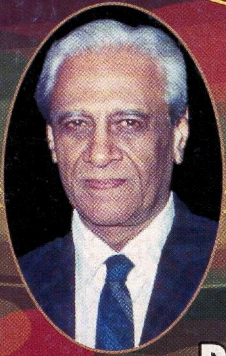

Prof. Satish Dhawan Commemoration Lecture

ROLE OF ENGINEERING IN DEVELOPMENT OF ECONOMY, SOCIETY AND PEOPLE

Prof. Y.S. Rajan
Dr. Vikram Sarabhai Distinguished Professor
Indian Space Research Organisation
Bangalore

22 September 2010

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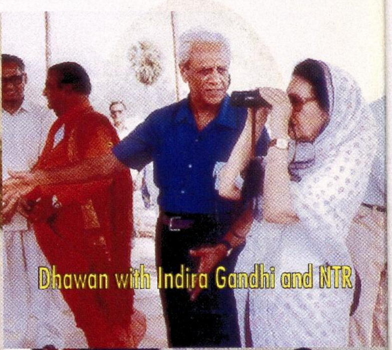
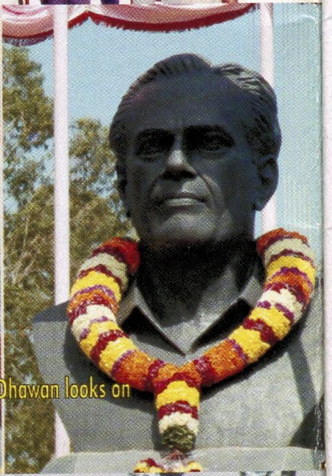
The Institution of Engineers (India)
Karnataka State Centre
Bangalore - 560 001

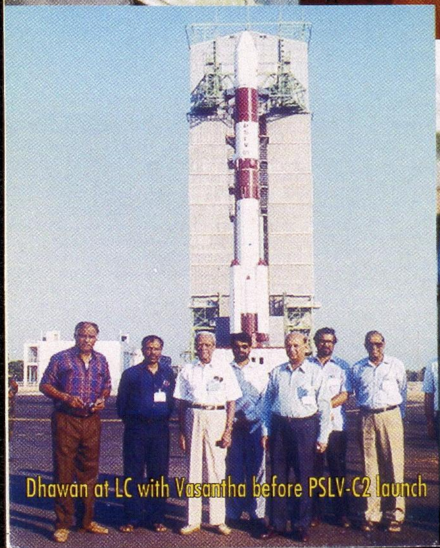
Prof. Satish Dhawan from the Pages of History


Dhawan with Indira Gandhi and Janardhan Reddy


Dhawan with Indira Gandhi and NTR


Prime Minister Manmohan Singh unvieling the bust of Prof. Dhawan as Mrs Dhawan looks on




Dhawan at LC with Vasantha before PSLV-C2 launch


Dhawan giving sweets to yanadi children

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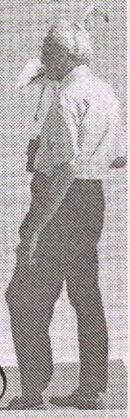


"Whenever ... to the country ... became a litt... went to see the birds of SHAR ... and came back feeling happy and invigorated."

-Prof. Dhawan

The Institution of Engineers (India)

Karnataka State Centre

Bangalore - 560 001

ROLE OF ENGINEERING IN DEVELOPMENT OF ECONOMY, SOCIETY AND PEOPLE

The first Professor Satish Dhawan Commemoration lecture organized by The Institution of Engineers (India) (IE), Karnataka State Centre to be delivered on 22nd September 2010 at The Institution of Engineers (India), Karnataka State Centre, No. 3, Dr. B R Ambedkar Veedhi, Bangalore 560 001.

Dr. Radhakrishnan, Chairman, ISRO / Secretary, DOS / Chairman, Space Commission, Dr. L.V Muralikrishna Reddy, Chairman, The Institution of Engineers (India) Karnataka Sate Centre, Dr. S.B Ganjigatti, Honorary Secretary and distinguished participants.

INVOCATION

It is indeed a great honour and unique privilege for me to be given the opportunity to deliver the first Professor Satish Dhawan Commemoration lecture remembering Professor Satish Dhawan (whose 90th birth anniversary is on September 25, 2010) a great teacher, distinguished researcher, an unparalled leader and administrator of academic institutions and scientific and technology organizations, and above all a committed engineer in heart and real life. The institutions he built are shining before us. For me it is a special memory as much of my life from 1973 was influenced and shaped by him. Our relationship is several combinations of his being Guru, Mentor, Guide, Boss and many more.

