to have saved approximately Rs 4 crores in foreign compared to my own, but instead, to attempt to expand their abilities.

exchange. The vision of the industrialist scientist had finally borne fruit.

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37



WINGS OF FIRE

ORIENTATION - 1

MOVERS

Dr Brahm Prakash advised me to take care of the performance was also imperative. Yet another major task was the augmentation of degraders and cautioned me against outrightly seeking optimal launch facilities at SHAR with systems integration and checkout facilities performance from the participating work centres. “Everyone will work and development of launch support systems such as launchers and vehicle to create their bit of SLV; your problem is going to be your dependency assembly fixtures. A target of ‘all line’ flight test within 64 months was on others in accomplishing the total SLV. The SLV mission will be set in March 1973.

accomplished with, and through, a large number of people. You will require I took up the executive responsibility of implementing the project a tremendous amount of tolerance and patience,” he said. It reminded within the framework of policy decisions taken, the approved me of what my father used to read to me from the Holy Qur’an on the management plan, and the project report; and also within the budget and distinction between right and wrong: “We have sent no apostle before through the powers delegated to me by the Director, VSSC. Dr Brahm you who did not eat or walk about the market squares. We test you by Prakash formed four Project Advisory Committees to advise me on means of one another. Will you not have patience?” specialized areas like rocket motors, materials and fabrication, control I was aware of the contradiction that often occurred in such situations.

and guidance, electronics, and mission and launching. I was assured of People heading teams often have one of the following two orientations: the guidance of outstanding scientists like DS Rane, Muthunayagam, for some, work is the most important motivation; for others, their workers TS Prahlad, AR Acharya, SC Gupta, and CII Amba Rao, to name a few.

are the all-consuming interest. There are many others who fall either The Holy Qur’an says: “We have sent down to you revelations between these two positions or outside them. My job was going to be to showing you an account of those who have gone before you and an avoid those who were interested neither in the work nor in the workers.

admonition to righteous men.” I sought to share the wisdom of these I was determined to prevent people from taking either extreme, and to extremely brilliant people. “Light upon light. Allah guides to His light promote conditions where work and workers went together. I visualized whom He will. He has knowledge of all things.” my team as a group in which each member worked to enrich the

others in the team and experience the enjoyment of working together.

We made three groups to carry out the project activities—a Programme Management Group, an Integration and Flight Testing Group. The primary objectives of the SLV Project were design, development and a Subsystems Development Group. The first Group was made and operation of a standard SLV system, SLV-3, capable of reliably and responsible for looking after the overall executive aspects of SLV-3: expeditiously fulfilling the specified mission of launching a 40 kg satellite project management, including administration, planning and evaluation, into a 400 km circular orbit around the earth.

subsystems specifications, materials, fabrication, quality assurance and As a first step, I translated the primary project objectives into some control. The Integration and Flight Testing Group was assigned the tasks major tasks. One such task was the development of a rocket motor of generation of facilities required for integration and flight testing of system for the four stages of the vehicle. The critical problems in the SLV-3. They were also asked to carry out the analysis of the vehicle, completion of this task were: making an 8.6 tonne propellant grain and a including mechanical and aerodynamic interface problems. The high mass ratio apogee rocket motor system which would use high-Subsystems Development Group was given the job of interacting with energy propellants. Another task was vehicle control and guidance. Three various divisions of VSSC and was made responsible for ensuring that types of control systems were involved in this task—aerodynamic surface all technological problems in the development of various subsystems control, thrust vector control and reaction control for the first, second were overcome by creating a synergy amongst the available talent in and third stages and the spin-up mechanism for the fourth stage. Inertial these divisions.

reference for control systems and guidance through inertial measurement e e prpersess

38



WINGS OF FIRE

ORIENTATION - 1

THRUSTERS

I projected a requirement of 275 engineers and scientists for SLV-3

but could get only about 50. If it had not been for synergistic efforts, the whole project would have remained a non-starter. Some young engineers like MSR Dev, G Madhavan Nair, S Srinivasan, US Singh, Sunderrajan, Abdul Majeed, Ved Prakash Sandlas, Namboodiri, Sasi Kumar, and Sivathanu Pillai developed their own ground rules designed to help them work efficiently as a project team, and produced outstanding individual and team results. These men were in the habit of celebrating their successes together—in a sort of mutual appreciation club. This boosted 7

morale, and helped them a great deal to accept setbacks and to revitalize themselves after periods of

intense work.

Each member of the SLV-3 project team was a specialist in his own field. It was natural therefore that each one of them valued his Thrusters

independence. To manage the performance of such specialists the team leader has to adopt a delicate balance between the hands-on and the hands-off approach. The hands-on approach takes an active interest in Having taken up the leadership of executing the SLV-3 project, I faced urgent and conflicting demands on my time—for a very regular basis in the members' work. The hands-off approach committee work, material procurement, correspondence, trusts team members and recognizes their need for autonomy to carry reviews, briefings, and for the need to be informed on a wide range of out their roles, as they see fit. It hinges on their self-motivation. When subjects.

the leader goes too far with the hands-on approach, he is seen as an My day would start with a stroll of about 2 km around the lodge I anxious and interfering type. If he goes too far hands-off, he is seen as was living in. I used to prepare a general schedule during my morning abdicating his responsibility or not being interested. Today, the members walk, and emphasize two or three things I would definitely like to of the SLV-3 team have grown to lead some of the country's most accomplish during the day, including at least one thing that would help prestigious programmes. MSR Dev heads the Augmented Satellite achieve long-term goals.

Launch Vehicle (ASLV) project, Madhavan Nair is the chief of the Polar Satellite Launch Vehicle (PSLV) project and Sandlas and Sivathanu Once in the office, I would clean the table first. Within the next ten Pillai are Chief Controllers in DRDO Headquarters. Each one of these minutes, I would scan all the papers and quickly divide them into different men rose to his present position through consistent hard work and rock-categories: those that required immediate action, low priority ones, ones like will power. It was indeed an exceptionally talented team.

that could be kept pending, and reading material. Then I would put the high priority papers in front of me and everything else out of sight.

* * *

Coming back to SLV-3, about 250 sub-assemblies and 44 major subsystems were conceived during the design. The list of materials went up to over 1 million components. A project implementation strategy had become essential to achieve sustained viability of this complex programme of seven to ten years' duration. From his side, Prof. Dhawan came up with a clear statement that all the manpower and funds at e e prpersess

39



WINGS OF FIRE

ORIENTATION - 1

THRUSTERS

VSSC and SHAR would have to be directed to us. From our side, we stainless steel, electroforming techniques, and ultra-precision process evolved a matrix type of management to achieve productive interfacing tooling. We also decided to make some important machines in-house, with more than 300 industries. The target was that our interaction with like the 254-litre vertical mixer and the groove machining facility for our them must lead to their technology empowerment. Three things I stressed third and fourth stages. Many of our subsystems were so massive and before my colleagues—importance of design capability, goal setting and complex that they implied sizeable financial outlays. Without any realisation, and the strength to withstand setbacks. Now, before I dwell hesitation, we approached industries in the private sector and developed on the finer aspects of the management of the SLV-3 project, let me talk contract management plans which later became blueprints for many about the SLV-3 itself.

government-run science and technology business organizations.

It is interesting to describe a launch vehicle anthropomorphically.

Coming to the life part of the SLV, there is the complex electrical The main mechanical structure may be visualized as the body of a human circuitry, which sets the mechanical structure in motion. This vast being, the control and guidance systems with their associated electronics spectrum of activities, encompassing simple electrical power supplies to constitute the brain. The musculature comes from propellants. How are sophisticated instrumentation as well as guidance and control systems is they made? What are the materials and techniques involved?

collectively referred to in aerospace research as ‘Avionics’.

A large variety of materials go into the making of a launch vehicle—

Development efforts in avionic systems had already been initiated at both metallic and non-metallic, which include composites and ceramics.

VSSC in the field of digital electronics, microwave radars and radar In metals, different types of stainless steel, alloys of aluminium, transponders, and inertial components and systems. It is very important magnesium, titanium, copper, beryllium, tungsten and molybdenum are to know the state of the SLV when it is in flight. SLV brought a new used. Composite materials are composed of a mixture or combination of surge of activity in the development of a variety of transducers for two or more constituents which differ in form and material composition measurement of physical parameters like pressure, thrust, vibration, and which are essentially insoluble in one another. The materials which acceleration, etc. The transducers convert the physical parameters of combine may be metallic, organic or inorganic. While other material the vehicle into electrical signals. An on-board telemetry system processes combinations possible are virtually unlimited, the most typical composites these signals suitably and transmits them in the form of radio signals to in launch vehicles are made of structural constituents, embedded in a the ground stations, where they are received and deciphered back to the matrix. We used a large variety of glass fibre reinforced plastic original information collected by the transducers. If the systems work composites and opened avenues for the entry of

Kevlar, polyamides and according to design there is little cause for concern; but in case something carbon-carbon composites. Ceramics are special types of baked clay goes wrong, the vehicle must be destroyed to stop it from making any used for microwave transparent enclosures. We considered using unexpected moves. To ensure safety, a special tele-command system ceramics, but had to reject the idea then due to technological limitations.

was made to destroy the rocket in case it malfunctions, and an interferometer system was developed to determine the range and position Through mechanical engineering, these materials are transformed of the SLV, as a added means to the radar system. The SLV project also into hardware. In fact, of all the engineering disciplines which feed directly initiated the indigenous production of sequencers which time the various into the development of rocketry, mechanical engineering is perhaps the events, such as ignition, stage separation, vehicle altitude programmers most intrinsic one. Be it a sophisticated system like a liquid engine or a which store the information for the rocket manoeuvres, and auto-pilot piece of hardware as simple as a fastener, its ultimate fabrication calls electronics which take appropriate decisions to steer the rocket along its for expert mechanical engineers and precision machine tools. We decided predetermined path.

to develop important technologies like welding techniques for low-alloy e e prpersess

40



WINGS OF FIRE

ORIENTATION - 1

THRUSTERS

Without the energy to propel the whole system, a launch vehicle proven missile and to establish, thereby, the necessary infrastructure remains grounded. A propellant is usually a combustible substance that required in the organization. It was thought that once one-to-one produces heat and supplies ejection particles in a rocket engine. It is indigenization was established, further advances in the sophisticated field both a source of energy and a working substance for expanding energy.

of guided missiles would be a natural fall-out. The project was sanctioned Because the distinction is more decisive in rocket engines, the term in February 1972 with the code name Devil and funding of about Rs. 5

propellant is used primarily to describe chemicals carried by rockets for crore was made available for the first three years. Almost half of it was propulsive purposes.

to go in foreign exchange.

It is customary to classify propellants as either solids or liquids. We By now promoted to Air Commodore, Narayanan took over as concentrated on solid propellants. A solid propellant consists

essentially Director, DRDL. He mobilized this young laboratory located in the south-of-three components: the oxidizer, the fuel and the additives. Solid eastern suburbs of Hyderabad to take up this enormous task. The propellants are further classified into two types: composite and double landscape dotted with tombs and old buildings started reverberating with base. The former consists of an oxidizer or inorganic material (like new life. Narayanan was a man of tremendous energy—a man always ammonium perchlorate) in a matrix of organic fuel (like synthetic rubber).

in the boost phase. He gathered around him a strong group of enthusiastic Double base propellants were distant dreams those days but nevertheless people, drawing many service officers into this predominantly civilian we dared to dream about them.

laboratory. Totally preoccupied with the SLV affairs, my participation in All this self sufficiency and indigenous manufacture came gradually, the Missile Panel meetings gradually dwindled, and then stopped and not always without pain. We were a team of almost self-trained altogether. However, stories about Narayanan and his Devil were engineers. In retrospect I feel the unique blend of our untutored talent, beginning to reach Trivandrum. A transformation of an unprecedented character, and dedication suited SLV development the most. Problems scale was taking place there.

surfaced regularly and almost consistently. But my team members never During my association with Narayanan in the RATO project, I had exhausted my patience. I recall writing after winding up a late night discovered that he was a hard taskmaster—one who went all out for shift:

control, mastery and domination. I used to wonder if managers like him, *Beautiful hands are those that do*

who aim at getting results no matter what the price, would face a rebellion *Work that is earnest and brave and true* of silence and non-cooperation in the long run.

Moment by moment

New Year's day, 1975, brought with it an opportunity to have a first-The long day through.

person assessment of the work going on under Narayanan's leadership.

Almost parallel to our work on SLV, the DRDO was preparing itself Prof. MGK Menon, who was working then as Scientific Advisor to the for developing an indigenous surface-to-air missile. The RATO project Defence Minister and was head of the DRDO, appointed a review was abandoned because the aircraft for which it was designed became committee under the chairmanship of Dr Brahm Prakash to evaluate obsolete. The new aircraft did not need RATO. With the project called the work carried out in the Devil Project. I was taken into the team as a off, Narayanan was DRDO's logical choice to lead the team for making rocket specialist to evaluate the progress made in the areas of the missile. Unlike us at ISRO, they preferred the philosophy of one-to-aerodynamics, structure and propulsion of the missile. On the propulsion one substitution rather than technology development and performance aspects, I was assisted by BR Somasekhar and by Wg Cdr P Kamaraju.

upgrading. The Surface-to-Air Missile SA-2 of Russian origin was The committee members included

Dr RP Shenoy and Prof. IG Sarma chosen to acquire detailed knowledge of all the design parameters of a who were to review the work done on the electronic systems.

e e prpersess

41



WINGS OF FIRE

ORIENTATION - 1

THRUSTERS

We met at DRDL on 1 and 2 January 1975, followed by a second Back home at VSSC, SLV was taking shape. In contrast to the DRDL

session after about six weeks. We visited the various development work which was sprinting ahead, we were moving slowly. Instead of following centres and held discussions with the scientists there. I was greatly the leader, my team was trekking towards success on several individual impressed by the vision of AV Ranga Rao, the dynamism of Wg Cdr R

paths. The essence of our method of work was an emphasis on Gopalaswami, the thoroughness of Dr I Achyuta Rao, the enterprise of communication, particularly in the lateral direction, among the teams G Ganesan, S Krishnan's clarity of thought and R Balakrishnan's critical and within the teams. In a way, communication was my mantra for eye for detail. The calm of JC Bhattacharya and Lt Coll R Swaminathan managing this gigantic project. To get the best from my team members, in the face of immense complexities was striking. The zeal and application I spoke to them frequently on the goals and objectives of the organization, of Lt Coll VJ Sundaram was conspicuous. They were a brilliant, committed emphasizing the importance of each member's specific contribution group of people—a mix of service officers and civilian scientists—who towards the realisation of these goals. At the same time, I tried to be had trained themselves in the areas of their own interest out of their receptive to every constructive idea emanating from my subordinates driving urge to fly an Indian missile.

and to relay it in an appropriate form for critical examination and We had our concluding meeting towards the end of March 1975 at implementation. I had written somewhere in my diary of that period: Trivandrum. We felt that the progress in the execution of the project *If you want to leave your footprints*

was adequate in respect of hardware fabrication to carry out the *On the sands of time*

philosophy of one-to-one substitution of missile subsystems except in *Do not drag your feet.*

the liquid rocket area, where some more time was required to succeed.

Most of the time, communication gets confused with conversation.

The committee was of the unanimous opinion that DRDL had achieved In fact, the two are distinctly different. I was (and am) a terrible the twin goals of hardware fabrication and system analysis creditably in conversationalist but consider myself a good communicator. At the design and development of the ground electronics complex assigned conversation full of pleasantries is most often devoid of any useful to them.

information, whereas communication is meant only for the exchange of We observed that the one-to-one substitution philosophy had taken information. It is very important to realise that communication is a two-precedence over the generation of design data. Consequently, many party affair which aims at passing on or receiving a specific piece of design engineers had not been able to pay adequate attention to the information.

necessary analysis which was the practice followed by us at VSSC.

While working on the SLV, I used communication to promote The system analysis studies carried out up to then had also been only of understanding and to come to an agreement with colleagues in defining a preliminary nature. In all, the results accomplished were outstanding, the problems that existed and in identifying the action necessary to be but we still had a long way to go. I recalled a school poem: taken to solve them. Authentic communication was one of the tools *Don't worry and fret, fainthearted,*

skilfully used in managing the project. How did I do that ? To begin with, *The chances have just begun,*

I tried to be factual and never sugar-coated the bitter pill of facts. At *For the best jobs haven't been started*, one of the Space Science Council (SSC) review meetings, frustrated by *The best work hasn't been done.*

the procurement delays, I erupted into an agitated complaint against the The committee made a strong recommendation to the Government indifference and red-tape tactics of the controller of accounts and to give Devil a further go-ahead. Our recommendation was accepted financial advisor of VSSC. I insisted that the systems of work followed and the project proceeded.

by the accounts staff had to change and demanded the delegation of e e prpersess

42



WINGS OF FIRE

ORIENTATION - 1

THRUSTERS

their functions to the project team. Dr Brahm Prakash was taken aback Athens ceased to be free and was never free again". The truth is that by the bluntness of my submission. He stubbed out his

cigarette and there is a great deal that most of us can individually do to increase our walked out of the meeting.

freedom. We can combat the forces that threaten to oppress us. We I spent the whole night regretting the pain my harsh words had caused can fortify ourselves with the qualities and conditions that promote Dr Brahm Prakash. However, I was determined to fight the inertia built individual freedom. In doing so, we help to create a stronger organization, into the system before I found myself being dragged down with it. I capable of achieving unprecedented goals.

asked myself a practical question: could one live with these insensitive As work on the SLV gained momentum, Prof. Dhawan introduced bureaucrats? The answer was a big no. Then I asked myself a private the system of reviewing progress with the entire team involved in the question: what would hurt Dr Brahm Prakash more, my seemingly harsh project. Prof. Dhawan was a man with a mission. He would effortlessly words now, or the burial of the SLV at a later stage? Finding my head pull together all the loose ends to make work move smoothly. At VSSC

and heart agreeing, I prayed to God for help. Fortunately for me, Dr the review meetings presided over by Prof. Dhawan used to be Brahm Prakash delegated financial powers to the project the next morning.

considered major events. He was a true captain of the ISRO ship—A Anyone who has taken up the responsibility to lead a team can be commander, navigator, housekeeper, all rolled into one. Yet, he never successful only if he is sufficiently independent, powerful and influential pretended to know more than he did. Instead, when something appeared in his own right to become a person to reckon with. This is perhaps also ambiguous, he would ask questions and discuss his doubts frankly. I the path to individual satisfaction in life, for freedom with responsibility remember him as a leader for whom to lead with a firm, but fair hand, is the only sound basis for personal happiness. What can one do to was a moral compulsion. His mind used to be very firm once it had been strengthen personal freedom? I would like to share with you two decided on any issue. But before taking a decision, it used to be like clay, techniques I adopt in this regard.

open to impressions until the final moulding. Then the decisions would be popped into the potter's oven for glazing, never failing to emerge First, by building your own education and skills. Knowledge is a hard and tough, resistant and enduring.

tangible asset, quite often the most important tool in your work. The more up-to-date the knowledge you possess, the freer you are.

I had the privilege of spending a great deal of time with Prof. Dhawan.

Knowledge cannot be taken away from anyone except by obsolescence.

He could hold the listener enthralled because of the logical, intellectual A leader can only be free to lead his team if he keeps abreast of all that acumen he could bring to bear on his analysis of any subject. He had an is happening around him—in real time. To lead, in a way, is to engage in unusual combination of degrees—a B.Sc. in Mathematics and Physics, continuing education. In many

countries, it is normal for professionals to an M.A. in English Literature, B.E. in Mechanical Engineering, M.S. in go to college several nights every week. To be a successful team leader, Aeronautical Engineering followed by a Ph.D. in Aeronautics and one has to stay back after the din and clutter of a working day to emerge Mathematics from the California Institute of Technology (Caltech) in better-equipped and ready to face a new day.

USA.

The second way is to develop a passion for personal responsibility.

Intellectual debates with him were very stimulating and could always The sovereign way to personal freedom is to help determine the forces mentally energize me and my team members. I found him full of optimism that determine you. Be active! Take on responsibility! Work for the and compassion. Although he often judged himself harshly, with no things you believe in. If you do not, you are surrendering your fate to allowances or excuses, he was generous to a fault when it came to others. The historian Edith Hamilton wrote of ancient Greece, “When others. Prof. Dhawan used to sternly pronounce his judgements and the freedom they wished for most was freedom from responsibility, then then pardon the contrite guilty parties.

e e prpersess

43



WINGS OF FIRE

ORIENTATION - 1

THRUSTERS

In 1975, ISRO became a government body. An ISRO council was solution, engineers show them yet another lumineu, yet one more formed consisting of Directors of different work centres and senior possibility. I cautioned my team against becoming scientists. Science is officers in the Department of Space (DoS). This provided a symbolic a passion—a never-ending voyage into promises and possibilities. We link as well as a forum for participative management between the DoS

had only limited time and limited funds. Our making the SLV depended which had the Governmental powers and the centres which would upon our awareness of our own limits. I preferred existing workable execute the jobs. In the traditional parlance of Government departments, solutions which would be the best options. Nothing that is new comes ISRO’s centres would have been subordinate units or attached offices, into time-bound projects without its own problems. In my opinion, a project but such words were never spoken either at ISRO or DoS. Participative leader should always work with proven technologies in most of the management, which calls for active interaction between those who wield systems as far as possible and experiment only from multiple resources.

administrative powers and the executing agencies, was a novel feature

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of ISRO management that would go a long way in Indian R&D

organizations.

The new set-up brought me in contact with TN Seshan, the Joint Secretary in the DoS. Till then, I had a latent reservation about bureaucrats, so I was not very comfortable when I first saw Seshan participating in a SLV-3 Management Board meeting. But soon, it changed to admiration for Seshan, who would meticulously go through the agenda and always come for the meetings prepared. He used to kindle the minds of scientists with his tremendous analytical capability.

The first three years of the SLV project was the period for the revelation of many fascinating mysteries of science. Being human, ignorance has always been with us, and always will be. What was new was my awareness of it, my awakening to its fathomless dimensions. I used to erroneously suppose that the function of science was to explain everything, and that unexplained phenomena were the province of people like my father and Lakshmana Sastry. However, I always refrained from discussing these matters with any of my scientist colleagues, fearing that it would threaten the hegemony of their meticulously formed views.

Gradually, I became aware of the difference between science and technology, between research and development. Science is inherently open-ended and exploratory. Development is a closed loop. Mistakes are imperative in development and are made every day, but each mistake is used for modification, upgradation or betterment. Probably, the Creator created engineers to make scientists achieve more. For each time scientists come up with a thoroughly researched and fully comprehended e e prpersess

44



WINGS OF FIRE

ORIENTATION - 1

EXPEDIENTS

job success, we can put them together to form a blueprint for outstanding performance in both thought and action.

Although SLV-3 was still in the future, its subsystems were being completed. In June 1974, we used the Centaur sounding rocket launch 8

to test some of our critical systems. A scaled down heat shield of SLV, Rate Gyro Unit, and Vehicle Attitude Programmer were integrated into the Centaur rocket. The three systems involved wide-

ranging expertise—

composite materials, control engineering and software, none of them ever having been tried before in the country. The test was a complete success. Until then the Indian Space Programme had not gone beyond Expedients

sounding rockets and even knowledgeable people were not ready to see and acknowledge its efforts as anything more serious than fiddling around with meteorological instruments. For the first time, we inspired the The SLV-3 project had been formulated in such a way that the major confidence of the nation. Prime Minister Indira Gandhi told Parliament technology work centres, both at VSSC and at SHAR could handle on 24 July 1974, “The development and fabrication of relevant propellant production, rocket motor testing and launch of any large technologies, subsystems and hardware (to make India’s first Satellite diameter rocket. As participants in the SLV-3 project, we set three Launch Vehicle) are progressing satisfactorily. A number of industries milestones for ourselves: development and flight qualification of all are engaged in the fabrication of components. The first orbital flight by subsystems through sounding rockets by 1975; sub-orbital flights by 1976; India is scheduled to take place in 1978.” and the final orbital flight in 1978. The work tempo had picked up now Like any other act of creation, the creation of the SLV-3 also had its and the atmosphere was charged with excitement. Wherever I went, painful moments. One day, when my team and I were totally engrossed our teams had something interesting to show me. A large number of in the preparation of the static test of the first stage motor, the news of things were being done for the first time in the country and the ground—a death in the family reached me. My brother-in-law and mentor Jenab level technicians had had no prior exposure to this kind of work. I saw Ahmed Jallaludin, was no more. For a couple of minutes, I was new performance dimensions growing among my team members.

immobilized, I could not think, could not feel anything. When I could Performance dimensions are factors that lead to creation. They go focus on my surroundings once more and attempted to participate in the beyond competencies such as the skills and knowledge of the individual.

work, I found myself talking incoherently—and then I realised that, with Performance dimensions are broader and deeper than what a person Jallaluddin, a part of me had passed away too. A vision of my childhood must know and be able to do in order to function well in his or her job.

reappeared before me—evening walks around the Rameswaram temple, They include attitudes, values and character traits. They exist at various shining sand and dancing tides in the moonlight, stars looking down from levels of the human personality. At the behavioural level—at the outermost an unlit sky on a new moon night, Jallaluddin showing me the horizon ring of the tree—we can observe skills and measure knowledge. Social sinking into the sea, arranging money for my books, and seeing me off at roles and self-image dimensions are found at the intermediate level.

Santa Cruz airport. I felt that I had been thrown into a whirlpool of time Motives and traits exist at the innermost or core level. If we can identify and space. My father, by now more than a hundred years old, pall-those performance dimensions which are most highly correlated with bearer for his son-in-law, who had been half his age; the bereft soul of my sister Zohara, her wounds from the loss of her four-year-old son still e e pperess



WINGS OF FIRE

ORIENTATION - 1

EXPEDIENTS

raw—these images came before my eyes in a blur, too terrible for me to fabrication with what was available. Namboodiri and Pillai were spending comprehend. I leaned on the assembly jig, composed myself and left a their days and nights at the propulsion laboratory developing four rocket few instructions with Dr S Srinivasan, Deputy Project Director, to carry motors simultaneously. MSR Dev and Sandlas drew up meticulous plans on with the work in my absence.

for mechanical and electrical integration of the vehicle. Madhavan Nair Travelling overnight in a combination of district buses, I reached and Murthy examined the systems developed by the VSSC electronics Rameswaram only the next day. During this time, I did my best to free laboratories and engineered them into flight sub- systems wherever it myself from the very past which appeared to have come to an end with was possible. US Singh brought up the first launch ground system, Jallaluddin. But the moment I reached my house, grief assailed me afresh.

comprising of telemetry, tele-command, and radar. He also chalked out I had no words for Zohara or for my niece Mehboob, both of whom a detailed work plan with SHAR for the flight trials. Dr Sundararajan were crying uncontrollably. I had no tears to shed. We sorrowfully put closely monitored mission objectives and concurrently updated the Jallaluddin's body to rest.

systems. Dr Srinivasan, a competent launch vehicle designer, discharged all my complementary and supplementary functions as the SLV deputy My father held my hands for a long time. There were no tears in his project director. He noticed what I had overlooked, heard the points I eyes either. "Do you not see, Abul, how the Lord lengthens the shadows?"

failed to listen to, and suggested possibilities that I had not so much as Had it been His will, He could have made them constant. But He makes visualized.

the sun their guide, little by little He shortens them. It is He who has made the night a mantle for you, and sleep a rest. Jallaluddin has gone We learned the hard way that the biggest problem of project into a long sleep—a dreamless sleep, a complete rest of all his being management is to achieve a regular and efficient interfacing between within simple unconsciousness. Nothing will befall us except what Allah the different individuals and work centres. Hard work can be set at has ordained. He is our Guardian. In Allah, my son, put your trust." He nought in the absence of proper coordination.

slowly closed his wrinkled eyelids and went into a trance-like state.

I had the fortune of having YS Rajan from the ISRO headquarters. Death has never frightened me. After all, everyone has to go one as my friend in those times. Rajan was (and is) a universal friend. His day. But perhaps Jallaluddin went a little too early, a little too soon. I friendship embraced with equal warmth turners, fitters, electricians and could not bring myself to stay for long at home. I felt the whole of my drivers as well as scientists, engineers, contractors and bureaucrats.

inner self drowning in a sort of anxious agitation, and inner conflicts Today when the press calls me a ‘welder of people’, I attribute this to between my personal and my professional life. For many days, back in Rajan. His close interaction with different work centres created such a Thumba, I felt a sense of futility I had never known before—about harmony in SLV affairs that the fine threads of individual efforts were everything I was doing.

woven into a mighty fabric of great strength.

I had long talks with Prof. Dhawan. He told me that my progress on In 1976, my father passed away. He had been in poor health for the SLV project would bring me solace. The confusion would first lessen quite some time due to his advanced age. The death of Jallaluddin had and would later pass away altogether. He drew my attention to the also taken a toll on his health and spirit. He had lost his desire to live, as wonders of technology and its achievements.

though after seeing Jallaluddin return to his divine source, he too had become eager to return to his.

Gradually, the hardware began emerging from the drawing boards.

Sasi Kumar built a very effective network of fabrication work centres.

Whenever I learnt about my father’s indifferent health, I would visit Within days of getting a component drawing, he would embark on the Rameswaram with a good city doctor. Every time I did so, he would chide me for my unnecessary concern and lecture me on the expenses e e prpersess

46



WINGS OF FIRE

ORIENTATION - 1

EXPEDIENTS

incurred on the doctor. “Your visit is enough for me to get well, why own affairs in order to listen to her? I regretfully realised this only when bring a doctor and spend money on his fees?” he would ask. This time she passed away soon afterwards.

he had gone beyond the capabilities of any doctor, care or money. My The SLV-3 Apogee rocket, developed as a common upper stage father Jainulabdeen, who had lived on Rameswaram island for 102 years, with Diamont, scheduled to be flight tested in France was mired in a had passed away

leaving behind fifteen grandchildren and one great-series of knotty problems. I had to rush to France to sort them out.

grandson. He had led an exemplary life. Sitting alone, on the night after Before I could depart, late in the afternoon, I was informed that my the burial, I remembered a poem written on the death of Yeats by his mother had passed away. I took the first available bus to Nagarcoil.

friend Auden, and felt as if it was written for my father: From there, I travelled to Rameswaram spending a whole night in the *Earth, receive an honoured guest;*

train and performed the last rites the next morning. Both the people who *William Yeats is laid to rest:* had formed me had left for their heavenly abode. The departed had

.....

reached the end of their journey. The rest of us had to continue walking *In the prison of his daysTeach the*

the weary road and life had to go on. I prayed in the mosque my father *free man how to praise.*

had once taken me to every evening. I told Him that my mother could In worldly terms, it was the death of just another old man. No public not have lived longer in the world without the care and love of her husband, mourning was organized, no flags were lowered to half-mast, no and therefore had preferred to join him. I begged His forgiveness. “They newspaper carried an obituary for him. He was not a politician, a scholar, carried out the task I designed for them with great care, dedication and or a businessman. He was a plain and transparent man. My father honesty and came back to me. Why are you mourning their day of pursued the supreme value, the Good. His life inspired the growth of all accomplishment? Concentrate on the assignments that lie before you, that was benign and angelic, wise and noble.

and proclaim my glory through your deeds!” Nobody had said these words, but I heard them loud and clear. An inspiring aphorism in the My father had always reminded me of the legendary Abou Ben Qur’an on the passing away of souls filled my mind: “Your wealth and Adhem who, waking one night from a deep dream of peace, saw an children are only a temptation whereas: Allah! with Him is an eternal angel writing in a book of gold the names of those who love the Lord.

award.” I came out of the mosque with my mind at peace and proceeded Abou asked the Angel if his own name was on the list. The Angel replied to the railway station. I always remember that when the call for namaz in the negative. Disappointed but still cheerful, Abou said, “Write my sounded, our home would transform into a small mosque. My father and name down as one that loves his fellowmen”. The angel wrote, and my mother leading, and their children and grandchildren following.

vanished. The next night, it came again with a great wakening light, and showed the names of those whom the love of God had blessed. And The next morning I was back at Thumba, physically exhausted, Abou’s name was the first on the list.

emotionally shattered, but determined to fulfill our ambition of flying an Indian rocket motor on foreign soil.

I sat for a long time with my mother, but could not speak. She blessed me in a choked voice when I took leave of her to return to Thumba. She On my return from France, after successfully testing the SLV-3

knew that she was not to leave the house of her husband, of which she apogee motor, Dr Brahm Prakash informed me one day about the arrival was the custodian, and I was not to live with her there. Both of us had to of Wernher von Braun. Everybody working in rocketry knows of von live out our own destinies. Was I too stubborn or was I excessively Braun, who made the lethal V-2 missiles that devastated London in the preoccupied with the SLV? Should I not have forgotten for a while my Second World War. In the final stages of the War, von Braun was captured by the Allied Forces. As a tribute to his genius, von Braun was e e prpersess

47



WINGS OF FIRE

ORIENTATION - 1

EXPEDIENTS

given a top position in the rocketry programme at NASA. Working for They suffer from a deep-rooted NIH—Not Invented Here—complex the US Army, von Braun produced the landmark Jupiter missile, which and look down on alien technologies. If you want to do anything in rocketry, was the first IRBM with a 3000 km range. When I was asked by Dr do it yourself,” von Braun advised me. He commented, “SLV-3 is a Brahm Prakash to receive von Braun at Madras and escort him to genuine Indian design and you may be having your own troubles. But Thumba, I was naturally excited.

you should always remember that we don’t just build on successes, we The V-2 missile (an abbreviation of the German word also build on failures.”

Vergeltungswaffe) was by far the greatest single achievement in the On the topic of the inevitable hard work that goes with rocket history of rockets and missiles. It was the culmination of the efforts development and the degree of commitment involved, he smiled and made by von Braun and his team in the VFR (Society for Space Flight) said with a glint of mischief in his eyes, “Hard work is not enough in in the 1920s. What had begun as a civilian effort soon became an official rocketry. It is not a sport where mere hard work can fetch you honours.

army one, and von Braun became the technical director of the German Here, not only do you have to have a goal but you have to have strategies Missile Laboratory at Kummersdorf. The first V-2 missile was first tested to achieve it as fast as possible.”

unsuccessfully in June 1942. It toppled over on to its side and exploded.

“Total commitment is not just hard work, it is total involvement.

But on 16 August 1942, it became the first missile to exceed the speed of sound. Building a rock wall is back-breaking work. There are some people who of sound. Under the supervision of von Braun, more than 10,000 V-2

build rock walls all their lives. And when they die, there are miles of missiles were produced between April and October 1944 at the gigantic walls, mute testimonials to how hard those people had worked.” underground production unit near Nordhausen in Germany. That I would be travelling with this man—a scientist, a designer, a production engineer, He continued, “But there are other men who while placing one rock an administrator, a technology manager all rolled into one—what more on top of another have a vision in their minds, a goal. It may be a terrace could I have asked for?

with roses climbing over the rock walls and chairs set out for lazy summer days. Or the rock wall may enclose an apple orchard or mark a boundary.

We flew in an Avro aircraft which took around ninety minutes from When they finish, they have more than a wall. It is the goal that makes Madras to Trivandrum. von Braun asked me about our work and listened the difference. Do not make rocketry your profession, your livelihood—

as if he was just another student of rocketry. I never expected the father make it your religion, your mission.” Did I see something of Prof. Vikram of modern rocketry to be so humble, receptive and encouraging. He Sarabhai in von Braun? It made me happy to think so.

made me feel comfortable right through the flight. It was hard to imagine that I was talking to a giant of missile systems, as he was so self-effacing.

With three deaths in the family in as many successive years, I needed total commitment to my work in order to keep performing. I wanted to He observed that the length to diameter l/D ratio of the SLV—throw all my being into the creation of the SLV. I felt as if I had discovered 3, which was designed to be 22 was on the higher side and cautioned me the path I was meant to follow, God’s mission for me and my purpose on about the aero-elastic problems which must be avoided during flight.

His earth. During this period, it was as though I had pushed a hold Having spent the major part of his working life in Germany, how did button—no badminton in the evenings, no more weekends or holidays, he feel in America? I asked this of von Braun who had become a cult no family, no relations, not even any friends outside the SLV circle.

figure in the States after creating the Saturn rocket in the Apollo mission To succeed in your mission, you must have single-minded devotion to which put man on the moon. “America is a country of great possibilities, your goal. Individuals like myself are often called ‘workaholics’. I question but they look upon everything un-American with suspicion and contempt.

this term because that implies a pathological condition or an illness. If I e e prpersess



WINGS OF FIRE

ORIENTATION - 1

EXPEDIENTS

do that which I desire more than anything else in the world and which Sivaramakrishnan Nair was one among the six persons injured. The makes me happy, such work can never be an aberration. Words from acid had burned his body at a number of places. By the time we got a the twenty-sixth Psalm come to mind while I work: “Examine me, O

bed in the hospital, he was in severe pain. I kept vigil at his bedside.

Lord, and prove me.”

Around 3 o’ clock in the morning, Sivarama-krishnan regained Total commitment is a crucial quality for those who want to reach consciousness. His first words expressed regret over the mishap and the very top of their profession. The desire to work at optimum capacity assured me that he would make up the slippage in schedules caused by leaves hardly any room for anything else. I have had people with me the accident. His sincerity and optimism, even in the midst of such severe who would scoff at the 40-hours-a-week job they were being paid for. I pain, impressed me deeply.

have known others who used to work 60, 80 and even 100 hours a week Men like Sivaramakrishnan are a breed apart. They are the strivers, because they found their work exciting and rewarding. Total commitment always reaching higher than the last time. And with their social and is the common denominator among all successful men and women. Are family life welded to their dream, they find the rewards of their drive you able to manage the stresses you encounter in your life? The difference overwhelming—the inherent joy of being in flow. This event greatly between an energetic and a confused person is the difference in the enhanced my confidence in my team; a team that would stand like a way their minds handle their experiences. Man needs his difficulties rock in success and failure.

because they are necessary to enjoy success. All of us carry some sort I have used the word ‘flow’ at many places without really elaborating of a super-intelligence within us. Let it be stimulated to enable us to its meaning. What is this flow? And what are these joys? I could call examine our deepest thoughts, desires, and beliefs.

them moments of magic. I see an analogy between these moments and Once you have done this—charged yourself, as it were, with your the high that you experience when you play badminton or go jogging.

commitment to your work—you also need good health and boundless Flow is a sensation we

experience when we act with total involvement.

energy. Climbing to the top demands strength, whether to the top of Mount Everest or to the top of your career. People are born with different energy reserves and the one who tires first and burns out easily will do so in no hurry; there are no distracting demands on one's attention. The well to reorganize his or her life at the earliest.

past and the future disappear. So does the distinction between self and In 1979, a six-member team was preparing the flight version of a the activity. We had all come under the current of the SLV flow. Although complex second stage control system for static test and evaluation. The we were working very hard we were very relaxed, energetic and fresh.

team was in countdown mode at T-15 minutes (15 minutes before the How did it happen? Who had created this flow?

test). One of the twelve valves did not respond during checkout. Anxiety Perhaps it was the meaningful organization of the purposes we sought drove the members of the team to the test site to look into the problem.

to achieve. We would identify the broadest possible purpose level and Suddenly the oxidizer tank, filled with red fuming nitric acid (RFNA), then work towards developing a feasible target solution from a variety burst, causing severe acid burns to the team members. It was a very of alternatives. It was this working backwards to develop a creative traumatic experience to see the suffering of the injured. Kurup and I change in the problem solution, that used to put us in 'flow'.

rushed to the Trivandrum Medical College Hospital and begged to have When the SLV-3 hardware started emerging, our ability to concentrate our colleagues admitted, as six beds were not available in the hospital at increased markedly. I felt a tremendous surge of confidence; in complete that point of time.

control over myself and over the SLV-3 project. Flow is a by-product of e e prpersess

49



WINGS OF FIRE

ORIENTATION - 1

EXPEDIENTS

controlled creativity. The first requirement is to work as hard as you can We had scheduled the first experimental flight trial of SLV-3 for 10

at something that presents a challenge and is approved by your heart. It August 1979. The primary

goals of the mission were to realise a fully may not be an overwhelming challenge, but one that stretches you a integrated launch vehicle; to evaluate on-board systems like stage motors, little, something that makes you realise that you are performing a task guidance and control systems and electronic subsystems; and to evaluate better today than you did yesterday, or the last time you tried to do it.

ground systems, like checkout, tracking, telemetry and real-time data Another prerequisite for being in flow is the availability of a significant facilities in launch operations built at the Sriharikota launch complex.

span of uninterrupted time. In my experience, it is difficult to switch into The 23 metre-long, four-stage SLV rocket weighing 17 tonnes finally the flow state in less than half an hour. And it is almost impossible if you took off elegantly at 0758 hours and immediately started following its are bedevilled by interruptions.

programmed trajectory.

Is it possible to switch yourself into flow by using some sort of a Stage I performed to perfection. There was a smooth transition from conditioning device in much the same way that we condition ourselves this stage to the second stage. We were spellbound to see our hopes to learn effectively? The answer is yes, and the secret is to analyse flying in the form of the SLV-3. Suddenly, the spell was broken. The previous occasions when you have been in flow, because each person second stage went out of control. The flight was terminated after 317

has his or her unique natural frequency which responds to a particular seconds and the vehicle's remains, including my favourite fourth stage stimulus. You alone can identify the common denominator in your case.

with the payload splashed into the sea, 560 km off Sriharikota.

Once you have isolated this common denominator, you can set the stage The incident caused us profound disappointment. I felt a strange mix for flow.

of anger and frustration. Suddenly, I felt my legs become so stiff that I have experienced this state many times, almost every day of the they ached. The problem was not with my body; something was SLV mission. There have been days in the laboratory when I have looked happening in my mind.

up to find the laboratory empty and realised that it was way past the The premature death of my hovercraft Nandi, the abandoning of the quitting time. On other days, my team members and I have been so RATO, the abortion of the SLV-Diamont fourth stage—all came alive in caught up in our work that the lunch hour slipped by without our even a flash, like a long-buried Phoenix rising from its ashes. Over the years, being conscious that we were hungry.

I had somehow learned to absorb these aborted endeavours, had come Analysing such occasions in retrospect, I find them similar in the to terms with them and pursued fresh dreams. That day, I re-lived each sense that this flow was experienced when the project was nearing of those setbacks in my deep despondency.

completion, or when the project had reached that phase when all the

“What do you suppose could be the cause of it?” somebody asked necessary data had been gathered and we were ready to start summing me in the Block House. I tried to find an answer, but I was too tired to up the problem, outlining the demands made by conflicting criteria and try and think it out, and gave up the effort as futile. The launch was the various positions presented by opposing interests and making our conducted in the early morning, preceded by a full night’s count-down.

recommendations for action. I also realised that this tended to happen Moreover, I had hardly had any sleep in the past week. Completely on days that were relatively quiet in the office, with no crises or meetings.

drained—mentally as well as physically—I went straight to my room Such spells increased steadily in frequency, and the SLV-3 dream was and slumped onto the bed.

finally realised in the middle of 1979.