True to the tradition in which he has moulded many of us for several years, I am not going to dwell on his life and his contributions to science, technology, engineering, management, economy and society. There are only a few writings on him. I would refer to two recent articles. One by me: Bibliographical memories of the Indian National Science Academy (INSA, Vol. 28, 2005) which gives the earlier references and draws from a few unique writings by him post-retirement. Another is a brilliant piece in the Hindu last year on 25th September 2009 by Dr. Manoranjan Rao.

ENGINEERING AS A DISCIPLINE

The crucial role of engineering for modern civilization is implicit in every aspect of our lives. Rapid progress in the development of the country post-independence has taken place through the application of engineering to different sectors: dams and irrigation systems which paved the way for green revolution; roads, civil construction of many types including building of major cities; sanitation systems; manufacturing industries; transport systems from trucks, buses, trains, ships, aircrafts, shipyards and airports, pharmaceutical industries, one can list many more.

However, the unique role of engineering, got submerged in the romance of the word "science" used by Jawaharlal Nehru who meant it in a broader sense of generation, acquisition and application of modern knowledge as well as a rational way of looking at life, which he termed as scientific temper.

So much so, the prestigious Indian science academies ignored the achievers in engineering discipline and even engineering researchers. This led to the formation of Indian National academy of Engineers (INAE).

Prof. S. Dhawan did not like such a separation even while he was clear about their different roles. Science and engineering intertwine and feed each other. Building of a new improved observing equipment or instrument is an engineering activity. But it can help many new discoveries. Chandrayaan-1 is a great engineering feat of ISRO engineers and technicians and their partners from industries. It also helps first rate science. Similarly some new scientific discovery can pave way for new engineering activities. Prof S Dhawan ensured that the personnel policy of ISRO (Indian Space Research Organisation) does not create such a separation and dichotomy, as is so in many of our scientific and technology establishments. He went even to the detail of the designation of each individual professional in ISRO as Scientist/Engineer, SC, SD, SE.......G, H etc., Every one carries both the titles, irrespective of the basic degree he/she caries.

But the national science policy makers and public system in general ignored the role of engineering and somehow assumed that scientific research alone would suffice and would automatically lead to further developments in industry, agriculture etc. Results of such a negligence was clear with continued and repeated import of technology, engineering drawings and consultancy services by industry in public and private sector. Then these policy makers started using a word "Technology". "Technology Policy" since 1983 started emphasizing more on the research aspects of engineering and forgetting the crucial role of "engineering" which is the delivery of products and services to he society and people and thus growing the economy.

Around mid 1990's the word "technology" almost exclusively got "hijacked" by IT sector! Later the celebration of technology got symbolized by a high-tech event. It was, of course, a great engineering event with high intensity of scientific knowledge, important in itself for the country.

But engineering (and therefore technology) is much more inclusive and pervasive of all sectors and all walks of human endeavor. Where ever there is an actual delivery of goods and services, engineering has to come in. No wonder most of our youngsters rush for engineering degrees as in the final analysis industries or government agencies responsible for development have to deliver goods and services.

Even so, it is necessary for the country to recognize "Engineering" as a crucial discipline. Then alone a strong foundation for all round national development can take place. Present growth in the industrial and services sector is predominantly based on borrowed technologies ranging from engineering designs, drawings, know-how and above all heavy import of embodied technologies (and engineering) through import of machinery, equipment, software etc.

It is important in this context, to dwell upon some of the definitions of technology, science and engineering etc., and understand the distinctions as well.

Thereafter, we will briefly describe two major engineering challenges given by Prof. S Dhawan in one of his later speeches. After that we will touch upon a mega-challenge for the country, the people, society and the economy as a whole, which needs immediate, attention by the engineering community.

WHAT IS SCIENCE, ENGINEERING AND TECHNOLOGY?

And how they relate to economy society and people? Also how they are interlinked? It is better to see a few quotes from the address Sir David Davies. (Sir David Davies, "Engineering as an Innovator of change in Society and the Role of Engineering Academies", address by Sir David Davies, CBE, F Eng. FRS, Chief Adviser to the Ministry of Defence, UK and President, the Royal Academy of Engineering, at the annual

Function of the Indian National Academy of Engineering (INAE). New Delhi, December 3, 1998).

About Science: "Science is unquestionably a search for a better understanding of the laws of nature described in the broadest possible sense from astronomy to medicine and from engineering to genetics. Despite massive steps forward in each field, the understanding always remains incomplete...."

About Engineering: "Engineering on the other hand is about innovation, design and the construction of new products and new capabilities. We must take care not to define this solely in terms of physical products since engineering can also often offer new services often without the need for additional hardware...". However, whatever the form of the new innovation its design is inevitably a compromise between many different parameters. The success of the products is therefore bound up with the efficiency of the design process which has the role of matching the design to the requirements in as efficient a way as possible...".