A gentle touch on my shoulder woke me up. It was late in the afternoon, almost approaching evening. I saw Dr Brahm Prakash sitting e e prpersess

50



WINGS OF FIRE

ORIENTATION - 1

BUILDERS

by my bedside. “What about going for lunch?” he asked. I was deeply touched by his affection and concern. I found out later that Dr Brahm Prakash had come to my room twice before that but had gone away on finding me asleep. He had waited all that time for me to get up and have lunch with him. I was sad, but not alone. The company of Dr Brahm Prakash filled me with a new confidence. He made light conversation during the meal, carefully avoiding the SLV-3, but gently providing me solace.

* * *

9

Builders

Dr Brahm Prakash helped me endure this difficult period. In practice, Dr Brahm Prakash employed the front-line damage control principle:

“Just get the fellow home alive. He’ll recover.” He drew the entire SLV

team close and demonstrated to me that I was not alone in my sorrow at the SLV-3’s failure. “All your comrades are standing by you,” he said.

This gave me vital emotional support, encouragement, and guidance.

A post-flight review conducted on 11 August 1979 was attended by more than seventy scientists. A detailed technical appraisal of the failure was completed. Later, the post-flight analysis committee headed by SK

Athithan pinpointed the reasons for the malfunction of the vehicle. It was established that the mishap occurred because of the failure of the second stage control system. No control force was available during the second stage flight due to which the vehicle became aerodynamically unstable, resulting in altitude and velocity loss. This caused the vehicle to fall into the sea even before the other stages could ignite.

Further in-depth analysis of the second-stage failure identified the reason as the draining of a good amount of Red Fuming Nitric Acid (RFNA) used as the oxidizer for the fuel power at that stage.

Consequently, when the control force was demanded, only fuel was injected resulting in zero force. ‘A solenoid valve in the oxidizer tank e e prpersess

51



WINGS OF FIRE

ORIENTATION - 1

BUILDERS

remaining open due to contamination after the first command at T-8

thoughts helped to give me the ability to withstand apparently irreversible minutes’, was identified as the reason for the draining of RFNA.

setbacks.

The findings were presented to Prof. Dhawan at a meeting of top Early in November 1979, Dr Brahm Prakash retired. He had always ISRO scientists and were accepted. Everybody was convinced by the been my sheet-anchor in the turbulent waters of VSSC. His belief in technical cause-and-effect sequence presented and there was a general team spirit had inspired the management pattern for the

SLV project, feeling of satisfaction about the whole exercise of failure-management which later became a blueprint for all scientific projects in the country.

measures taken. I was still unconvinced though and felt restless. To me, Dr Brahm Prakash was a very wise counsellor who gave me valuable the level of responsibility is measured by one's ability to confront the guidance whenever I deviated from my mission objectives.

decision-making process without any delay or distraction.

Dr Brahm Prakash not only reinforced the traits which I had acquired On the spur of the moment, I stood up and addressed Prof. Dhawan, from Prof. Sarabhai, but also helped me give them new dimensions. He

“Sir, even though my friends have technically justified the failure, I take always cautioned me against haste. “Big scientific projects are like the responsibility for judging the RFNA leak detected during the final mountains, which should be climbed with as little effort as possible and phase of countdown as insignificant. As a Mission Director, I should without urgency. The reality of your own nature should determine your have put the launch on hold and saved the flight if possible. In a similar speed. If you become restless, speed up. If you become tense and high-situation abroad, the Mission Director would have lost his job. I therefore strung, slow down. You should climb the mountain in a state of equilibrium.

take responsibility for the SLV-3 failure.” For quite some time there When each task of your project is not just a means to an end but a was pin-drop silence in the hall. Then Prof. Dhawan got up and said, “I unique event in itself, then you are doing it well,” he would tell me. The am going to put Kalam in orbit!”, and left the place signalling that the echo of Dr Brahm Prakash's advice could be heard in Emerson's poem meeting was over.

on Brahma:

The pursuit of science is a combination of great elation and great *If the red slayer think he slays,*

despair. I went over many such episodes in my mind. Johannes Kepler, *Or, if the slain think he is slain,*

whose three orbital laws form the basis of space research, took nearly *They know not well, the subtle ways*

17 years after formulating the two laws about planetary motion around *I keep, and pass, and turn again.*

the sun, to enunciate his third law which gives the relation between the To live only for some unknown future is superficial. It is like climbing size of the elliptical orbit and the length of time it takes for the planet to a mountain to reach the peak without experiencing its sides. The sides go around the sun. How many failures and frustrations must he have of the mountain sustain life, not the peak. This is where things grow, gone through? The idea that man could land on the moon, developed

by experience is gained, and technologies are mastered. The importance of the Russian mathematician Konstantin Tsiolkovsky, was realised after the peak lies only in the fact that it defines the sides. So I went on nearly four decades—and by the United States, at that. Prof.

towards the top, but always experiencing the sides. I had a long way to Chandrasekhar had to wait nearly 50 years before receiving the Nobel go but I was in no hurry. I went in little steps—just one step after Prize for his discovery of the ‘Chandrasekhar Limit’, a discovery made another—but each step towards the top.

while he was a graduate student at Cambridge in the 1930s. If his work had been recognized then, it could have led to the discovery of the Black At every stage, the SLV-3 team was blessed with some Hole decades earlier. How many failures must von Braun have gone extraordinarily courageous people. Along with Sudhakar and Sivarama-through before his Saturn launch vehicle put man on the moon? These krishnan, there was also Sivakaminathan. He was entrusted with bringing e e prpersess

52



WINGS OF FIRE

ORIENTATION - 1

BUILDERS

the C-Band transponder from Trivandrum to SHAR for integration with highlighted SLV-3’s possible military implications in terms of acquiring the SLV-3. The transponder is a device fitted with the rocket system to the capability for building IRBMs. Some were a general prognosis of all give the radar signals which are powerful enough to help it track the that ailed our country and related it to the SLV-3. I knew that the next vehicle from the take-off site to the final impact point. The SLV-3 launch day’s launch was going to decide the future of the Indian space schedule was dependent on the arrival and integration of this equipment.

programme. In fact, to put it simply, the eyes of the whole nation were On landing at the Madras airport, the aircraft which Sivakami was on us.

travelling in skidded and overshot the runway. Dense smoke engulfed In the early hours of the next day, 18 July 1980—at 0803 hrs to be the aircraft. Everyone jumped out of the aircraft through emergency precise, India’s first Satellite Launch Vehicle, SLV-3 lifted off from exits, and desperately fought to save themselves—all except Sivakami, SHAR. At 600 seconds before take-off, I saw the computer displaying who stayed in the aircraft till he removed the transponder from his data about stage IV giving the required velocity to the Rohini Satellite baggage. He was among the last few persons, the others being mostly (carried as payload) to enter its orbit. Within the next two minutes, Rohini aircraft crew, to emerge from the smoke and he was hugging the was set into motion in a low earth orbit. I spoke, in the midst of screeching transponder close to his chest.

decibels, the most important words I had ever uttered in my life, “Mission Another incident from those days that I recall clearly relates to Prof.

Director calling all stations. Stand by for an important announcement.

Dhawan’s visit to the SLV-3 assembly building. Prof. Dhawan, All stages performed to mission requirements. The fourth stage apogee Madhavan Nair and I were discussing some finer aspects of the SLV-3

motor has given the required velocity to put Rohini Satellite into orbit”.

integration. The vehicle was kept on the launcher in a horizontal position.

There were happy cries everywhere. When I came out of the Block When we were moving around and examining the readiness of the House, I was lifted onto the shoulders of my jubilant colleagues and integrated hardware, I noticed the presence of big water-ports for carried in a procession.

extinguishing fire in case of an accident. For some reason, I felt The whole nation was excited. India had made its entry into the uncomfortable at the sight of the ports facing the SLV-3 on the launcher.

small group of nations which possessed satellite launch capability.

I suggested to Madhavan Nair that we could rotate the port so that they Newspapers carried news of the event in their headlines. Radio and were apart by a full 180o. This would prevent the freak possibility of television stations aired special programmes. Parliament greeted the water gushing out and damaging the rocket. To our surprise, within achievement with the thumping of desks. It was both the culmination of minutes of Madhavan Nair getting the ports reversed, powerful water a national dream, and the beginning of a very important phase in our jets gushed out of the ports. The Vehicle Safety Officer had ensured the nation’s history. Prof. Satish Dhawan, Chairman ISRO, threw his functioning of the fire-fighting system without realising that it could have customary guardedness to the winds and announced that it was now wrecked the entire rocket. This was a lesson in foresight. Or did we well within our ability to explore space. Prime Minister Indira Gandhi have divine protection?

cabled her congratulations. But the most important reaction was that of On 17 July 1980, 30 hours before the launch of the second SLV-3, the Indian scientific community—everybody was proud of this hundred the newspapers were filled with all kinds of predictions. One of the per cent indigenous effort.

newspapers reported, “The Project Director is missing and could not be I experienced mixed feelings. I was happy to achieve the success contacted.” Many reports preferred to trace the history of the first SLV-which had been evading me for the past two decades, but I was sad 3 flight, and recalled how the third stage had failed to ignite because of because the people who had inspired me were no longer there to share lack of fuel and the rocket had nosedived into the ocean. Some my joy—my father, my brother-in-law Jallaluddin, and Prof. Sarabhai.



WINGS OF FIRE

ORIENTATION - 1

BUILDERS

The credit for the successful SLV-3 flight goes, first, to the giants of Hesitantly, I rose and responded, “I am indeed honoured to be in this the Indian space programme, Prof. Sarabhai in particular, who had great gathering of nation-builders. I only know how to build a rocket preceded this effort; next to the hundreds of VSSC personnel who had system in our country, which would inject a satellite, built in our country, through sheer will-power proved the mettle of our countrymen and also, by imparting to it a velocity of 25,000 km per hour.” There was thunderous not least, to Prof. Dhawan and Dr Brahm Prakash, who had led the applause. I thanked the members for giving us an opportunity to work project.

on a project like the SLV-3 and prove the scientific strength of our We had a late dinner that evening. Gradually, the din and clatter of country. The entire room was irradiated with happiness.

the celebrations calmed down. I retired to my bed with almost no energy Now that Project SLV-3 had been successfully completed, VSSC

left. Through the open window, I could see the moon among the clouds.

had to re-organize its resources and redefine its goals. I wanted to be The sea breeze seemed to reflect the buoyancy of the mood on relieved of the project activities, and consequently Ved Prakash Sandlas Sriharikota island that day.

from my team was made the Project Director for the SLV-3 Continuation Within a month of the SLV-3 success, I visited the Nehru Science Project, which aimed at making operational satellite launch vehicles of a Centre in Bombay for a day, in response to an invitation to share my similar class. With a view to upgrade the SLV-3 by means of certain experiences with the SLV-3. There, I received a telephone call from technological innovations, the development of Augmented Satellite Prof. Dhawan in Delhi, asking me to join him the next morning. We Launch Vehicles (ASLVs) had been on the cards for some time. The were to meet the Prime Minister, Mrs Indira Gandhi. My hosts at the aim was to enhance the SLV-3 payload capability from 40 kg to 150 kg.

Nehru Centre were kind enough to arrange my ticket to Delhi, but I had MSR Dev from my team was appointed Project Director ASLV. Then, a small problem. It had to do with my clothes. I was dressed casually as to reach the sun-synchronous orbit (900 km), a PSLV was to be made.

is my wont and wearing slippers—not, by any standards of etiquette, The Geo Satellite Launch

Vehicle (GSLV) was also envisaged, though suitable attire in which to meet the Prime Minister! When I told Prof.

as a distant dream. I took up the position of Director, Aerospace Dhawan about this problem, he told me not to worry about my dress.

Dynamics and Design Group, so that I could configure the forthcoming

“You are beautifully clothed in your success,” he quipped.

launch vehicles and technology development.

Prof. Dhawan and I arrived at the Parliament House Annexe the The existing VSSC infrastructure was inadequate to handle the size next morning. A meeting of the Parliamentary Panel on Science & and weight of the future launch vehicle systems and the implementation Technology chaired by the Prime Minister was scheduled. There were of all these projects was going to require highly specialized facilities.

about 30 Members of the Lok Sabha and Rajya Sabha in the room, New sites were identified for the expanded activities of VSSC, at which was lit by a majestic chandelier. Prof. MGK Menon and Dr Nag Vattiyoorkavu and Valiamala. Dr Srinivasan drew up a detailed plan of Chaudhuri were also present. Shrimati Gandhi spoke to the Members the facilities. Meanwhile, I carried out an analysis of the application of about the success of the SLV-3 and lauded our achievement. Prof.

SLV-3 and its variants with Sivathanu Pillai, and compared the existing Dhawan thanked the gathering for the encouragement given by them to launch vehicles of the world for missile applications. We established space research in the country and expressed the gratitude of the ISRO

that the SLV-3 solid rocket systems would meet the national requirements scientists and engineers. Suddenly, I saw Shrimati Gandhi smiling at me of payload delivery vehicles for short and intermediate ranges (4000

as she said, “Kalam! We would like to hear you speak.” I was surprised km). We contended that the development of one additional solid booster by the request as Prof. Dhawan had already addressed the gathering.

of 1.8 m diameter with 36 tonnes of propellant along with SLV-3

subsystems would meet the ICBM requirement (above 5000 km for a e e prpersess

54



WINGS OF FIRE

ORIENTATION - 1

BUILDERS

1000 kg payload). This proposal was, however, never considered. It natural that I was soon in full spate about it. Later, Prof. Raja Ramanna nevertheless paved the way for the formulation of the Re-entry invited me for a private meeting over tea.

Experiment (REX) which, much later on, became Agni.

The first thing that struck me when I met Prof. Ramanna was his The next SLV-3 flight, SLV3-D1, took off on 31 May 1981. I witnessed genuine pleasure at meeting me. There was an eagerness in his talk, an this flight from the visitors' gallery. This was the first time I witnessed a immediate, sympathetic friendliness, accompanied by quick, graceful launch from outside the Control Centre. The unpalatable truth I had to movements. The evening brought back memories of my first meeting face was that by becoming the focus of media attention, I had aroused with Prof. Sarabhai—as if it was yesterday. The world of Prof. Sarabhai envy among some of my senior colleagues, all of whom had equally was internally simple and externally easy. Each of us working with him contributed to the success of SLV-3. Was I hurt at the coldness of the was driven by a single-minded need to create, and lived under conditions new environment? Perhaps yes, but I was willing to accept what I which made the object of that need directly accessible. Sarabhai's world couldn't change.

was tailor-made to our dreams. It had neither too much nor too little of I have never lived off the profits of others' minds. My life, in keeping anything needed by any one of us. We could divide it by our requirements with my nature, has never been that of a ruthless achiever. The SLV-3

without a remainder.

was made not by force and manipulation, but through consistent collective My world, by now, had no simplicity left in it. It had become an effort. Then why this sense of bitterness? Was it peculiar to the VSSC

internally complex and externally difficult world. My efforts in rocketry top level or a universal reality? As a scientist, I was trained to reason out and in achieving the goal of making indigenous rockets were impeded reality. In science, reality is that which exists. And because this bitterness by external obstacles and complicated by internal wavering. I was aware was real, I had to reason it out. But can these things be reasoned out?

that it required a special effort of the will to sustain my trajectory. The Were my post-SLV experiences leading me into a critical situation?

coordination of my present with my past had already been jeopardised.

Yes and no. Yes, because the glory of SLV-3 had not gone to everyone The coordination of my present with my future was uppermost in my who deserved it—but hardly anything could have been done about that.

mind when I went to have tea with Prof. Ramanna.

No, because a situation can be considered critical for a person only He did not take long to come to the point. The Devil Missile when realisation of the internal necessity becomes impossible. And that programme had been shelved in spite of tremendous achievements made certainly was not the case. In fact, the concept of conflict is built upon by Narayanan and his team at DRDL. The entire programme of military this basic idea. In retrospect, I can only say that I was fully aware of a rockets was reeling under a persistent apathy. The DRDO needed great need for actualization and renewal.

somebody to take command of their missile programmes which had In January 1981, I was invited by Dr Bhagiratha Rao of the High been stuck at the drawing board and static test bed stages for quite a Altitude Laboratory (now the Defence Electronics Applications while. Prof. Ramanna asked me if I would like to join DRDL and shoulder Laboratory (DEAL)), Dehra Dun to give a lecture on the SLV-3. The the responsibility of shaping their Guided Missile Development renowned nuclear scientist, Prof. Raja Ramanna, whom I had always Programme (GMDP). Prof. Ramanna's proposal evoked a mixture of admired, and who was then the Scientific Adviser to the Defence Minister, emotions in me.

presided over the gathering. He spoke on India's efforts in generating When again would I have such an opportunity to consolidate all our nuclear energy and the challenge in conducting the first nuclear test for knowledge of rocketry and apply it?

peaceful purposes. As I had been so closely involved with SLV-3, it was e e prpersess

55



WINGS OF FIRE

ORIENTATION - 1

BUILDERS

I felt honoured by the esteem in which Prof. Ramanna held me. He and hugged my mother. My father ran his caring fingers through my hair. He had been the guiding spirit behind the Pokharan nuclear test, and I was hair. My mentor, Jallaluddin, announced the news to the crowd gathered thrilled by the impact he had helped create on the outside world about on Mosque Street. My sister, Zohara, prepared special sweets for me.

India's technical competence. I knew I would not be able to refuse him.

Pakshi Lakshmana Sastry put a tilak on my forehead. Fr. Solomon blessed Prof. Ramanna advised me to talk to Prof. Dhawan on this issue so that me holding the holy cross. I saw Prof. Sarabhai smiling with a sense of he could work out the modalities of my transfer from ISRO to DRDL.

achievement—the sapling which he had planted twenty years ago had I met Prof. Dhawan on 14 January 1981. He gave me a patient finally grown into a tree whose fruits were being appreciated by the hearing, with his typical penchant for weighing everything carefully to people of India.

make sure he didn't miss a point. A markedly pleasant expression came My Padma Bhushan evoked mixed reactions at VSSC. While there to his face. He said, "I am pleased with their appraisal of my man's were some who shared my happiness, there were others who felt I was work". He then smiled. I have never met anyone with a smile quite like being unduly singled out for recognition. Some of my close associates Prof. Dhawan's—a soft white cloud—you could picture it in any shape turned envious. Why do some people fail to see the great values of life you wanted to.

because of sadly twisted thought processes? Happiness, satisfaction, I wondered how I should proceed. "Should I formally apply for the and success in life depend on making the right choices, the winning post so that DRDL could send the appointment order?" I enquired of choices. There are forces in life working for you and against you. One Prof. Dhawan. "No. Don't pressurise them. Let me talk to the top-level must distinguish the beneficial forces from the malevolent ones and choose management during my next visit to New Delhi," Prof. Dhawan said. "I correctly between them.

know you have always had one foot in DRDO, now your whole centre An inner voice told me that the time had come for a long felt, but of gravity seems to have shifted towards them." Perhaps what Prof.

ignored, need for renewal. Let me clean my slate and write new 'sums'.

Dhawan was telling me had an element of truth in it, but my heart had Were the earlier sums done correctly? Evaluating one's own progress in always been at ISRO. Was he really unaware of that?

life is not an easy task. Here the student has to set his own questions, Republic Day, 1981 brought with it a pleasant surprise. On the evening seek his own answers and evaluate them to his own satisfaction.

of 25 January, Mahadevan, Secretary to Prof. UR Rao, rang up from Judgement aside, eighteen years at ISRO was too long a stay to leave Delhi to inform me about the Home Ministry announcement about the without pain. As for my afflicted friends, the lines by Lewis Carroll conferment of the Padma Bhushan award on me. The next important seemed very appropriate:

call was from Prof. Dhawan to congrat-ulate me. I felt blissfully elated *You may charge me with murder* –

as it was from my guru. I rejoiced with Prof. Dhawan at his receiving *Or want of sense*

the Padma Vibhushan and I congratulated him wholeheartedly. I then *(We are all of us weak at times):*

rang up Dr Brahm Prakash and thanked him. Dr Brahm Prakash chided *But the slightest approach to a false pretence* me for the formality and said, "I feel as if my son has got the award." I *Was never among my crimes!*

was so deeply touched by Dr Brahm Prakash's affection that I could no

* * *

longer keep my emotions in check.

I filled my room with the music of Bismillah Khan's shehnai. The music took me to another time, another place. I visited Rameswaram e e prpersess

56



WINGS OF FIRE

ORIENTATION - 1

III

PROPITIATION

[1981 – 1991]

Let craft, ambition, spite,

Be quenched in Reason's night,

Till weakness turn to might,

Till what is dark be light,

Till what is wrong be right!

Lewis Carroll

e e prpersess

57



WINGS OF FIRE

ORIENTATION - 1

SEEKERS

Prof. Dhawan asked me to give a talk on the Space Programme Profile in India by the year 2000. Almost the entire ISRO management and staff attended my talk, which was by way of a farewell meeting.

I had met Dr VS Arunachalam in 1976, when I visited DMRL in connection with the aluminium alloy

inertial guidance platform. Taking it as a personal challenge, Dr Arunachalam had the investment casting, the first of its kind in the country, made in the incredibly short time of two months. His youthful energy and enthusiasm never failed to amaze me. This young metallurgist had within a short span of time lifted the science of metal-making to the technology of metal-forming and then to the art of alloy development.

Seekers

With a tall and elegant figure, Dr Arunachalam was like an electrically charged dynamo himself. I found him an unusually friendly person with a forceful manner, as well as an excellent working partner.

A minor tussle over my services occurred at this time, between I visited DRDL in April 1982 to acquaint myself with my potential ISRO, which was a little hesitant to relieve me, and DRDO, work site. The Director of DRDL then, SII Bansal, took me around and which wanted to take me in. Many months went by, and introduced me to the senior scientists in the laboratory. DRDL was many letters were exchanged between ISRO and DRDO; and meetings working on five staff projects and sixteen competence build-up projects.

were held in the secretariats of the Defence R&D establishment and They were also involved in several technology-oriented activities with a the Department of Space to precipitate a mutually convenient course of view to gain lead time for the development of indigenous missile systems action. Meanwhile, Prof. Ramanna retired from the office of the Scientific in future. I was particularly impressed by their efforts on the twin 30-ton Advisor to Defence Minister. Dr VS Arunachalam, till then Director of Liquid Propellant Rocket Engine.

the Defence Metallurgical Research Laboratory (DMRL) in Hyderabad, Meanwhile, Anna University, Madras, conferred the honorary degree succeeded Prof. Ramanna. Dr Arunachalam was known for his of Doctor of Science on me. It had been nearly twenty years since I had confidence, and he cared little for the intricacies and nuances of the acquired my degree in aeronautical engineering. I was happy that Anna scientific bureaucracy. Meanwhile, I understand that the Defence University had recognized my efforts in the field of rocketry, but what Minister at that time, R Venkataraman discussed the matter of my taking pleased me most was the recognition of the value of our work in academic over the missile laboratory with Prof. Dhawan. Prof. Dhawan also circles. To my delight, the honorary doctorate degree was awarded at a seemed to be waiting for a decisive step at the highest level in the Defence convocation presided over by Prof. Raja Ramanna.

Ministry. Overcoming the niggling doubts that had caused delays over the past year, the decision to appoint me Director, DRDL was finally I joined DRDL on 1 June, 1982. Very soon, I realized that this taken in February, 1982.

laboratory was still haunted by the winding up of the Devil missile project.

Many excellent professionals had not yet recovered from the Prof. Dhawan used to visit my room in the ISRO headquarters and disappointment. People outside the scientific world may find it difficult spend many hours in evolving space launch vehicle projects. It was a to comprehend how a scientist feels when the umbilical cord to his work great privilege to work with such a great scientist. Before I left ISRO, is suddenly snapped, for reasons totally alien to his understanding and e e prpersess

58



WINGS OF FIRE

ORIENTATION - 1

SEEKERS

interests. The general mood and work tempo at DRDL reminded me of Very good work on a Surface-to-Surface missile with a vertical rise-Samuel Taylor Coleridge's poem The Rime of the Ancient Mariner: turn straight line climb-ballistic path had been done by that time. I was *Day after day, day after day,*

astonished to see the determination of the DRDL workforce, who, in *We stuck, nor breath, nor motion;*

spite of the premature winding up of their earlier projects, were eager to *As idle as a painted ship*

go ahead. I arranged reviews for its various subsystems, to arrive at *Upon a painted ocean.*

precise specifications. To the horror of many old-timers in DRDO, I started inviting people from the Indian Institute of Science, Indian I found almost all my senior colleagues living with the pain of dashed Institutes of Technology, Council for Scientific and Industrial Research, hopes. There was a widespread feeling that the scientists of this Tata Institute of Fundamental Research, and many other educational laboratory had been cheated by the senior officials in the Ministry of institutions where related experts could be found. I felt that the stuffy Defence. It was clear to me that the burial of the Devil was essential work centres of DRDL needed a breath of fresh air. Once we opened for the rise of hope and vision.

the windows wide, the light of scientific talent began to pour in. Once When about a month later, Admiral OS Dawson, then the Chief of more, Coleridge's Ancient Mariner came to mind: "Swiftly, swiftly flew Naval Staff, visited DRDL, I used it as an opportunity to make a point the ship, \ Riding gently the oncoming tide." with my team. The Tactical Core Vehicle (TCV) project had been Sometime in the beginning of 1983, Prof. Dhawan visited DRDL. I hanging fire for quite some time. It was conceived as a single core reminded him of his own advice to me almost a decade ago: "You have vehicle with certain common subsystems to meet the requirements of to dream before your dreams can come true. Some people stride towards the services for a quick reaction Surface-to-Air Missile, an anti-radiation whatever it is that they want in life; others shuffle their feet and never Air-

to-Surface Missile which could be launched from helicopters or fixed get started because they do not know what they want—and do not wing aircraft. I emphasized the sea-skimming role of the core vehicle to know how to find it either.” ISRO was lucky to have had Prof. Sarabhai Admiral Dawson. I focussed not on its technical intricacies, but on its and Prof. Dhawan at the helm—leaders who elucidated their goals, battlefield capabilities; and I highlighted the production plans. The message made their missions larger than their lives, and could then inspire their was loud and clear to my new associates—do not make anything which entire workforce. DRDL had not been so lucky. This excellent laboratory you cannot sell later and do not spend your life on making one thing only.

played a truncated role that did not reflect its existing or potential Missile development is a multi-dimensional business—if you remain in capabilities or even fulfill the expectations in South Block. I told Prof.

any one dimension for a long time, you will get stuck.

Dhawan about the highly professional, but slightly bewildered team My initial few months at DRDL were largely interactive. I had read I had. Prof. Dhawan responded with his characteristic broad smile at St. Joseph’s that an electron may appear as a particle or wave which could be interpreted in any way one chose.

depending on how you look at it. If you ask a particle question, it will In order to accelerate the pace of R&D activities at DRDL, it was give you a particle answer; if you ask a wave question, it will give you a imperative that decisions on vital scientific, technical and technological wave answer. I not only described and explained our goals, but also problems be taken quickly. Throughout my career I had zealously pursued made them an interplay between our work and ourselves. I still recall openness in scientific matters. I had seen from very close quarters the quoting Ronald Fischer at one of the meetings, “The sweetness we taste decay and disintegration that go with management through closed-door in a piece of sugar is neither a property of the sugar nor a property of consultations and secret manipulations. I always despised and resisted ourselves. We are producing the experience of sweetness in the process such efforts. So the first major decision which we took was to create a of interacting with the sugar.”

forum of senior scientists where important matters could be discussed e e prpersess



WINGS OF FIRE

ORIENTATION - 1

SEEKERS

Plate 9 The twin-engine indigenous hovercraft prototype Nandi developed at ADE, Bangalore. As inventor and pilot, I took my rightful place at the controls.

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WINGS OF FIRE

ORIENTATION - 1

SEEKERS

Plate 10 The Christian community in Thumba very graciously gave up this beautiful Church to house the first unit of the Space Research Centre.

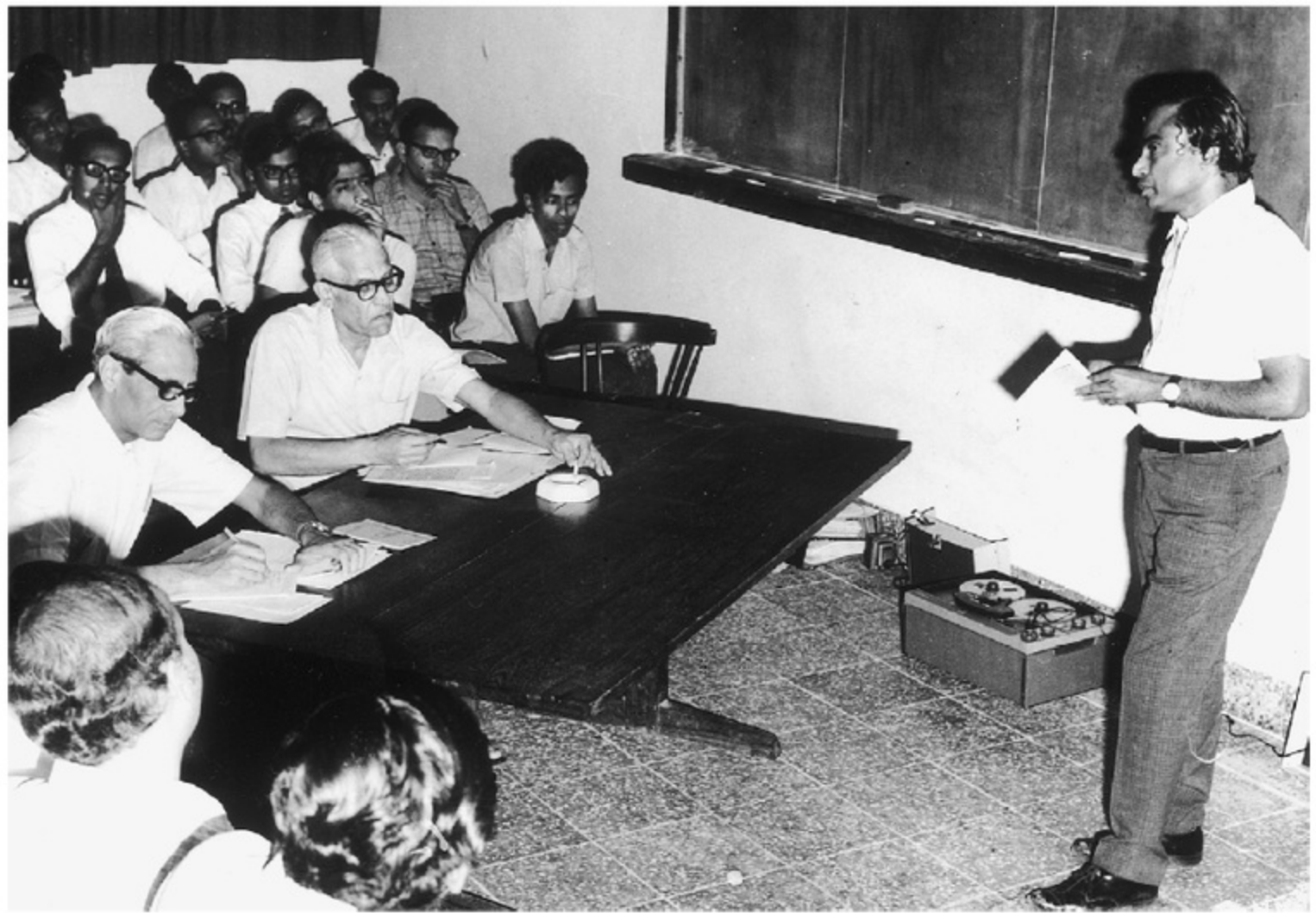
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WINGS OF FIRE

ORIENTATION - 1

Plate 11 With Prof Vikram Sarabhai, a great visionary and the master planner behind India's Missile Development programme, at Thumba e e prpersess



WINGS OF FIRE

ORIENTATION - 1

SEEKERS

Plate 12 Two gurus of Indian Space Research who mentored and gently guided the young scientists – Prof Satish Dhawan and Dr Brahm Prakash – at one of the SLV-3 review meetings.

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WINGS OF FIRE

ORIENTATION - 1

SEEKERS

Plate 13 A presentation by a member of my SLV-3 team. In an unusual move, I made each of them present their portion of the work—my idea of project management.

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WINGS OF FIRE

ORIENTATION - 1

SEEKERS

Plate 14 Dr Brahm Prakash inspecting SLV-3 in its final phase of integration. He helped me deal with subsequent frustrations in its launching and consoled me when I was at my lowest ebb.

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WINGS OF FIRE

ORIENTATION - 1

SEEKERS

Plate 15 Prof Satish Dhawan and I explaining SLV-3 results to Prime Minister Indira Gandhi.

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WINGS OF FIRE

ORIENTATION - 1

SEEKERS

Plate 17 Receiving the Padma Bushan from Dr Neelam Sanjeeva Reddy, then President of India.

Plate 16 SLV-3 on the launch pad. This gave us many anxious moments!



WINGS OF FIRE

ORIENTATION - 1

SEEKERS

Plate 18 Successful launch of Prithvi, the surface-to-surface weapons system.

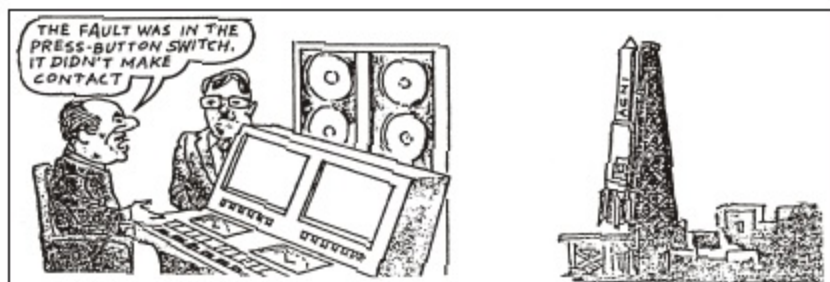
**Plate 19 Agni on the launch pad,
my long-cherished dream.**

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68

You said it

By LAXMAN



WINGS OF FIRE

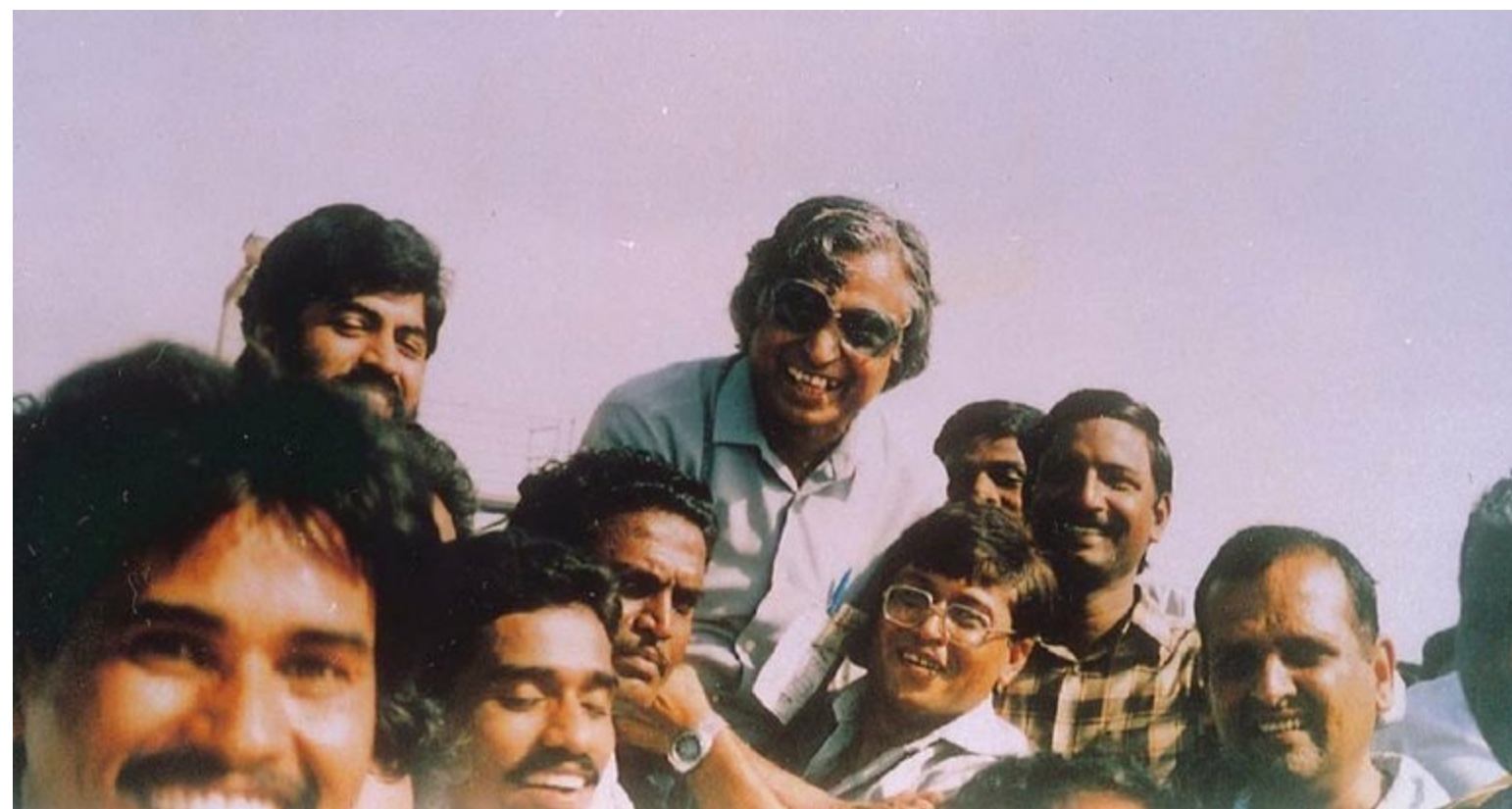
ORIENTATION - 1

SEEKERS

Plate 21 Many a slip between the cup and the lip... .

Nothing to be discouraged! We have
postponed it again because we want
to be absolutely certain!

Plate 20 One of the cartoons in the media after the failure of the first two Agni launches.



WINGS OF FIRE

ORIENTATION - 1

SEEKERS

Plate 22 Being carried by a jubilant crowd after the successful launch of Agni.



WINGS OF FIRE

ORIENTATION - 1

SEEKERS

Plate 23 Receiving the Bharat Ratna from President KR Narayanan.

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WINGS OF FIRE

ORIENTATION - 1

SEEKERS

Plate 24 With three Service Chiefs. To my left is Admiral VS Shekhawat, on his right is General BC Joshi, and Air Chief Marshall SK Kaul.

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WINGS OF FIRE

ORIENTATION - 1

SEEKERS

and debated as a collective endeavour. Thus, a high level body called I made a presentation in the South Block. The presentation was the Missile Technology Committee was formed within DRDL. The presided over by the Defence Minister of the time R Venkataraman, concept of management by

participation was evoked and earnest efforts and attended by the three Service Chiefs: General Krishna Rao, Air were made to involve middle-level scientists and engineers in the Chief Marshall Dilbagh Singh and Admiral Dawson. The Cabinet management activities of the laboratory.

Secretary, Krishna Rao Sahib, Defence Secretary, SM Ghosh and Days of debate and weeks of thinking finally culminated in the long-Secretary, Expenditure, R Ganapathy were present. Everyone seemed term ‘Guided Missile Development Programme’. I had read somewhere, to have all sorts of doubts—about our capabilities, about the feasibility

“Know where you are going. The great thing in the world is not knowing and availability of required technological infrastructure, about the viability, so much where we stand, as in what direction we are moving.” What if the schedule and cost. Dr Arunachalam stood by me like a rock we did not have the technological might of the Western countries, we throughout the entire question-answer session. Members were skeptical knew we had to attain that might, and this determination was our driving and apprehensive of drift—which they felt was common among scientists.

force. To draw up a clear and well-defined missile development Although some questioned our ambitious proposal, everyone, even the programme for the production of indigenous missiles, a committee was doubting Thomases, were very excited about the idea of India having constituted under my chairmanship. The members were ZP Marshall, her own missile systems. In the end, we were asked by Defence Minister then the Chief of Bharat Dynamics Limited, Hyderabad, NR Iyer, Venkataraman to meet him in the evening, about three hours later.

AK Kapoor and KS Venkataraman. We drafted a paper for the perusal We spent the intervening time working on permutations and of the Cabinet Committee for Political Affairs (CCPA). The paper was combinations. If they sanctioned only Rs 100 crores, how would we given its final shape after consulting the representatives of the three allocate it? Suppose they gave us Rs 200 crores, then what would we Defence Services. We estimated an expenditure of about Rs 390 crores, do? When we met the Defence Minister in the evening, I had a hunch spread over a period of twelve years.

we were going to get some funds at any rate. But when he suggested Development programmes often get stuck by the time they reach that we launch an integrated guided missile development programme, the production stage, mainly because of lack of funding. We wanted to instead of making missiles in phases, we could not believe our ears.

get funds to develop and produce two missiles—a low-level quick We were quite dumbfounded by the Defence Minister’s suggestion.

reaction Tactical Core Vehicle and a Medium Range Surface-to-Surface After a long pause, Dr Arunachalam replied, “We beg for time to rethink Weapon System. We planned to make a surface-to-air medium range and return, Sir!” “You come back tomorrow morning please,” the weapon system with multi-target handling capability during the second Defence Minister replied. It was reminiscent of Prof. Sarabhai’s zeal phase. DRDL had been known for its pioneering work in the field of and vision. That night, Dr Arunachalam and I laboured together on anti-tank missiles. We proposed to develop a third generation anti-tank reworking our plan.

guided missile having ‘fire-and-forget’ capabilities. All my colleagues We worked out some very important extensions and improvements were pleased with the proposal. They saw an opportunity to pursue in our proposal, taking all the variables, such as design, fabrication, system afresh activities initiated long ago. But I was not entirely satisfied. I integration, qualification, experimental flights, evaluation, updating, user longed to revive my buried dream of a Re-entry Experiment Launch trials, producibility, quality, reliability, and financial viability into account.

Vehicle (REX). I persuaded my colleagues to take up a technology We then integrated them into a single function of total accountability, in development project to generate data for use in the design of heat shields.

order to meet the needs of the country’s armed forces with an indigenous These shields were required for building up capability to make long-endeavour. We worked out the concepts of design, development, range missiles in the future.

e e prpersess

73



WINGS OF FIRE

ORIENTATION - 1

SEEKERS

production concurrency and proposed the participation of user and the all-powerful South Block, be concerned about a wedding which was inspection agencies right from the drawing-board stage. We also suggested to take place on a far-flung island in a small house on Mosque Street?

a methodology to achieve state-of-the-art systems after all the years of I have always had a high regard for Dr Arunachalam. He has together developmental activities. We wanted to deliver contemporary missiles with a command over language as he displayed on this occasion, an to our Services and not some outdated inventory of weapons. It was a uncanny presence of mind. I was overwhelmed when the Defence very exciting challenge that had been thrown to us.