What is Innovation?: "In terms of an engineering product or service an innovation enables it to offer some new advantage in capability or performance (including cost) that there is a strong coupling between engineering and science but this does not necessarily mean that this engineering innovation derives directly from the latest improvements or understanding in scientific theories...".

An example: "Perhaps the most obvious example here is the steam engine. That innovation arose from experimental observation but is was not based upon any current understanding a theory of heat at the time. Indeed the whole subject of thermodynamics was developed afterwards. It provided better understanding of the performance of heat engines and was further evolved in order to aid the design of improved equipment".

For Sir David Davies the word technology and engineering are synonymous. In the later part of his talk he has discussed the role of Engineering Academies (I would place the Institution of Engineers also as one, though it may not have been very active in terms of new and innovative engineering aspects recently). He points out that for the implementation of most of the Government policies for various social and economic sectors the strong link required is engineering (technology). Policies have to link to engineering aspects in the implementation. He has implied that without such strong links most policy statements may not achieve the stated goals.

You may judge for yourselves what has happened in India over the past six decades and why the Indian performance lags seriously behind the policy and programme statements.

Another quote about the definition of technology and technology policy by Lewis M. Branscomb, Empowering technology: implementing a US strategy edited by LMB, 1993, MIT Press emphasizes this point again: "A technology is the aggregation of capabilities, facilities, skills, knowledge, and organization required to successfully create a useful service or product. Technology policy concerns the public means for nurturing those capabilities and optimizing their applications in the service of national goals and the public interest".

The word technology here encompasses engineering and the processes of engineering.

The boundaries which distinguish technology (engineering) policy from economic and industrial policy are fuzzy at best. It is therefore necessary for Engineers and Engineering Academies or Institutions not to be quiet spectators or mere implementers of policies done elsewhere but to be proactive shapers of various socio-economic-trade and industrial policies. I have elaborated in detail the interplay of these policies in my book "Empowering Indians with economic, business, and technology strengths for the 21st century" (2001, revised print 2002).

It is with this spirit and a special appeal, I outline there major tasks which the Engineering community can give attention to. To be sure India needs many more such mega engineering tasks but I give these three important ones as illustrations due to limitations of time. One of these tasks is for medium term; second is for very very long term (these two are drawn from Prof. S Dhawan's address "Whither Space and Astronautics," delivered at the Astronautical Society of India Bangalore, September 6,1996) and the third one is for immediate action and just now (already too late!) type of attention and implementation.

MEGA TASK ONE

The National Early Warning and Response System (NEWARS) This useful and grand idea was proposed by Prof Satish Dhawan about 14 years ago and he was passionate about it. Being an engineer and par excellence programme manager he built the system (programme) design around the existing and proven systems established by ISRO especially the National Natural Resources Management System (NNRMS) and Indian National Satellites (INSAT) system, though the scale, scope and complexity of NEWARS will be much greater. In his words as in the address quoted earlier "Consolidation, extension and systematic utilization of what has been accomplished in the last 15 years of NNRMS and INSAT locally leads to NEWARS - a Space Based Early Warning and Response System which would collect timely information on all major aspects of national life which have a strong coupling with and depend upon protection and effective use of natural and organized human resources. The system goes well beyond information collection and dissemination and seeks to feed and nurture not only organized sectors of public life but also create awareness, initiative and action among wide sections of rural and urban India".

He explains in detail how NEWARS can develop without seeking to displace the existing systems and tune them into a comprehensive network in stages.

While the current systems are useful and really touch the lives of people in many beneficial ways, there are still many gaps in giving early warning/alerts which can reach village groupings or urban areas, in providing real time monitoring as well as in receiving the (ultimate) user feedback on issues concerning their lives.

The main areas to be covered by NEWARS include:

- Agriculture
- Geology
- Plants & Forests
- Soils
- Industry & Mining
- Ecology & environment
- Urbanization
- Transport & Energy sectors etc.,

Note : etc., etc., which is from his lecture.

In addition to several useful early warnings and post event information such as crop stress, water/moisture availability, pest formation, crop yield forecast, post harvest crop yield estimates etc., in "Agriculture" sector: and similarly for other items listed above, he envisaged the following benefits as well:

"NEWARS encompass all the above elements and one can envisage in addition during the course of growth

Smuggling – Land & Sea	-	Loss to the economy
	-	Distress to fisher & farm folk
	-	Illegal intrusions into Indian Territory
Large Scale community gatherings	-	Pilgrimage areas (Oct 29, 1995)
Amarnath-Sabarimalai-Kurukshetra 10 lakh persons Holy Dip-Sravanabelagola	-	A million visit Sabarimalai
Holy fairs of Sangams	-	Accidents, illness etc.,
Population migrations	-	Bangladesh displaced. Biharis driven towards Delhi
Large scale Epidemics	-	Induced by Natural/Man made disasters/ Spread of VIRUS etc.,
Insurgency & Terrorists	-	Disruptive of Civil life
& National Security	-	India's borders and within the country."