Minister located an Air Force helicopter doing sorties between Madras By the time we finished our work, it was already morning. Suddenly, and Madurai later in the day to take me to Madurai as soon as I at the breakfast table, I remembered that I was to attend my niece disembarked at Madras from the regular Indian Airlines flight, which Zameela’s wedding at Rameswaram that evening. I thought it was was leaving Delhi in an hour’s time. Dr Arunachalam told me, “You already too late to do anything. Even if I could catch the Madras flight have earned this for your hard work of the last six months.” later in the day, how would I reach Rameswaram from there? There Flying towards Madras, I scribbled on the back of my boarding pass: was no air link between Madras and Madurai from where I could board the evening train to Rameswaram. A pang of guilt dampened my spirits.

Was it fair, I asked myself, to forget my family commitments and *Can such a foot explore* obligations? Zameela was more like a daughter to me. The thought of *The purple territories* missing her wedding because of professional preoccupations at Delhi *On Rameswaram's shore?* was very distressing. I finished breakfast and left for the meeting.

The Air Force helicopter landed close to the Indian Airlines aircraft. When we met Defence Minister Venkataraman and showed him our proposal as soon as it arrived from Delhi. Within the next few minutes I was on revised proposal, he was visibly pleased. The proposal of the missile my way to Madurai. The Air Force commandant there was kind enough development project had been turned overnight into the blueprint of an integrated programme with far-reaching consequences. It would have just about to roll out of the platform. I was in Rameswaram well in time wide-ranging technological spinoffs, and was exactly what the Defence for Zameela's wedding. I blessed my brother's daughter with a father's Minister had had in mind the previous evening. Notwithstanding the great love.

respect I had for the Defence Minister, I was not really sure if he would. The Defence Minister put up our proposal before the Cabinet and clear our entire proposal. But he did. I was absolutely delighted! saw it through. His recommendations on our proposal were accepted. The Defence Minister stood up, signalling that the meeting was over.

and an unprecedented amount of Rs 388 crores was sanctioned for this. Turning to me he said, "Since I brought you here, I was expecting you to purpose. Thus was born India's prestigious Integrated Guided Missile come up with something like this. I am happy to see your work." In a Development Programme, later abbreviated to IGMDP.

split second, the mystery surrounding the clearance of my appointment. When I presented the government sanction letter before the Missile as Director DRDL in 1982 was cleared. So it was Defence Minister Technology Committee at DRDL, they were enthused with fire and Venkataraman who had brought me in! Bowing in thanks, I turned action. The proposed projects were christened in accordance with the spirit of India's self-reliance. Thus the Surface-to-Surface weapon about Zameela's wedding being scheduled for that evening at system became Prithvi ("the Earth") and the Tactical Core Vehicle was Rameswaram. It amazed me that Dr Arunachalam should bring up this called Trishul (the trident of Lord Shiva). The Surface-to-Air area matter before the Minister. Why would a person of his stature, sitting in defence system was named as Akash ("sky") and the anti-tank missile e e prpersess



STEWARDS

project Nag (“Cobra”). I gave the name Agni (“Fire”) to my long cherished dream of REX. Dr Arunachalam came to DRDL and formally launched the IGMDP on 27 July 1983. It was a great event in which every single employee of DRDL participated. Everybody who was somebody in Indian Aerospace Research was invited. A large number of scientists from other laboratories and organizations, professors from academic institutions, representatives of the armed forces, production centres, and inspection authorities, who were our business partners now, were present on this occasion. A closed-circuit TV network had to be pressed into operation to ensure proper communication between the 11

participants for we had no single place to accommodate all the invitees.

This was the second most significant day in my career, next only to 18

July 1980, when the SLV-3 had launched Rohini into the earth’s orbit.

* * *

Stewards

The launch of the IGMDP was like a bright flash on the Indian scientific firmament. Missile Technology had been considered the domain of a few selected nations in the world. People were curious to see how, with what India had at that point of time, we were going to achieve all that was promised. The magnitude of the IGMDP was really unprecedented in the country and the schedules projected were quite quixotic by the norms and standards prevailing in the Indian R&D establishments. I was fully aware that obtaining sanction for the programme could at best be seen as only ten per cent of the work done. To get it going would be quite a different matter altogether.

The more you have, the more there is to maintain. Now that we had been given all the necessary money and freedom to proceed, I had to take my team forward and fulfill the promises I had made.

What would be needed to realise this missile programme, from the design to the deployment stages? Excellent manpower was available; money had been sanctioned; and some infrastructure also existed. What was lacking then? What else does a project need to succeed apart from these three vital inputs? From my SLV-3 experience, I thought I knew the answer. The crux was going to be out mastery over missile technology.

I expected nothing from abroad. Technology is a group activity and we e e prpersess



ORIENTATION - 1

STEWARDS

would need leaders who could not only put their heart and soul into the During this period, the most important task before me was the selection missile programme, but also carry along with them hundreds of other of the Project Directors to lead individual missile projects. We had a engineers and scientists. We knew we had to be prepared to encounter very large pool of talent. In fact, it was a market of plenty. The question numerous contradictions and procedural absurdities that were prevalent was whom to pick—a go-getter, a planner, a maverick, a dictator or a in the participating laboratories. We would have to counteract the existing team man? I had to get the right type of leader who could clearly visualize attitudes of our public sector units, which believed that their performance the goal, and channelise the energies of his team members who would would never be tested. The whole system—its people, procedures, be working at different work centres in pursuit of their own individual infrastructure—would have to learn to extend itself. We decided to goals.

achieve something that was way beyond our collective national capability and I, for one, had no illusions about the fact that unless our teams worked on the basis of proportion or probability, nothing would be It was a difficult game, some rules of which I had learnt while working achieved.

on ISRO's high priority projects for two decades. The wrong choice would jeopardise the entire future of the programme. I had a detailed The most remarkable thing about DRDL was its large pool of highly discussion with a large number of prospective scientists and engineers.

talented people, many of whom were, unfortunately, full of egotism and I wanted these five Project Directors to train another twenty-five project rebelliousness. Unfortunately, they had not even accumulated enough directors and team leaders of tomorrow.

experience to make them confident about their own judgement. On the whole, they would discuss matters very enthusiastically, but would finally Many of my senior colleagues—naming them would be unfair, accept what a select few said. They would unquestioningly believe in because it could be only my imagination—tried to befriend me during outside specialists.

this period. I respected their concern for a lonely man, but avoided any close contacts. Through loyalty to a friend one can be easily led into A particularly interesting person I met in DRDL was AV Ranga Rao.

doing something that is not in the best interests of the organization.

He was very articulate and had an impressive personality. His usual garb consisted of a red neck-tie with a checked coat and loose trousers.

Perhaps the main motive behind my isolation was my desire to escape He would wear this in the hot climate of Hyderabad, where even a long-from the demands of relationships, which I consider very difficult in sleeved shirt and shoes are considered an avoidable inconvenience. With comparison to making rockets. All I desired was to be true to my way of his thick white beard and a pipe clamped

between his teeth, there was a life, to uphold the science of rocketry in my country and to retire with a certain aura around this extremely gifted, but rather egocentric individual.

clean conscience. I took quite some time and did a lot of hard thinking to decide who should lead the five projects. I examined the working styles I consulted Ranga Rao on revamping the existing management system of many scientists before making my decision. I think some of my to achieve an optimum utilization of human resources. Ranga Rao had a observations may interest you.

series of meetings with the scientists sharing our vision of developing indigenous missile technology and explaining the different aspects of the A basic aspect of a person's working style is how he plans and IGMDP. After prolonged discussions, we decided to reorganize the organizes tasks. At one extreme is the cautious planner, who carefully laboratory into a technology-oriented structure. We needed to spells out each step before making any move. With a sharp eye for what accommodate a matrix type of structure for the execution of various can possibly go wrong, he tries to cover all contingencies. At the other activities needed for the projects. In less than four months, four hundred end is the fast mover, who weaves and dodges without a plan. Inspired scientists began to work on the missile programme.

by an idea, the fast mover is always ready for action.

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76



WINGS OF FIRE

ORIENTATION - 1

STEWARDS

Another aspect of a person's working style is control—the energy For Trishul, I was looking for a man who not only had a sound and attention devoted to ensuring that things happen in a certain way. At knowledge of electronics and missile warfare, but who could also one extreme is the tight controller, a strict administrator with frequent communicate the complexities to his team in order to promote checkpoints. Rules and policies are to be followed with religious fervour.

understanding and to earn his team's support. I found in Cmde SR Mohan, At the opposite end are those who move with freedom and flexibility.

who sailed into Defence R&D from the Indian Navy, a talent for detail They have little patience for bureaucracy. They delegate easily and give and an almost magical power of persuasion.

their subordinates wide latitude for movement. I wanted leaders who For Agni, my dream project, I needed somebody who would tolerate tread the middle path, those who could control without stifling dissent or my occasional meddling in the running of this project. In RN Agarwal I being rigid.

found the right person. He was an alumnus of MIT with a brilliant I wanted men who had the capability to grow with possibilities, with academic record and had been managing the Aeronautical Test Facilities the patience to explore all possible alternatives, with the wisdom to apply at DRDL with keen professional acumen.

old principles to new situations; people with the skill to negotiate their Due to technological complexities, Akash and Nag were then way forward. I wanted them to be accommodating, to be willing to considered missiles of the future; their activities were expected to peak share their power with others and work in teams, delegating good jobs, about half a decade later. Therefore, I selected the relatively young assimilating fresh opinions, respecting intelligent people, and listening to Prahlada and NR Iyer for Akash and Nag. Two other young men, VK

wise counsel. They would have to be able to sort out things amicably, Saraswat and AK Kapoor were made deputies to Sundaram and Mohan and take responsibility for slip-ups. Above all, they should be able to respectively.

take failure in their stride and share in both success and failure.

In those days, there was no forum in DRDL where issues of general My search for someone to lead the Prithvi project ended with importance could be openly discussed and decisions debated. Scientists, Coll VJ Sundaram who belonged to the EME Corps of the Indian Army.

it must be remembered, are basically emotional people. Once they With a post-graduate degree in Aeronautical Engineering and expertise stumble, it is difficult for them to pull themselves together. Setbacks and in mechanical vibrations, Sundaram was head of the Structures Group disappointments have always been and always will be an inherent part at DRDL. I found in him a readiness to experiment with new ways of of any career, even one in science. However, I did not want any of my resolving conflicting points of view. He was an experimenter and scientists to face disappointments alone. I also wanted to ensure that innovator in team work. He had an extraordinary capability for evaluating none of them set their goals when they were at a low ebb. To avoid such alternative ways of operating. He would suggest moving forward into eventualities a Science Council was created—a sort of panchayat where new terrains that could lead to a solution which had not been perceived the community would sit together and take common decisions. Every earlier. Though a particular goal might be clear to a project leader, and three months, all scientists—juniors and seniors, veterans and freshers—

he may be capable of giving adequate directions for accomplishing it, would sit together and let off steam.

there can be resistance from subordinates if the goal makes no sense to them. Therein lies the importance of a leader who provides effective The very first meeting of the Council was eventful. After a spell of work directions. I thought the Project Director of Prithvi would be the half-hearted enquiries and expressions of doubt, one senior scientist, first to make decisions with production agencies and the armed forces, MN Rao, shot a straight question: “On what basis did you select these and Sundaram would be the ideal choice to see that sound decisions five Pandavas (he meant the Project Directors)?” I was, in fact, expecting were taken.

this question. I wanted to tell him that I found all these five Pandavas married to the Draupadi of positive thinking. Instead, I told Rao to wait e e prpersess

77



WINGS OF FIRE

ORIENTATION - 1

STEWARDS

and see. I had chosen them to take charge of a long-term programme to locate the integration and check-out facilities needed for the missile where new storms would arise everyday.

projects here. For the next three years, this became my mission.

Every tomorrow, I told Rao, will give opportunities to these We drew up a proposal to establish a model high technology research enthusiastic people—the Agarwals, Prahladas, Iyers, and Saras-wats —

centre with very advanced technical facilities like an inertial to gain a fresh perspective on their goals and a strong hold on their instrumentation laboratory, full-scale environmental and electronic commitments.

warfare (EMI/EMC) test facilities, a composites production centre, high What makes a productive leader? In my opinion, a productive leader enthalpy facility, and a state-of-the-art missile integration and checkout must be very competent in staffing. He should continually introduce centre. By any standards, this was a gigantic task. An altogether different new blood into the organization. He must be adept at dealing with problems brand of expertise, grit and determination were required to realise this and new concepts. The problems encountered by an R&D organization project. Goals and objectives had already been decided upon. Now they typically involve trade-offs among a wide variety of known and unknown had to be shared with a large number of people from various agencies, parameters. Skill in handling these complex entities is important in through the problem-solving and communication processes that the leader achieving high productivity. The leader must be capable of instilling of the team must build and maintain. Who would be the most suitable enthusiasm in his team. He should give appropriate credit where it is person to do so? I saw almost all the required leadership qualities in MV

due; praise publicly, but criticize privately.

Suryakantha Rao. Then, as a large number of agencies would participate in the creation of Research Centre Imarat (RCI), someone had to protect One of the most difficult questions came from a young scientist: hierarchical sensitivities. I selected Krishna Mohan, who was in his mid-

“How are you going to stop these projects from going the Devil way?” thirties, to complement

Suryakantha Rao, who was in his late fifties at I explained to him the philosophy behind IGMDP—it begins with design that time. Krishna Mohan would encourage involvement rather than and ends in deployment. The participation of the production centres and relying on obedience and monitoring people at their workplaces.

user agencies right from the design stage had been ensured and there was no question of going back till the missile systems had been successfully According to the established procedure, we approached the Military deployed in the battlefield.

Engineering Services (MES) for the RCI construction work. They said it would take five years to complete the task. The matter was discussed While the process of forming teams and organizing work was going in depth at the highest level in the Ministry of Defence and a landmark on, I found that the space available at DRDL was grossly inadequate to decision to entrust the responsibility of building defence structures to an meet the enhanced requirements of IGMDP. Some of the facilities would outside construction company was taken. We liaised with the Survey of have to be located at a nearby site. The missile integration and checkout India and the National Remote Sensing Agency for the inspection of the facility built during the Devil phase consisted only of a 120 sq. metre contour maps and for obtaining aerial photographs of the Imarat Kancha shed thickly populated with pigeons. Where was the space and the facility to prepare a layout for the approach roads and the location of the to integrate the five missiles which would arrive here shortly? The facilities. The Central Ground Water Board identified twenty locations Environmental Test Facility and the Avionics Laboratory were equally amid the rocks to tap water. Infrastructure to provide 40 MVA power cramped and ill-equipped. I visited the nearby Imarat Kancha area. It and 5 million litres of water per day was planned.

used to be the test range for anti-tank missiles developed by DRDL

decades ago. The terrain was barren—there were hardly any trees—

It was also at this time that Coll SK Salwan, a mechanical engineer and dotted with large boulders typical of the Deccan plateau. I felt as if with boundless energy, joined us. In the final phase of construction, there was some tremendous energy trapped in these stones. I decided Salwan discovered an ancient place of worship among the boulders. It seemed to me that this place was blessed.

e e prpersess

78



WINGS OF FIRE

ORIENTATION - 1

WORKERS

Now that we had started working on the design of the missile systems and development had already commenced for their integration and checkout, the next logical step was to look for a suitable site for the missile flight trials. With SHAR also in Andhra Pradesh, the search for a suitable site spread towards the eastern coastline and finally ended at Balasore in Orissa. A site along the north-eastern coast was identified for a National Test Range. Unfortunately the entire project ran into rough weather because of the political issues raised around the evacuation of people living in that area. We decided therefore to create an interim

infrastructure adjacent to the Proof Experimental Establishment (PXE) at Chandipur in Balasore district of Orissa. A funding of Rs 30 crores had been given to construct the range, called the Interim Test Range (ITR). Dr HS Rama Rao and his team did an excellent job of working out innovative and cost-effective specifications for electro-optical tracking

Workers instruments, a tracking telescope system and an instrumentation tracking radar. Lt Gen RS Deswal and Maj Gen KN Singh took charge of creating the launch pad and range infrastructure. There was a beautiful bird We were at a meeting laying down the targets for 1984, when news sanctuary in Chandipur. I asked the engineers to design the test range came of Dr Brahm Prakash's death on the evening of 3 January at without disturbing it.

Bombay. It was a great emotional loss for me, for I had had the privilege of working under him during the most challenging period of my career.

Creating the RCI was perhaps the most satisfying experience of my His compassion and humility were exemplary. His healing touch on the life. Developing this centre of excellence of missile technology was akin day of the failed SLV-E1 flight surfaced in my memory serving to deepen to the joy of a potter shaping artifacts of lasting beauty from the mundane my sorrow.

clay.

If Prof. Sarabhai was the creator of VSSC, Dr Brahm Prakash was Defence Minister R Venkataraman visited DRDL in September 1983

the executor. He had nurtured the institution when it most needed to appraise himself of the activities of IGMDP. He advised us to list all nourishment. Dr Brahm Prakash played a very important role in shaping the resources we needed to achieve our goals, overlooking nothing, and my leadership skills. In fact my association with him was a turning point then include in the list our own positive imagination and faith. "What you in my life. His humility mellowed me and helped me discard my aggressive imagine, is what will transpire. What you believe is what you will approach. His humility did not consist merely in being modest about his achieve," he said. Both Dr Arunachalam and I saw in the horizon endless talents or virtues, but in respecting the dignity of all those who worked possibilities stretching out before IGMDP; and our enthusiasm proved under him and in recognizing the fact that no one is infallible, not even infectious. We were excited and encouraged to see the best professionals the leader. He was an intellectual giant with a frail constitution; he had a in the country gravitating towards IGMDP. Who would not want to childlike innocence and I always considered him a saint among scientists.

associate with a winner? The word had evidently got around that the IGMDP was a born winner.

During this period of renaissance at DRDL, an altitude control system and an on-board computer developed by P Banerjee, KV Ramana

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Sai and their team was almost ready. The success of this effort was e e prpersess

79



WINGS OF FIRE

ORIENTATION - 1

WORKERS

very vital for any indigenous missile development programme. All the of excellence. “No matter what you achieve, you should never be same, we had to have a missile to test this important system.

completely satisfied and should always be searching for ways to prove After many brainstorming sessions, we decided to improvise a Devil yourself,” she added. Within a month, she demonstrated her interest and missile to test the system. A Devil missile was dis-assembled, many support by sending the newly appointed Defence Minister, SB Chavan, modifications made, extensive subsystem testing was done and the missile to review our projects. Shrimati Gandhi’s follow-up approach was not checkout system was reconfigured. After installing a make-shift launcher, only impressive, it was effective too. Today, everyone associated with the modified and extended range Devil missile was fired on 26 June aerospace research in our country knows that excellence is synonymous 1984 to flight test the first indigenous Strap-down Inertial Guidance with the IGMDP.

system. The system met all the requirements. This was the first and We had our home-grown, but effective, management techniques.

very significant step in the history of Indian missile development, which One such technique was concerned with follow-up of project activities.

had so far been restricted to reverse engineering, towards designing our It basically consisted of analysing the technical as well as procedural own systems. A long-denied opportunity was at last utilized by missile applicability of a possible solution, testing it with the work centres, scientists at DRDL. The message was loud and clear. We could do it!

discussing it with the general body of associates and implementing it It did not take long for the message to reach Delhi. Prime Minister after enlisting everybody’s support. A large number of original ideas Indira Gandhi expressed her desire to personally apprise herself of the sprung up from the grass root level of participating work centres. If you progress of the IGMDP. The entire

organization was filled with an aura were to ask me to indicate the single most important managerial tactic in of excitement. On 19 July 1984, Shrimati Gandhi visited DRDL.

this successful programme, I would point to the pro-active follow-up.

Through follow-up on the work done at different laboratories on design, Prime Minister Indira Gandhi was a person with a tremendous sense planning, supporting services, and by the inspection agencies and of pride—in herself, in her work and in her country. I deemed it an academic institutions, rapid progress has been achieved in the most honour to receive her at DRDL as she had instilled some of her own harmonious manner. In fact, the work code in the Guided Missile pride into my otherwise modest frame of mind. She was immensely Programme Office was: if you need to write a letter to a work centre, conscious that she was the leader of eight hundred million people. Every send a fax; if you need to send a telex or fax, telephone; and if the need step, every gesture, every movement of her hands was optimised. The arises for telephonic discussions, visit the place personally.

esteem in which she held our work in the field of guided missiles boosted our morale immensely.

The power of this approach came to light when Dr Arunachalam conducted a comprehensive status review of IGMDP on 27 September During the one hour that she spent at DRDL, she covered wide-1984. Experts from DRDO Laboratories, ISRO, academic institutions, ranging aspects of the IGMDP, from flight system plans to multiple and production agencies gathered to critically review the progress made development laboratories. In the end, she addressed the 2000-strong and problems faced in the first year of implementation. Major decisions DRDL community. She asked for the schedules of the flight system that like the creation of facilities at Imarat Kancha and the establishment of we were working on. “When are you going to flight test Prithvi?” Shrimati a test facility were crystallized during the review. The future infrastructure Gandhi asked. I said, “June 1987.” She immediately responded, “Let me at the Imarat Kancha was given the name of Research Centre Imarat know what is needed to accelerate the flight schedule.” She wanted (RCI), retaining the original identity of the place.

scientific and technological results fast. “Your fast pace of work is the hope of the entire nation,” she said. She also told me that the emphasis It was a pleasure to find an old acquaintance, TN Seshan, on the of the IGMDP should be not only on schedule but also on the pursuance review board. Between SLV-3 and now, we had developed a mutual e e prpersess

80



WINGS OF FIRE

ORIENTATION - 1

WORKERS

affection. However, this time as the Defence Secretary, Seshan's queries was enough talent available in the country to tackle major technological about the schedules and viability of financial propositions presented were challenges.

much more pointed. Seshan is a person who enjoys verbally bringing When India carried out its first nuclear explosion for peaceful adversaries to their knees. Using his sharp-edged humour, Seshan would purposes, we declared ourselves the sixth country in the world to explode make his opponents look ridiculous. Although he is prone to be loud and a nuclear device. When we launched SLV-3 we were the fifth country can turn argumentative on occasions, in the end he would always ensure to achieve satellite launch capability. When were we going to be the maximization of all available resources towards a solution that was within first or second country in the world to achieve a technological feat?

implementation. At a personal level, Seshan is a very kind-hearted and considerate person. My team was particularly pleased to answer his I listened carefully to the review members as they aired their opinions questions about the advanced technology employed in the IGMDP. I still and doubts, and I learned from their collective wisdom. It was indeed a remember his uncanny curiosity about the indigenous development of great education for me. Ironically, all through school, we were taught to carbon-carbon composites. And to let you into a small secret—Seshan read, write and speak, but never to listen, and the situation remains much is perhaps the only person in the world who enjoys calling me by my full the same today. Traditionally, Indian scientists have been very good name which contains 31 letters and five words—Avul Pakir Jainulabdeen speakers, but have inadequately developed listening skills. We made a Abdul Kalam.

resolution to be attentive listeners. Are engineering structures not built on the foundation of functional utility? Does technical know-how not The missile programme had been pursued concurrently and had form its bricks? And, are these bricks not put together with the mortar partners in design, development and production from 12 academic of constructive criticism? The foundation had been laid, the bricks baked, institutions and 30 laboratories from DRDO, the Council of Scientific and now the mortar to cement our act together was being mixed.

and Industrial Research (CSIR), ISRO and industry. In fact, more than 50 professors and 100 research scholars worked on missile-related We were working on the action plan that had emerged from the problems in the laboratories of their respective institutes. The quality of earlier month's review, when the news of Shrimati Gandhi's assassination work achieved through this partnership in that one year had given me broke. This was followed by the news of widespread violence and riots.

tremendous confidence that any development task could be undertaken A curfew had been imposed in Hyderabad city. We rolled up the PERT

within the country so long as we have our focussed schedules. Four charts and a city map was spread out over the table to organize transport months before this review, I think it was during April–June 1984, six of and safe passage for all employees. In less than an hour, the laboratory us in the missile programme visited academic campuses and enlisted wore a deserted look. I was left sitting alone in my office. The promising young graduates. We presented an outline of the missile circumstances of Shrimati Gandhi's death were very ominous. The programme before the professors and the aspiring

students, about 350

memories of her visit barely three months ago further deepened my of them, and requested them to participate. I informed the reviewers pain. Why should great people meet with such horrific ends? I recollected that we were expecting around 300 young engineers to join our my father telling someone in a similar context: “Good and bad people laboratories.

live together under the sun as the black thread and the white are woven together in a cloth. When either one of the black or white thread breaks, Roddam Narasimha, then Director of the National Aeronautical the weaver shall look into the whole cloth, and he shall examine the Laboratory, used the occasion of this review to put up a strong case for loom also.” When I drove out of the laboratory there was not a single technology initiative. He cited the experiences of the green revolution, soul on the road. I kept thinking about the loom of the broken thread.

which had demonstrated beyond doubt that if the goals were clear, there e e prpersess

81



WINGS OF FIRE

ORIENTATION - 1

WORKERS

Shrimati Gandhi’s death was a tremendous loss to the scientific by Schuller. “God can do tremendous things through the person who community. She had given impetus to scientific research in the country.

doesn’t care about who gets the credit. The ego involvement must go,” But India is a very resilient nation. It gradually absorbed the shock of writes Schuller. “Before God trusts you with success, you have to prove Shrimati Gandhi’s assassination, although at the cost of thousands of yourself humble enough to handle the big prize.” I prayed to God in lives and a colossal loss of property. Her son, Rajiv Gandhi, took over as Schuller’s church to help me build a Research Centre at the Imarat the new Prime Minister of India. He went to the polls and obtained a Kancha—that would be my Crystal Cathedral.

mandate from the people to carry forward the policies of Mrs. Gandhi,

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the Integrated Guided Missile Development Programme being a part of them.

By the summer of 1985, all the groundwork had been completed for building the Missile Technology Research Centre at Imarat Kancha.

Prime Minister Rajiv Gandhi laid the foundation stone of the Research Centre Imarat (RCI) on 3

August 1985. He appeared very pleased with the progress made. There was a child-like curiosity in him which was very engaging. The grit and determination displayed by his mother when she visited us a year ago was also present in him, although with a small difference. Madam Gandhi was a taskmaster, whereas Prime Minister Rajiv Gandhi used his charisma to achieve his ends. He told the DRDL

family that he realised the hardships faced by Indian scientists and expressed his gratitude towards those who preferred to stay back and work in their motherland rather than go abroad for comfortable careers.

He said that nobody could concentrate on work of this type unless he was free from the trivialities of daily life, and assured us that whatever necessary would be done to make scientists' lives more comfortable.

Within a week of his visit, I left for the USA with Dr Arunachalam on an invitation from the United States Air Force. Roddam Narasimha of National Aeronautical Laboratory and KK Ganapathy of HAL

accompanied us. After finishing our work at the Pentagon in Washington, we landed in San Francisco on our way to Los Angeles to visit Northrop Corporation. I utilized this opportunity to visit the Crystal Cathedral built by my favourite author, Robert Schuller. I was amazed by the sheer beauty of this all-glass, four-pointed, star-shaped structure that is more than 400 feet from one point to another. The glass roof which is 100 feet longer than a football field seemed to float in space. This Cathedral has been built at the cost of several million dollars through donations organized e e prpersess

82



WINGS OF FIRE

ORIENTATION - 1

TRIUMPHANT

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 13

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 Triumphant

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 young engineers, 280 to be precise, changed the dynamics of The first launch of the Missile Programme was conducted on DRDL. It was a valuable experience for all of us. We were now in a 16 September 1985, when Trishul took off from the test range at position to develop, through these young teams, a re-entry technology Sriharikota (SHAR). It was a ballistic flight meant for testing the in-and structure, a millimetric wave radar, a phased array radar, rocket flight performance of the solid propellant rocket motor. Two C-Band systems and other such equipment. When we first assigned these tasks radars and Kalidieo-theodolite (KTLs) were used to track the missile to the young scientists, they did not fully grasp the importance of their from the ground. The test was successful. The launcher, rocket motor work. Once they did, they felt uneasy under the burden of the tremendous and telemetry systems functioned as planned. The aerodynamic drag faith placed in them. I still remember one young man telling me, "There however was higher than the estimates predicted on the basis of wind is no big shot in our team, how will we be able to break through?" I told tunnel testing. In terms of technology breakthrough or experience him, "A big shot is a little shot who keeps on shooting, so keep trying." It enrichment, this test was of little value but the real achievement of this was astonishing to see how in the young scientific environment, negative test was to remind my DRDL friends that they could fly missiles without attitudes changed to positive and things that were previously thought being driven by the brute demands of compliance or reverse engineering.

impractical began happening. Many older scientists were rejuvenated In a swift stroke, the psyche of the DRDL scientists experienced a simply by being part of a young team.

multi-dimensional expansion.

It has been my personal experience that the true flavour, the real fun, This was followed by the successful test flight of the Pilotless Target the continuous excitement of work lie in the process of doing it rather Aircraft (PTA). Our engineers had developed the rocket motor for the than in having it over and done with. To return to the four basic factors PTA designed by the Bangalore-based Aeronautical Development that I am convinced are involved in successful outcomes: goal-setting, Establishment (ADE). The motor had been type- approved by DTD&P

positive thinking, visualizing, and believing.

(Air). This was a small but significant step towards developing missile hardware that is not only functional but also acceptable to the user By now, we had gone through an elaborate exercise of goal-setting agencies. A private sector firm was engaged to produce a reliable, and enthused the young scientists about these goals. At the review airworthy, high thrust-to-weight ratio rocket motor with technology input e e prpersess



ORIENTATION - 1

TRIUMPHANT

from DRDL. We were slowly graduating from single laboratory projects development of a re-entry vehicle structure. The payload with guidance to multi-laboratory programmes to laboratory-industry exercises. The electronics is housed in the re-entry vehicle structure, which is meant to development of PTA symbolized a great confluence of four different protect the payload by keeping the inside temperature within the limit of organizations. I felt as if I was standing at a meeting point and looking at 40°C, when the outside skin temperature is greater than 2500°C. An the roads coming from ADE, DTD&P (Air) and ISRO. The fourth road inertial guidance system with an on-board computer guides the payload was the DRDL, a highway to national self-reliance in missile technology.

to the required target. For any re-entry missile system, three-dimensional Taking our partnership with the academic institutions of the country preforms are core material for making the carbon-carbon nose tip that a step further, Joint Advanced Technology Programmes were started at will remain strong even at such high temperatures. Four laboratories of the Indian Institute of Science (IISc), and Jadavpur University. I have DRDO and the CSIR achieved this in a short span of 18 months—

always had a deep regard for academic institutions and reverence for something other countries could do only after a decade of research and excellent academicians. I value the inputs that academicians can make development!

to development. Formal requests had been placed with these institutions Another challenge involved in the Agni payload design was related and arrangements arrived at under which expertise from their faculties to the tremendous speed with which it would re-enter the atmosphere.

would be extended to DRDL in pursuance of its projects.

In fact, Agni would re-enter the atmosphere at twelve times the speed Let me highlight a few contributions of academic institutions to the of sound (12 Mach, as we call it in science). At this tremendous speed, various missile systems. Prithvi had been designed as an inertially guided we had no experience of how to keep the vehicle under control. To missile. To reach the target accurately, the trajectory parameters have carry out a test, we had no wind tunnel to generate that kind of speed. If to be loaded into its brain—an on-board computer. A team of young we sought American help, we would have been seen as aspiring to engineering graduates at Jadavpur University under the guidance of Prof.

something they considered their exclusive privilege. Even if they Ghoshal developed the required robust guidance algorithm. At the IISc, consented to co-operate, they would be certain to quote a price for their postgraduate students under the leadership of Prof. IG Sharma developed wind tunnel greater than our entire project budget. Now, the question air defence software for multi-target acquisition by Akash. The re- entry was how to beat the system. Prof. SM Deshpande of the IISc found vehicle system design methodology for Agni was developed by a young four young, bright scientists working in the field of fluid dynamics and, team at IIT Madras and DRDO scientists. Osmania University's within six months, developed the software for Computational Fluid

Navigational Electronics Research and Training Unit had developed state-Dynamics for Hypersonic Regimes, which is one of its kind in the world.

of-the-art signal processing algorithms for Nag. I have only given a few Another achievement was the development of a missile trajectory examples of collaborative endeavour. In fact, it would have been very simulation software, ANUKALPANA by Prof. IG Sharma of IISc to difficult to achieve our advanced technological goals without the active evaluate multi-target acquisition capabilities of an Akash-type weapon partnership of our academic institutions.

system. No country would have given us this kind of software, but we Let us consider the example of the Agni payload breakthrough. Agni developed it indigenously.

is a two-stage rocket system and employs re-entry technology developed In yet another example of creating a synergy of scientific talent, in the country for the first time. It is boosted by a first-stage solid rocket Prof. Bharati Bhatt of IIT Delhi, working with the Solid Physics motor derived from SLV-3 and further accelerated at the second stage Laboratory (SPL) and Central Electronics Limited (CEL), broke the with the liquid rocket engines of Prithvi. For the Agni, the payload gets monopoly of the western countries by developing ferrite phase shifters delivered at hypersonic speeds, which calls for the design and for use in the multi-function, multi-tasking 3-D Phased Army Radar for e e prpersess

84



WINGS OF FIRE

ORIENTATION - 1

TRIUMPHANT

surveillance, tracking and guidance of Akash. Prof. Saraf of IIT, to be more than what I was at that moment. I desired to feel more, learn Kharagpur, working with BK Mukho-padhyay, my colleague at RCI, more, express more. I desired to grow, improve, purify, expand. I never made a millimetric wave (MMW) antenna for the Nag Seeker Head in used any outside influence to advance my career. All I had was the two years, a record even by international standards. The Central inner urge to seek more within myself. The key to my motivation has Electrical and Electronics Research Institute (CEERI), Pilani developed always been to look at how far I had still to go rather than how far I had an Impatt Diode in consortium with the SPL and RCI to overcome come. After all, what is life but a mixture of unsolved problems, ambiguous technological foreign dependence in creating these components, which victories, and amorphous defeats?

are the heart of any MMW device.

The trouble is that we often merely analyse life instead of dealing As work on the project spread horizontally, performance appraisal with it. People dissect their failures for causes and effects, but

seldom became more and more difficult. DRDO has an assessment-linked policy.

deal with them and gain experience to master them and thereby avoid Leading nearly 500 scientists, I had to finalize their performance their recurrence. This is my belief: that through difficulties and problems appraisals in the form of Annual Confidential Reports (ACRs). These God gives us the opportunity to grow. So when your hopes and dreams reports would be forwarded to an assessment board comprised of outside and goals are dashed, search among the wreckage, you may find a specialists for recommendations. Many people viewed this part of my golden opportunity hidden in the ruins.

job uncharitably. Missing a promotion was conveniently translated as a To motivate people to enhance their performance and deal with dislike I had towards them. Promotions of other colleagues were seen depression is always a challenge for a leader. I have observed an analogy as subjective favours granted by me. Entrusted with the task of between a force field equilibrium and resistance to change in performance evaluation, I had to be a fair judge.

organizations. Let us imagine change to be a coiled spring in a field of To truly understand a judge, you must understand the riddle of the opposing forces, such that some forces support change and others resist scales; one side heaped high with hope, the other side holding it. By increasing the supportive forces such as supervisory pressure, apprehension. When the scales dip, bright optimism turns into silent panic.

prospects of career growth and monetary benefits or decreasing the When a person looks at himself, he is likely to misjudge what he resisting forces such as group norms, social rewards, and work avoidance, finds. He sees only his intentions. Most people have good intentions and the situation can be directed towards the desired result—but for a short hence conclude that whatever they are doing is good. It is difficult for time only, and that too only to a certain extent. After a while the resisting an individual to objectively judge his actions, which may be, and often forces push back with greater force as they are compressed even more are, contradictory to his good intentions. Most people come to work tightly. Therefore, a better approach would be to decrease the resisting with the intention of doing it. Many of them do their work in a manner force in such a manner that there is no concomitant increase in the they find convenient and leave for home in the evening with a sense of supporting forces. In this way, less energy will be needed to bring about satisfaction. They do not evaluate their performance, only their intentions.

and maintain change.

It is assumed that because an individual has worked with the intention of The result of the forces I mentioned above, is motive. It is a force finishing his work in time, if delays occurred, they were due to reasons which is internal to the individual and forms the basis of his behaviour in beyond his control. He had no intention of causing the delay. But if his the work environment. In my experience, most people possess a strong action or inaction caused that delay, was it not intentional?

inner drive for growth, competence, and self- actualization. The problem, Looking back on my days as a young scientist, I am aware that one however, has been the lack of a work environment that stimulates of the most constant and powerful urges I experienced was my desire and permits them to

give full expression to this drive. Leaders can create e e prpersess

85



WINGS OF FIRE

ORIENTATION - 1

TRIUMPHANT

a high productivity level by providing the appropriate organizational factor'. Our intellectual capacity was renewed through contact with structure and job design, and by acknowledging and appreciating hard enthusiastic young minds and had achieved these outstanding results.

work.

Now, besides the renewal of manpower, emphasis had to be laid on I first attempted to build up such a supportive environment in 1983, augmenting the strength of project groups. Often people seek to satisfy while launching IGMDP. The projects were in the design phase at that their social, egoistic, and self-actualization needs at their workplaces. A time. The re-organization resulted in at least forty per cent to fifty per good leader must identify two different sets of environmental features.

cent increase in the level of activity. Now that the multiple projects One, which satisfies a person's needs and the other, which creates were entering into the development and flight-testing stage, the major dissatisfaction with his work. We have already observed that people and minor milestones reached gave the programme visibility and look for those characteristics in their work that relate to the values and continuous commitment. With the absorption of a young team of scientists, goals which they consider important as giving meaning to their lives. If a the average age had been brought down from 42 to 33 years. I felt it job meets the employees' need for achievement, recognition, responsibility, was time for a second re-organization. But how should I go about it? I growth and advancement, they will work hard to achieve goals.

took stock of the motivational inventory available at that time—let me Once the work is satisfying, a person then looks at the environment explain to you what I mean by this term. The motivational inventory of a and circumstances in the workplace. He observes the policies of the leader is made up of three types of understanding: an understanding of administration, qualities of his leader, security, status and working the needs that people expect to satisfy in their jobs, an understanding of conditions. Then, he correlates these factors to the inter-personal the effect that job design has on motivation, and an understanding of the relations he has with his peers and examines his personal life in the light power of positive reinforcement in influencing people's behaviour.

of these factors. It is the agglomerate of all these aspects that decides The 1983 re-organization was done with the objective of renewal: it the degree and quality of a person's effort and performance.

was indeed a very complex exercise handled deftly by AV Ranga Rao. The matrix organization evolved in 1983 proved excellent in meeting and Coll R Swaminathan. We created a team of newly-joined young all these requirements. So, while retaining this structure of the laboratory, scientists with just one experienced person and gave them the challenge we undertook a task-design exercise. The scientists working in of building the strap-down inertial guidance system, an on-board computer technology directorates were made system managers to interact and a ram rocket in propulsion system. These exercises were being exclusively with one project. An external fabrication wing was formed attempted for the first time in the country, and the technology involved under PK Biswas, a developmental fabrication technologist of long was comparable with world-class systems. The guidance technology is standing, to deal with the public sector undertakings (PSUs) and private centred around the gyro and accelerometer package, and electronics, to sector firms associated with the development of the missile hardware.

process the sensor output. The on-board computer carries the mission This reduced pressure on the in-house fabrication facilities and enabled computations and flight sequencing. A ram rocket system breathes air them to concentrate on jobs which could not be undertaken outside, to sustain its high velocity for long durations after it is put through a which in fact occupied all the three shifts.

booster rocket. The young teams not only designed these systems but also developed them into operational equipment. Later Prithvi and then Work on Prithvi was nearing completion when we entered 1988. For Agni used similar guidance systems, with excellent results. The effort the first time in the country, clustered Liquid Propellant (LP) rocket of these young teams made the country self-reliant in the area of engines with programmable total impulse were going to be used in a protected technologies. It was a good demonstration of the ‘renewal missile system to attain flexibility in payload range combination. Now, besides the scope and quality of the policy decisions Sundaram and I e e prpersess

86



WINGS OF FIRE

ORIENTATION - 1

TRIUMPHANT

were providing to the Prithvi team, the project’s success depended on us with his experience in range testing and range safety and worked creative ideas being converted into workable products and the quality with great enthusiasm in propellant filling, making the maiden Prithvi and thoroughness of the team members’ contribution. Saraswat with Y

launch campaign a memorable experience.

Gyaneshwar and P Venugopalan did a commendable job in this regard.

Prithvi was launched at 11:23 hrs on 25 February 1988. It was an They instilled in their team a sense of pride and achievement. The epoch-making event in the history of rocketry in the country. Prithvi importance of these rocket engines was not restricted to the Prithvi was not merely a surface-to-surface missile with a capability of delivering project—it was a national achievement. Under their collective leadership, a 1000 kg conventional warhead to a distance of 150 km with an accuracy a large number of engineers and technicians understood and committed of 50 meter CEP; it was in fact the basic module for all future guided themselves to the team goals, as well as the specific goals which each missiles in the country. It already had the provision for modification from one of them was committed to accomplish personally. Their entire team a long-range surface to an air missile system, and could also be deployed worked under a self-evident sort of direction. Working together with the on a ship.

Ordnance Factory, Kirkee, they also completely eliminated the import content in the propellant for these engines.

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

Leaving the vehicle development in the safe and efficient hands of per cent of the missiles fired will impact. In other words, if a missile has Sundaram and Saraswat, I started looking at the mission's vulnerable a CEP of 1 km (such as the Iraqi Scud missiles fired in the Gulf War), areas. Meticulous planning had gone into the development of the launch this means that half of them should impact within 1 km of their target. A release mechanism (LRM) for the smooth lift-off of the missile. The missile with a conventional high-explosive warhead and a CEP of 1 km joint development of explosive bolts to hold the LRM prior to the launch would not normally be expected to destroy or disable fixed military targets by DRDL and Explosive Research and Development Laboratory such as a Command and Control Facility or an Air Base. It would however (ERDL) was an excellent example of multi- work centre coordination.

be effective against an undefined target such as a city.

While flying, drifting into spells of contemplation and looking down at The German V-2 missiles fired at London between September 1944

the landscape below has always been my favourite preoccupation. It is and March 1945 had a conventional high-explosive warhead and a very so beautiful, so harmonious, so peaceful from a distance that I wonder large CEP of some 17 km. Yet the 500 V-2s which hit London succeeded where all those boundaries are which separate district from district, state in causing more than 21,000 casualties and destroying about 200,000

from state, and country from country. Maybe such a sense of distance homes.

and detachment is required in dealing with all the activities of our life.

When the West were crying themselves hoarse over the NPT, we Since the Interim Test Range at Balasore was still at least a year stressed upon building competence in core guidance and control

away from completion, we had set up special facilities at SHAR for the technologies to achieve a CEP as precise as 50 m. With the success of launch of Prithvi. These included a launch pad, block house, control the Prithvi trials, the cold reality of a possible strategic strike even consoles and mobile telemetry stations. I had a happy reunion with my without a nuclear warhead had silenced the critics to whispers about old friend MR Kurup who was the Director, SHAR Centre by then.

a possible technology-conspiracy theory.

Working with Kurup on the Prithvi launch campaign gave me great satisfaction. Kurup worked for Prithvi as a team member, ignoring the The launch of Prithvi sent shock waves across the unfriendly boundary lines that divide DRDO and ISRO, DRDL and SHAR. Kurup neighbouring countries. The response of the Western bloc was initially used to spend a lot of time with us at the launch pad. He complemented one of shock and then of anger. A seven-nation technology embargo e e prpersess

87



WINGS OF FIRE

ORIENTATION - 1

TORCHBEARERS

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.

* * *

14

Torchbearers

Indian core competence in rocketry has been firmly established again, beyond any doubt. The robust civilian space industry and viable missile-based defences has brought India into the select club of nations that call themselves superpowers. Always encouraged to follow Buddha's or Gandhi's teachings, how and why did India become a missile power is a question that needs to be answered for future generations.

Two centuries of subjugation, oppression and denial have failed to kill the creativity and capability of the Indian people. Within just a decade of gaining independence and achieving sovereignty, Indian Space and Atomic Energy Programmes were launched with a perfect orientation towards peaceful applications. There were neither funds for investing in missile development nor any established requirement from the Armed Forces. The bitter experiences of 1962 forced us to take the basic first steps towards missile development.

Would a Prithvi suffice? Would the indigenous development of four or five missile systems make us sufficiently strong? Or would having nuclear weapons make us stronger? Missiles and atomic weapons are merely parts of a greater whole. As I saw it, the development of Prithvi represented the self-reliance of our country in the field of advanced technology. High technology is synonymous with huge amounts of money and massive infrastructure. Neither of these was available, unfortunately, e e prpersess

88



WINGS OF FIRE

ORIENTATION - 1

TORCHBEARERS

in adequate measure. So what could we do? Perhaps the Agni missile The Agni launch had been scheduled for 20 April 1989. This was being developed as a technology demonstrator project, pooling all the going to be an unprecedented exercise. Unlike space launch vehicles, a resources available in the country, could provide an answer?

missile launch involves wide-ranging safety hazards. Two radars, three I was very sure, even when we discussed REX in ISRO about a telemetry stations, one telecommand station and four electro-optical decade ago, that Indian scientists and technologists working together tracking instruments to monitor the missile trajectory had been deployed.

had the capability to achieve this technological breakthrough. India can In addition, the telemetry station at Car Nicobar (ISTRAC) and the most certainly achieve state-of-the-art technology through a combined SHAR radars were also commissioned to track the vehicle. Dynamic effort of the scientific laboratories and the academic institutions. If one surveillance was employed to cover the electrical power that flows from can liberate Indian industry from the self-created image of being mere the missile batteries within the vehicle and to control system pressures.

fabricating factories, they can implement indigenously developed Should any deviation be noticed either in voltage or in pressure, the technology and attain excellent results. To do this, we adopted a three-specially designed automatic checkout system would signal “Hold”. The fold strategy— multi-institutional participation, the consortium approach, flight operations would then be sequenced only if the defect was rectified.

and the empowering technology. These were the stones rubbed together The countdown for the launch started at T-36 hours. The countdown to create Agni.

from T-7.5 minutes was to be computer controlled.

The Agni team was comprised of more than 500 scientists. Many All activities preparatory to the

launch went according to schedule.

organizations were networked to undertake this huge effort of launching. We had decided to move the people living in nearby villages to safety at Agni. The Agni mission had two basic orientations—work and workers.

the time of the launch. This attracted media attention, and led to much. Each member was dependent on the others in his team to accomplish the task. By the time 20 April 1989 arrived, the whole nation was his target. Contradiction and confusion are the two things most likely to watch us. Foreign pressure was exerted through diplomatic channels in such situations. Different leaders accommodate concern for to abort the flight trial, but the Indian Government stood behind us like a workers while getting work done, in their own personal ways. Some rock and staved off any distraction to our work. We were at T-14 seconds shed all concern for workers in order to get results. They use people when the computer signalled “Hold”, indicating that one of the instruments merely as instruments to reach goals. Some give less importance to the was functioning erratically. This was immediately rectified. Meanwhile, work, and make an effort to gain the warmth and approval of people the down-range station asked for a “Hold”. In another few seconds, working with them. But what this team achieved was the highest possible multiple Holds were necessitated, resulting in irreversible internal power integration in terms of both the quality of work and human relationships.

consumption. We had to abort the launch. The missile had to be opened up to replace the on-board power supplies. A weeping Nagaraj, by now involvement, participation and commitment were the key words to informed about the tragedy in his family, met me and promised that he functioning. Each of the team members appeared to be performing by would be back within three days. The profiles of these courageous people choice. The launching of Agni was the common stake not only for our will never be written about in any history book, but it is such silent people scientists, but for their families too. VR Nagaraj was the leader of the on whose hard work generations thrive and nations progress. Sending electrical integration team. Dedicated technologist that he is, Nagaraj Nagaraj off, I met my team members who were in a state of shock and would forget basic requirements like food and sleep while on the sorrow. I shared my SLV-3 experience with them. “I lost my launch integration gig. His brother-in-law passed away while he was at ITR.

vehicle in the sea but recovered successfully. Your missile is in front of His family kept this information from Nagaraj so that there would be no you. In fact you have lost nothing but a few weeks of rework.” This interruption in his work towards the launching of Agni.

shook them out of their immobility and the entire team went back to retrieve the subsystems and recharge them.

e e prpersess



WINGS OF FIRE

ORIENTATION - 1

TORCHBEARERS

The press was up in arms, and fielded various interpretations of the Detailed analysis of the component failure during the second attempt postponement of the flight to suit the fancies of their readership.

led to the refurbishment of the control system. This task was entrusted Cartoonist Sudhir Dar sketched a shopkeeper returning a product to the to a DRDO-ISRO team. The team carried out the rectification of the salesman saying that like Agni it would not take off. Another cartoonist first stage control system at the Liquid Propellant System Complex showed one Agni scientist explaining that the launch was postponed (LPSC) of ISRO and completed the task in record time with tremendous because the press button did not make contact. The Hindustan Times concentration and will-power. It was nothing short of amazing how showed a leader consoling press reporters, “There’s no need for any hundreds of scientists and staff worked continuously and completed the alarm ... it’s a purely peaceful, non-violent missile”.

system readiness with acceptance tests in just 10 days. The aircraft After a detailed analysis conducted virtually around the clock for the took off from Trivandrum with the rectified control systems and landed next ten days, our scientists had the missile ready for launch on 1 May close to ITR on the eleventh day. But now it was the turn of hostile 1989. But, again, during the automatic computer checkout period at T-weather conditions to impede us. A cyclone threat was looming large.

10 seconds, a Hold signal was indicated. A closer inspection showed All the work centres were connected through satellite communication that one of the control components, S1-TVC was not working according and HF links. Meteorological data started flowing in at ten-minute to the mission requirements. The launch had to be postponed yet again.

intervals.

Now, such things are very common in rocketry and quite often happen Finally, the launch was scheduled for 22 May 1989. The previous in other countries too. But the expectant nation was in no mood to night, Dr Arunachalam, Gen KN Singh and I were walking together appreciate our difficulties. The Hindu carried a cartoon by Keshav with the Defence Minister KC Pant, who had come to ITR to witness showing a villager counting some currency notes and commenting to the launch. It was a full-moon night, it was high tide and the waves another, “Yes, it’s the compensation for moving away from my hut near crashed and roared, as if singing of His glory and power. Would we the test site—a few more postponements and I can build a house of my succeed with the Agni launch tomorrow? This question was foremost in own...”. Another cartoonist designated Agni as “IDBM— Intermittently all our minds, but none of us was willing to break the spell cast by the Delayed Ballistic Missile.” Amul’s cartoon suggested that what Agni beautiful moonlit night. Breaking a long silence, the Defence Minister needed to do was use their butter as fuel!

finally asked me, “Kalam! what would you like me to do to celebrate the I took some time off, leaving my team at ITR to talk to the DRDL-Agni success tomorrow?” It was a simple question, to which I could not RCI community. The entire DRDL-RCI community assembled after think of an answer immediately. What did I want? What was it that I did working hours on 8 May 1989. I addressed the gathering of more than not have? What could make me happier? And then I found the answer.

2,000 persons, “Very rarely is a laboratory or an R&D establishment

“We need 100,000 saplings to plant at RCI,” I said. His face lit up with given an opportunity to be the first in the country to develop a system a friendly glow. “You are buying the blessings of Mother Earth for Agni,” such as Agni. A great opportunity has been given to us. Naturally major Defence Minister KC Pant quipped. “We will succeed tomorrow”, he opportunities are accompanied by equally major challenges. We should predicted.

not give up and we should not allow the problem to defeat us. The The next day Agni took off at 0710 hrs. It was a perfect launch. The country doesn’t deserve anything less than success from us. Let us aim missile followed a textbook trajectory. All flight parameters were met. It for success”. I had almost completed my address, when I found myself was like waking up to a beautiful morning from a nightmarish sleep. We telling my people, “I promise you, we will be back after successfully had reached the launch pad after five years of continuous work at multiple launching Agni before the end of this month.” work centres. We had lived through the ordeal of a series of snags in the e e prpersess

90



WINGS OF FIRE

ORIENTATION - 1

TORCHBEARERS

last five weeks. We had survived pressure from everywhere to stop the Gary Milhollin, a so-called specialist in missiles and warhead whole thing. But we did it at last! It was one of the greatest moments of technologies, had made a claim in The Wall Street Journal that India had my life. A mere 600 seconds of elegant flight washed off our entire made Agni with the help of West Germany. I had a hearty laugh reading fatigue in an instant. What a wonderful culmination of our years of labour.

that the German Aerospace Research Establishment (DLR) had I wrote in my diary that night:

developed Agni’s guidance system, the first-stage rocket, and a composite *Do not look at Agni*

nose cone, and that the aerodynamic model of Agni was tested in the *as an entity directed upward*

DLR wind tunnel. An immediate denial came from the DLR, who in *to deter the ominous*

turn speculated that France had supplied the Agni guidance electronics.

or exhibit your might.

American Senator Jeff Bingaman even went to the extent of suggesting *It is fire*

that I picked up everything needed for Agni during my four-month stay *in the heart of an Indian.*

at Wallop's Island in 1962. The fact that I was in Wallop's Island more *Do not even give it*

than 25 years ago and at that time the technology used in Agni did not *the form of a missile*

exist even in the United States was not mentioned.

as it clings to the

In today's world, technological backwardness leads to subjugation.

burning pride of this nation

Can we allow our freedom to be compromised on this account? It is our *and thus is bright.*

bounden duty to guarantee the security and integrity of our nation against Prime Minister Rajiv Gandhi called the Agni launch "a major threat. Should we not uphold the mandate bequeathed to us by our achievement in our continuing efforts to safeguard our independence forefathers who fought for the liberation of our country from imperialism?

and security by self-reliant means. The technology demonstration through Only when we are technologically self-reliant will we be able to fulfill their Agni is a reflection of our commitment to the indigenous development of dream.

advanced technologies for the nation's defence." "The country is proud Till the Agni launch, the Indian Armed Forces had been structured of your efforts," he told me. President Venkataraman saw in the Agni for a strictly defensive role to safeguard our nation, to shield our success the fulfilment of his dream. He cabled from Simla, "It is a tribute democratic processes from the turbulence in the countries around us to your dedication, hard work, and talent." and to raise the cost of any external intervention to an unacceptable A great deal of misinformation and disinformation had been spread level for countries which may entertain such notions. With Agni, India by vested interests about this technology mission. Agni had never been had reached the stage where she had the option of preventing wars intended only as a nuclear weapon system. What it did was to afford us involving her.

the option of developing the ability to deliver non-nuclear weapons with Agni marked the completion of five years of IGMDP. Now that it high precision at long ranges. That it provided us with a viable non-had demonstrated our competence in the crucial area of re-entry nuclear option was of the greatest relevance to contemporary strategic technology and with tactical missiles like Prithvi and Trishul already test-doctrines.

fired, the launches of Nag and Akash would take us into areas of Great ire was raised by the test

firing of Agni, according to a well-competence where there is little or no international competition. These known American defence journal, especially in the United States where two missile systems contained within themselves the stuff of major Congressmen threatened to put a stop to all dual-use and missile-related technological breakthroughs. There was a need to focus our efforts technologies, along with all multinational aid.

more intensively on them.

e e prpersess

91



WINGS OF FIRE

ORIENTATION - 1

TORCHBEARERS

In September 1989, I was invited by the Maharashtra Academy of Sciences in Bombay to deliver the Jawaharlal Nehru Memorial Lecture.

I used this opportunity to share with the budding scientists my plans of making an indigenous Air-to-Air missile, Astra. It would dovetail with the development of the Indian Light Combat Aircraft (LCA). I told them that our work in Imaging Infra Red (IIR) and Millimetric Wave (MMW) radar technology for the Nag missile system had placed us in the vanguard of international R&D efforts in missile technology. I also drew their attention to the crucial role that carbon-carbon and other advanced composite materials play in mastering the re-entry technology. Agni was the conclusion of a technological effort that was given its start by Prime Minister Indira Gandhi when the country decided to break free from the paralysing fetters of technological backwardness and slough off the dead skin of subordination to industrialized nations.

The second flight of Prithvi at the end of September 1988 was again a great success. Prithvi has proved to be the best surface-to-surface missile in the world today. It can carry 1000 kg of warhead to a distance of 250 km and deliver it within a radius of 50 metres. Through computer controlled operations, numerous warhead weight and delivery distance combinations can be achieved in a very short time and in battlefield conditions. It is a hundred per cent indigenous in all respects—design, operations, deployment. It can be produced in large numbers as the production facilities at BDII were concurrently developed during the development phase itself. The Army was quick to recognize the potential of this commendable effort and approached the CCPA for placing orders for Prithvi and Trishul missile systems, something that had never happened before.

* * *

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WINGS OF FIRE

ORIENTATION - 1

IV

CONTEMPLATION

[1991 –]

We create and destroy

And again recreate

In forms of which no one knows.

AL-WAQUIAH

Qur'an 56:61

e e prpersess



WINGS OF FIRE

ORIENTATION - 1

EMANCIPATORS

I sat alone for a while in silent contemplation. The sand and shells of Rameswaram, the care of Iyadurai Solomon in Ramanathapuram, the guidance of Rev. Father Sequeira in Trichi and Prof. Pandalai in Madras, the encouragement of Dr Mediratta in Bangalore, the hovercraft ride with Prof. Menon, the pre-dawn visit to the Tilpat Range with Prof.

Sarabhai, the healing touch of Dr Brahm Prakash on the day of the SLV3 failure, the national jubilation on the SLV-3 launch, Madam Gandhi's appreciative smile, the post-SLV-3 simmering at VSSC, Dr Ramanna's 15

faith in inviting me to DRDO, the IGMDP, the creation of RCI, Prithvi, Agni...a flood of memories swept over me. Where were all these men now? My father, Prof. Sarabhai, Dr Brahm Prakash? I

wished I could meet them and share my joy with them. I felt the paternal forces of heaven and the maternal and cosmic forces of nature embrace me as parents would hug their long-lost child. I scribbled in my diary: Emancipators

Away! fond thoughts, and vex my soul no more!

Work claimed my wakeful nights, my busy days Albeit brought memories of Rameswaram shore On Republic Day 1990, the nation celebrated the success of *Yet haunt my dreaming gaze!*

its missile programme. I was conferred the Padma Vibhushan A fortnight later, Iyer and his team celebrated the awards for the along with Dr Arunachalam. Two of my other colleagues—

missile programme with the maiden flight of Nag. They repeated the JC Bhattacharya and RN Agarwal—were also decorated with the Padma feat again on the very next day, thus testing twice over the first Indian Shree awards. It was the first time in the history of free India that so all-composite airframe and the propulsion system. These tests also proved many scientists affiliated to the same organization found their names on the worth of the indigenous thermal batteries.

the awards list. Memories of the Padma Bhushan awarded a decade ago came alive. I still lived more or less as I had lived then—in a room India had achieved the status of having a third generation anti-tank ten feet wide and twelve feet long, furnished mainly with books, papers missile system with ‘fire-and-forget’ capability—on par with any state-and a few pieces of hired furniture. The only difference was at that time, of-the-art technology in the world. Indigenous composite technology had my room was in Trivandrum and now it was in Hyderabad. The mess achieved a major milestone. The success of Nag also confirmed the bearer brought me my breakfast of idlis and buttermilk and smiled in efficacy of the consortium approach, which had led to the successful silent congratulation for the award. I was touched by the recognition development of Agni.

bestowed on me by my countrymen. A large number of scientists and Nag uses two key technologies—an Imaging Infra Red (IIR) system engineers leave this country at their first opportunity to earn more money and a Millimetric Wave (MMW) seeker radar as its guiding eye. No abroad. It is true that they definitely get greater monetary benefits, but single laboratory in the country possessed the capability of developing could anything compensate for this love and respect from one’s own these highly advanced systems. But the urge to succeed existed, which countrymen?

resulted in a very effective joint effort. The Semi Conductor Complex at e e prpersess

94



WINGS OF FIRE

ORIENTATION - 1

EMANCIPATORS

Chandigarh developed the Charge Coupled Devices (CCD) array. The We celebrated the nation's forty-fourth Independence Day with the Solid Physics Laboratory, Delhi, made the matching Mercury Cadmium test firing of Akash. Prahlada and his team evaluated a new solid propellant Telluride (MCT) detectors. The Defence Science Centre (DSC), Delhi, booster system based on a composite modified double base propellant.

put together an indigenous cooling system based on the Joules Thomson This propellant with its unprecedented high energy properties was crucial effect. The transmitter receiver front end was devised at the Defence in assuring the long-range surface-to-air missiles. The country had taken Electronics Application Laboratory (DEAL), Dehra Dun.

an important step in ground-based air defence of vulnerable areas.

The special gallium arsenide gun, schottky barrier mixer diodes, Towards the end of 1990, Jadavpur University conferred on me the compact comparator for antenna system—India was banned from buying honour of Doctor of Science at a special convocation. I was a little any one of these high technology devices, but innovation cannot be embarrassed at finding my name mentioned along with that of the suppressed by international restrictions.

legendary Nelson Mandela, who was also honoured at the same I went to Madurai Kamaraj University the same month to deliver convocation. What could I possible have in common with a legend like their convocation address. When I reached Madurai, I asked after my Mandela? Perhaps it was our persistence in our missions. My mission of high school teacher Iyadurai Solomon, who was by now a Reverend and advancing rocketry in my country was perhaps nothing when compared eighty years old. I was told that he lived in a suburb of Madurai, so I took with Mandela's mission of achieving dignity for a great mass of humanity; a taxi and looked for his house. Rev. Solomon knew that I was going to but there was no difference in the intensity of our passions. "Be more give the convocation address that day. However, he had no way of getting dedicated to making solid achievements than in running after swift but there. There was a touching reunion between teacher and pupil. Dr PC

synthetic happiness," was my advice to the young audience.

Alexander, the Governor of Tamil Nadu, who was presiding over the The Missile Council declared 1991 the Year of Initiative for DRDL

function, was deeply moved on seeing the elderly teacher who had not and RCI. When we chose the route of concurrent engineering in IGMDP, forgotten his pupil of long ago, and requested him to share the dais.

we selected a rough track. With the completion of developmental trials

"Every convocation day of every University is like opening the on Prithvi and Trishul, our choice was on test now. I exhorted my floodgates of energy which, once harnessed by institutions, organizations colleagues to commence user trials within the year. I knew that it was and industry, aids in nation-building," I told the young graduates. Somehow going to be a tough task, but that was not going

to discourage us.

I felt I was echoing Rev. Solomon's words, spoken about half a century Rear Admiral Mohan retired and his deputy, Kapoor, was to take over. After my lecture, I bowed down before my teacher. "Great dreams over Trishul. I had always admired Mohan's understanding of missile of great dreamers are always transcended," I told Rev. Solomon. "You command guidance. This sailor-teacher-scientist could outwit any other have not only reached my goals, Kalam! You have eclipsed them," he expert in the country in this field. I will always remember his candid told me in a voice choked with emotion.

exposition of various aspects of the Command Line of Sight (CLOS) The next month, I happened to be in Trichi and used that opportunity guidance system during the Trishul meetings. Once, he showed me a to visit St. Joseph's College. I did not find Rev. Father Sequeira, Rev.

verse that he had composed to highlight the woes of an IGMDP Project Father Erhart, Prof. Subramanyam, Prof. Iyyamperumal Konar, or Prof.

Director. It was a good way of letting off steam: Thothathri Iyengar there, but it seemed to me that the stones of the St.

Impossible timeframes,

Joseph's building still carried the imprint of the wisdom of those great *PERT charts to boot*

people. I shared with the young students my memories of St. Joseph's *Are driving me almost crazy as a coot*; and paid tribute to the teachers who had moulded me.

Presentations to MC add to one's woes, e e prpersess

95



WINGS OF FIRE

ORIENTATION - 1

EMANCIPATORS

If they solve anything, Heaven only knows.

philosopher, Sun Tzu ruminated over 2000 years ago that what matters *Meetings on holidays, even at night,*

in war is not decimating the enemy army physically but breaking his will *The family is fed up,*

so as to make him concede defeat in the mind, he seems to have visualized *And all ready to fight.*

the domination of technology in the twentieth century theatres of war.

My hands are itching

The missile force coupled with the electronic warfare used in the Gulf *to tear my hair* —

War was a feast for military strategic experts. It acted as a curtain-But alas! I haven't any more to tear ...

raiser for the twenty-first century war scenario with missiles and I told him, "I have handed over all my problems to my best teams in electronic and information warfare playing the lead roles.

DRDL, RCI, and other participating labs. That has given me a full head In India, even today, the term technology, for most people, conjures of hair."

up images of smoky steel mills or clanking machines. This is a rather The year 1991 began on a very ominous note. On the night of 15

inadequate conception of what technology denotes. The invention of the January 1991, the Gulf War broke out between Iraq and the Allied Forces horse collar in the Middle Ages led to major changes in agricultural led by the USA. In one stroke, thanks to satellite television invading methods, and was as much a technological advance as the invention of Indian skies by that time, rockets and missiles captured the imagination the Bessemer furnace centuries later. Moreover, technology includes of the entire nation. People started discussing Scuds and Patriots in coffee techniques as well as the machines that may or may not be necessary to houses and tea shops. Children began flying paper kites shaped like apply them. It includes ways to make chemical reactions occur, ways to missiles, and playing war games along the lines of what they saw on breed fish, eradicate weeds, light theatres, treat patients, teach history, American television networks. The successful test firing of Prithvi and fight wars, or even prevent them.

Trishul during the course of the Gulf War was enough to make an anxious Today, most advanced technological processes are carried out far nation relax. The newspaper reports of the programmable trajectory from assembly lines or open hearths. Indeed, in electronics, in space capability of the Prithvi and Trishul guidance system, using microwave technology, in most of the new industries, relative silence and clean frequencies in virtually unjammable bands, created widespread surroundings are characteristic, even essential. The assembly line, with awareness. The nation was quick to draw parallels between the missiles the organization of armies of men, to carry out simple, routine functions operational in the Gulf War and our own warhead carriers. A common is an anachronism. Our symbols of technology must change before we query I encountered was whether Prithvi was superior to a Scud, whether can keep pace with changes in technology itself. We should never forget Akash could perform like a Patriot, and so on. Hearing a "Yes" or a that technology feeds on itself. Technology makes more technology

"Why not?" from me, people's faces would light up with pride and possible. In fact, technological innovation consists of three stages linked satisfaction.

together in a self-reinforcing cycle. First, there is the creative stage, with The Allied Forces had a marked technological edge, as they were the blueprint of a feasible idea. This is made real by its practical application, fielding systems built using the technologies of the eighties and nineties.

and this finally ends in its diffusion through society. The process is then Iraq was fighting with the by-and-large vintage weapon systems of the complete; the loop is closed when the diffusion of technology embodying sixties and seventies.

the new idea in its turn helps generate new creative ideas. Today, all over the developed world, the time gap between each of the steps in this Now, this is where the key to the modern world order lies — superiority cycle has been shortened. In India, we are just progressing towards that through technology. Deprive the opponent of the latest technology and stage—closing the loop.

then dictate your terms in an unequal contest. When the Chinese war e e prpersess

96



WINGS OF FIRE

ORIENTATION - 1

EMANCIPATORS

After the Gulf War concluded with the victory of the technologically with me to establish what he called the Rao-Kalam school. We were superior Allied Forces, over 500 scientists of DRDL and RCI gathered unanimous in our opinion that carrying out certain missions and reaching to discuss issues that had emerged. I posed a question before the certain milestones, however important they may be or however assembly: was technology or weapon symmetry with other nations impressive they might appear to be, is not all there is to life. But we had feasible, and if so, should it be attempted? The discussion led to many to postpone our plan as neither of us was relieved from our post by the more serious questions, such as, how to establish effective electronic Government of India.

warfare support? How to make missile development proceed apace with It was during this period that I decided to put down my memoirs and the development of equally necessary systems like the LCA; and what express my observations and opinions on certain issues.

were the key areas where a push would bring progress?

The biggest problem Indian youth faced, I felt, was a lack of clarity At the end of a lively discussion spread over three hours, the consensus of vision, a lack of direction. It was then that I decided to write about the emerged that there was no way to redress asymmetry in military capability circumstances and people who made me what I am today; the idea was except to have the same capability in specific areas as your potential not merely to pay tribute to some individuals or highlight

certain aspects opponent. The scientists vowed to achieve a reduced CEP in the accuracy of my life. What I wanted to say was that no one, however poor, of Prithvi's delivery, perfecting the Ka band guidance system for Trishul underprivileged or small, need feel disheartened about life. Problems are and realising all carbon-carbon re-entry control surfaces for Agni by the a part of life. Suffering is the essence of success. As someone said: end of the year. The vow was later fulfilled. The year also saw tube-launched Nag flights, and the manoeuvre of Trishul at seven metres *God has not promised*

above sea level, at speeds which exceeded three times the speed of *Skies always blue*,

sound. The latter was a breakthrough in the development of an indigenous *Flower-strewn pathways* ship-launched anti-sea-skimmer missile.

All our life through;

God has not promised

The same year, I received an honorary degree of Doctor of Science *Sun without rain*,

from the IIT, Bombay. In the citation read by Prof. B Nag on the occasion, *Joy without sorrow*,

I was described as "an inspiration behind the creation of a solid *Peace without pain*."

technological base from which India's future aerospace programmes can be launched to meet the challenges of the twenty-first century".

I will not be presumptuous enough to say that my life can be a role Well, perhaps Prof. Nag was only being polite, but I do believe that India model for anybody; but some poor child living in an obscure place, in an will enter the next century with its own satellite in geo-stationary orbit underprivileged social setting may find a little solace in the way my destiny 36,000 km away in space, positioned by its own launch vehicle. India will has been shaped. It could perhaps help such children liberate themselves also become a missile power. Ours is a country with tremendous vitality.

from the bondage of their illusory backwardness and hopelessness.

Even though the world may not see its full potential or feel its full power, Irrespective of where they are right now, they should be aware that God no one dare ignore it any more.

is with them and when He is with them, who can be against them?

On 15 October, I turned sixty. I looked forward to retirement and *But God has promised*

planned to open a school for the less privileged children. My friend, Prof.

Strength for the day,

P Rama Rao, who was heading the Department of Science and *Rest for the labour*

Technology in the Government of India, even struck up a partnership *Light for the way*.

e e prpersess

97



WINGS OF FIRE

ORIENTATION - 1

LEADERS

It has been my observation that most Indians suffer unnecessary misery all their lives because they do not know how to manage their emotions. They are paralysed by some sort of a psychological inertia.

Phrases like ‘the next best alternative’, ‘the only feasible option or solution’, and ‘till things take a turn for the better’ are commonplace in our business conversations. Why not write about the deep-rooted character traits which manifest themselves in such widespread, self-defeatist thought patterns and negative behaviour? I have worked with 16

many people and organizations and have had to deal with people who were so full of their own limitations that they had no other way to prove their self-worth than by intimidating me. Why not write about the victimization which is a hallmark of the tragedy of Indian science and technology? And about the pathways to organizational success? Let the Leaders

latent fire in the heart of every Indian acquire wings, and the glory of this great country light up the sky.

* * *

Technology, unlike science, is a group activity. It is not based on individual intelligence, but on the interaction of many people. I think the biggest success of IGMDP is not the fact that in record time the country acquired the capability of making five state-of-the-art missile systems but that through it, some superb teams of scientists and engineers have been created. If someone asks me about my personal achievements in Indian rocketry, I would put it down to having created a challenging environment for teams of young people to work in.

In their formative stages, teams are much like children in spirit. They are as excitable, as full of vitality, enthusiasm, curiosity and the desire to please and excel. As with children, however, these positive attributes can be destroyed by the behaviour of misguided parents. For teams to be successful, the environment must offer scope for innovation. I confronted many such challenges during the course of my work at DTD&P (Air), ISRO, DRDO and elsewhere, but always ensured for my teams an environment which allowed innovation and risk-taking.

When we first began creating project teams during the SLV-3 project and later in IGMDP, people

working in these teams found themselves in the frontline of their organizations' ambitions. Since a great deal of psychological investment had been made in these teams, they became both highly visible and highly vulnerable. They were personally expected to make a disproportionate contribution to win collective glory.

e e prpersess

98



WINGS OF FIRE

ORIENTATION - 1

LEADERS

I was aware that any failure in the organizational support system The process of arriving at the success criteria within a team is an would negate the investment in team strategies. The teams would be intricate and skilled one because there are a lot of things going on below relegated to the league of average working groups and might fail even the surface. On the surface, the team is simply working to achieve the there, unable to meet the high expectations set for them. On several project's goals. But I have repeatedly seen how people are poor at occasions, the organization was on the verge of losing its nerve and articulating what they want—until they see a work centre doing something imposing restraints. The high level of uncertainty and complexity they don't want them to do. A project team member must in fact act like associated with team activity very often proves to be a trap for the unwary.

a detective. He should probe for clues as to how the project is proceeding, In the early years of the SLV-3 project, I often had to counter and then piece together different bits of evidence to build up a clear, nervousness of the top people because progress was not tangibly or comprehensive and deep understanding of the project's requirements.

immediately visible. Many felt that the organization had lost control over At another level, the relationship between the project teams and the SLV-3, that the team would run on unchecked, and cause chaos and work centres should be encouraged and developed by the project leader.

confusion. But on all occasions, these fears were proved imaginary. There Both parties must be very clear in their minds about their mutual were many people in powerful positions in organizations, for example at interdependence and the fact that both of them have a stake in the project.

VSSC, who underestimated our responsibility and commitment to At yet another level, each side should assess the other's capabilities and organizational objectives. Dealing with such people was a crucial part of identify areas of strength and weakness in order to plan what needs the whole operation, and this was performed dexterously by Dr Brahm doing and how it should be done. In fact, the whole game can be seen as Prakash.

a process of contracting. It is about exploring and arriving at an agreement When you work as a project team, you need to develop a complex on what each party expects of the other; about realistically understanding view of the success criteria. There are always multiple and often the constraints of the other party; and about communicating the success conflicting sets of expectations that exist about a team's performance.

criteria while defining some simple rules about how the relationship is to Then, quite often, the project teams are virtually torn apart in their attempt work; but above all, it's the best means of developing clarity in the to accommodate the needs and constraints of sub-contractors outside relationship, both at the technical and personal levels, in order to avoid the organization and specialist departments within the organization. Good any nasty surprises in the future. In IGMDP, Sivathanu Pillai and his project teams are able to quickly identify the key person or people with team did some remarkable work in this area through their home-grown whom negotiations must take place. A crucial aspect of the team leader's technique, PACE, which stands for Programme Analysis, Control and role is to negotiate with these key people for their requirements, and to Evaluation. Each day between 12 noon and 1 p.m., they would sit with a ensure that the dialogue continues on a regular basis as the situation project team and a particular work centre that was on the critical path develops or changes. If there is one thing outsiders dislike, it is unpleasant and assess the level of success among themselves. The excitement of surprises. Good teams ensure that there are none.

planning ways to succeed and the vision of future success provide an irresistible form of motivation which, I have found, always makes things The SLV-3 team developed their own internal success criteria. We happen.

articulated our standards, expectations and objectives. We summarised what was needed to happen for us to be successful and how we would The concept of Technology Management has its roots in the measure success. For instance, how we were going to accomplish our Developmental Management models which originated in the early Sixties tasks, who would do what and according to what standards, what were out of a conflict between harmony-seeking and output-oriented the time limits and how would the team conduct itself with reference to management structures. There are basically two types of management others in the organization.

orientations: primal, which values an economic employee, and rational, e e prpersess

99



WINGS OF FIRE

ORIENTATION - 1

LEADERS

which values an organizational employee. My concept of management self-actualization of needs, renewal, interdependence, and natural flow.

is woven around an employee who is a technology person. While the growth patterns are characteristic of the evolution process, which primal management school recognizes people for their independence, means that things move in a combination of slow change and sudden and rational management acknowledges them for their dependability, I transformation; each transformation causes either a leap into a new, value them for their interdependence. Whereas the primal manager more complex level or a devastating crash to some earlier level; dominant champions independent enterprise and the rational manager serves models reach a certain peak of success when they turn troublesome; cooperation, I moot interdependent joint ventures, getting the forces and the rate of change always accelerates.

together, networking people, resources, time schedules, costs, and so on.

The stem of the tree is the molecular structure in which all actions Abraham Maslow was the first person to suggest the new psychology are formative, all policies are normative, and all decisions are integrative.

of self-actualization at a conceptual level. In Europe, Rudolf Steiner and The branches of this tree are resources, assets, operations, and products Reg Revans developed this concept into the system of individual learning which are nourished by the stem through a continuous performance and organizational renewal. The Anglo-German management philosopher, evaluation and corrective update.

Fritz Schumacher introduced Buddhist economics and authored the This tree of technology management, if carefully tended, bears the concept of “Small is Beautiful”. In the Indian subcontinent, Mahatma fruits of an adaptive infrastructure: technological empowerment of the Gandhi emphasized grass root level technology and put the customer at institutions, the generation of technical skills among people, and finally the centre of the entire business activity. JRD Tata brought in progress-self-reliance of the nation and improvement in the quality of life of its driven infrastructure. Dr Homi Jehangir Bhabha and Prof. Vikram citizenry.

Sarabhai launched the high, technology-based atomic energy and space programmes with a clear-cut emphasis on the natural laws of totality When IGMDP was sanctioned in 1983, we did not have an adequate and flow. Advancing the developmental philosophy of Dr Bhabha and technology base. A few pockets of expertise were available, but we Prof. Sarabhai, Dr MS Swaminathan ushered the Green Revolution into lacked the authority to utilize that expert technology. The multi-project India working on another natural principle of integrity. Dr Verghese Kurien environment of the programme provided a challenge, for five advanced brought in a powerful cooperative movement through a revolution in the missile systems had to be simultaneously developed. This demanded dairy industry. Prof. Satish Dhawan developed mission management judicious sharing of resources, establishing priorities, and ongoing induction concepts in space research. These are but a few examples of individuals of manpower. Eventually, the IGMDP had 78 partners, including 36

who have not only articulated but also implemented their ideas, thus technology centres and 41 production centres spread over public sector changing forever the face of research and business organizations all undertakings, ordnance factories, private industries, and professional over the world.

societies, hand-in hand with a well-knit bureaucratic structure in the Government. In the management of the Programme, as much as in the In the IGMDP, I attempted to integrate the vision of Prof. Sarabhai technological inputs, we attempted to develop a model that was and the mission of Prof. Dhawan by adapting the high technology setting appropriate, even tailor-made, for our very specific needs and capabilities.

of Dr Brahm Prakash's space research. I attempted to add the natural We borrowed ideas that had been developed elsewhere, but adapted law of Latency in founding the Indian Guided Missile Programme in them in the light of what we knew were our strengths and what we order to create a completely indigenous variety of technology recognized as the constraints we would be compelled to work under. All management. Let me use a metaphor to illuminate this.

in all, the combination of appropriate management and our cooperative The tree of technology management takes root only if there is the endeavours helped to unearth the talent and potential that lay unused in e e prpersess

100



WINGS OF FIRE

ORIENTATION - 1

LEADERS

our research laboratories, government institutions and private industries.

Of these kings in the middle of the sands.

The Technology Management philosophy of IGMDP is not exclusive How did they feel so secure without anything to fall back upon? I to missile development. It represents the national urge to succeed and an believe they drew sustenance from within. They relied more on the inner awareness that the world will never again be directed by muscle or money signals and less on the external cues that I have mentioned above. Are power. In fact, both these powers will depend on technological excellence.

you aware of your inner signals? Do you trust them? Have you taken Technology respects only technology. And, as I said in the beginning, control over your life into your own hands? Take this from me, the more technology, unlike science, is a group activity. It does not grow only through decisions you can make avoiding external pressures, which will constantly individual intelligence, but by intelligences interacting and ceaselessly try to manipulate you, the better your life will be, the better your society influencing one another. And that is what I tried to make IGMDP: a 78-will become. Infact the entire nation will benefit by having strong, inward-strong Indian family which also makes missile systems.

looking people as their leaders. A citizenry that thinks for itself, a country There has been much speculation and philosophizing about the life of people who trust themselves as individuals, would be virtually immune and times of our scientists, but not enough exploration in determining to manipulation by any unscrupulous authority or vested interest.

where they wanted to go and how they reached there. In sharing with Your willingness to use your own inner resources to invest in your you the story of my struggle to become a person, I have perhaps given life, especially your imagination, will bring you success. When you address you some insight into this journey. I hope it will help at least a few young a task from your own uniquely individual standpoint, you become a whole people to stand up to the authoritarianism in our society. A characteristic person.

feature of this social authoritarianism is its insidious ability to addict people Everyone on this planet is sent forth by Him to cultivate all the creative to the endless pursuit of external rewards, wealth, prestige, position, potential within us and live at peace with our own choices. We differ in promotion, approval of one's lifestyle by others, ceremonial honours, and the way we make our choices and evolve our destiny. Life is a difficult status symbols of all kinds.

game. You can win only by retaining your birthright to be a person. And To successfully pursue these goals, they have to learn elaborate rules to retain this right, you will have to be willing to take the social or external of etiquette and familiarize themselves with customs, traditions, protocols risks involved in ignoring pressures to do things the way others say they and so on. The youth of today must unlearn this self-defeating way of should be done. What will you call Sivasubramania Iyer inviting me to life. The culture of working only for material possessions and rewards have lunch in his kitchen? Zohara, my sister, mortgaging her gold bangles must be discarded. When I see wealthy, powerful and learned people and chains to get me into engineering college? Prof. Sponder insisting struggling to be at peace with themselves, I remember people like Ahmed that I should sit with him in the front row for the group photograph?

Jallaluddin and Iyadurai Solomon. How happy they were with virtually Making a hovercraft in a motor-garage setup? Sudhakar's courage? Dr no possessions!

Brahm Prakash's support? Narayanan's management? Venkataraman's *On the coast of Coromandel* vision? Arunachalam's drive? Each is an example of a strong inner *Where the earthy shells blow*, strength and initiative. As Pythagoras had said twenty-five centuries ago, *In the middle of the sands* "Above all things, reverence yourself."

Lived some really rich souls.

I am not a philosopher. I am only a man of technology. I spent all my *One cotton lungi and half a candle* –

life learning rocketry. But as I have worked with a very large cross-One old jug without a handle

section of people in different organizations, I had an opportunity to *These were all the worldly possessions* understand the phenomenon of professional life in its bewildering e e prpersess

101



WINGS OF FIRE

ORIENTATION - 1

LEADERS

complexity. When I look back upon what I have narrated so far, my own I do not wish to set myself up as an example to others, but I believe observations and conclusions appear as dogmatic utterances. My that a few readers may draw inspiration and come to experience that colleagues, associates, leaders; the complex science of rocketry; the ultimate satisfaction which can only be found in the life of the spirit.

important issues of technology management; all seem to have been dealt God's providence is your inheritance. The bloodline of my great-with in a perfunctory manner. The despair and happiness, the grandfather Avul, my grandfather Pakir, and my father Jainulabdeen may achievements and the failures—differing markedly in context, time, and end with Abdul Kalam, but His grace will never cease, for it is Eternal.

space—all appear grouped together.

* * *

When you look down from an aircraft, people, houses, rocks, fields, trees, all appear as one homogeneous landscape, it is very difficult to distinguish one from another. What you have just read is a similar bird's-eye view of my life seen, as it were, from afar.

My worthiness is all my doubt –

His merit – all my fear –

Contrasting which my quality

Does however – appear.

This is the story of the period ending with the first Agni launch—life will go on. This great country will make enormous strides in all fields if we think like a united nation of 900 million people. My story—the story of the son of Jainulabdeen, who lived for over a hundred years on Mosque Street in Rameswaram island and died there; the story of a lad who sold newspapers to help his brother; the story of a pupil reared by Sivasubramania Iyer and Iyadurai Solomon; the story of a student taught by teachers like Pandalai; the story of an engineer spotted by MGK

Menon and groomed by the legendary Prof. Sarabhai; the story of a scientist tested by failures and setbacks; the story of a leader supported by a large team of brilliant and dedicated professionals. This story will end with me, for I have no belongings in the worldly sense. I have acquired nothing, built nothing, possess nothing—no family, sons, daughters.

I am a well in this great land

Looking at its millions of boys and girls To draw from me

The inexhaustible divinity

And spread His grace everywhere

As does the water drawn from a well.

e e prpersess

102



WINGS OF FIRE

ORIENTATION - 1

earnestly hope and pray that the development resulting from these two plans—Self Reliance Mission and Technology Vision – 2020—will eventually make our country strong and prosperous and take our rightful place among the ranks of the “developed” nations.

Epilogue

This book is interwoven with my deep involvement with India’s first Satellite Launch Vehicle SLV-3 and Agni Programmes, an involvement which eventually led to my participation in the recent important national event related to the nuclear tests in May, 1998. I have had the great opportunity and honour of working with three scientific establishments—

Space, Defence Research and Atomic Energy. I found, while working in these establishments, that the best of human beings and the best of innovative minds were available in plenty. One feature common to all three establishments, is that the scientists and technologists were never afraid of failures during their missions. Failures contain within themselves the seeds of further learning which can lead to better technology, and eventually, to a high level of success. These people were also great dreamers and their dreams finally culminated in spectacular achievements.

I feel that if we consider the combined technological strength of all these scientific institutions, it would certainly be comparable to the best found anywhere in the world. Above all, I have had the

opportunity of working with the great visionaries of the nation, namely Prof. Vikram Sarabhai, Prof. Satish Dhawan and Dr Brahm Prakash, each of whom have greatly enriched my life.

A nation needs both economic prosperity and strong security for growth and development. Our Self Reliance Mission in Defence System 1995–

2005 will provide the Armed Forces with a state-of-the-art competitive weapons system. The Technology Vision – 2020 plan will put into place certain schemes and plans for the economic growth and prosperity of the nation. These two plans have evolved out of the nation's dreams. I e e prpersess