He points out the crucial element of NEWARS as: "It is in the transformation of the acquired data/information into a variety of practically useful forms that the challenge lies".

Look at the huge engineering challenge before us. NEWARS is something that can be executed in about 3 decades if several private and public sector institutions industries and NGOs join together. Engineering community can take the lead, as NEWARS can help make most engineering efforts environment friendly and people friendly. And also help a true democratic participation in development and growth. Would persons from Bangalore chapter of Institution of Engineers like to take the lead along with institutions and industries here as well as with the help of state of Karnataka and ISRO? No doubt government money is required for building up the system and maintaining it. But if creative administrative and financial policies and procedures are adopted, it is possible to intertwine very effectively private commercial operators as well along with some user fees for some sectors. Such a government-private-public participation will reduce the government budgetary support.

I leave it here and go to another great engineering challenge "larger in scope, scale and time frame requiring participation in international multi disciplinary research with the inevitable geopolitics and uncertainties" that is in the next section.

MEGA TASK TWO

PLANETARY ENGINEERING

Basically he has described the following elements:

"First some definitions:

Ecopoleses – A term coined by R Haynes from the Greek (The words Greek root means the making of a home) it implies the fabrication of an ecosystem or biosphere on a lifeless plant.

Planetary Engineering - Implies application of engineering and scientific principles to planets to change them to suit human purposes.

Terra Forming - implies creation of an Aerobic Biosphere on another planet, suitable for humans and higher animals – in effect a second inhabitable Earth"

Prof. Dhawan also cautions as in the following:

"Before briefly seeing what would be involved in Planetary Engineering we note that serious ethical questions have been raised:

a) Is it morally justified for man to change the climate & environment of another planet?

b) If life exists on the planet has man the right to modify the ecosystem to suit humans? This may harm the life forms there/a problem man has encountered on Earth & is yet to fully understand & solve

C) If no life exists on the planet is it right to change the conditions to suit earth based life?"

He has then described in detail as to what is involved in transforming a planet and given an example for performing such a mission for Mars. He has posed a number questions from an engineering and project management view points.

This engineering mission is ridden with intellectual and aspirational challenges which you can all carry with you and transmit to subsequent generations.

I would like end this section with a quote from the end part of Prof S Dhawan's address:

"One may ask: can the advent into space provide a moral and practical substitute for WAR? War between people and also Man's war on the ECO SYSTEM? can exploring the Solar System fulfill a psychological need & also unify Mankind?

Civilizations have for long sought answers to problems of existence. In the last half a century it has slowly dawned on mankind that of the great variety of life forms on the earth, one of them Homosapiens- has reached a stage when its actions are endangering the Globe. The Skeptics asks: What is the moral justification for exploring the Planets & Stars when there is so much Hunger, misery, Poverty & Strife on earth? The optimist says: Programmes which focus on space and encounter complex issues of survival in a hostile environment, facing unexpected dangers &situations & overcoming them – enhance Man's capability to faced the unknown & survive as a truly civilized being.

Collectively can mankind enhance its capabilities to evolve a civilization on earth which is more humane, sensitive and harmonious not only to humans but to all forms of life? If yes, then we go into space to understand & resolve problems of life on earth.

JOURNEYS IN ~~PLACE~~ SPACE & TIME are SYMBIOTIC with MATTER, MIND AND VALUES - the MESSAGE OF THE VEDAS"

After describing these two Mega tasks derived from Prof. Satish Dhawan's address, I would like to emphasize that the first one NEWARS is with us and we can develop it at a pace desired by all of us. It will be immensely useful in taking the benefits science, technology, engineering and other knowledge systems directly to the people of India. It is a great engineering challenge. It comprises mostly known elements and nearly proven elements. The challenge is to put them together.

Now I would describe the third Mega task which is crucial for our economy, society and people. It is an item needed by all. It is something fully in the domain of engineering except for policy making on some aspects.

MEGA TASK THREE

WATER FOR THE NATION AND PEOPLE

We have all heard an old saying: "Water water everywhere but no water to drink". Most of us are familiar with the news of flooding and resultant damages in many parts of our country about two times in per year. We also read reports about severe water shortage for many crops. In the cities including metros we have continuous year round flow of large sewage systems even while there is a drinking water shortage in almost all cities.

Science, technology, engineering and academic institutions have neglected a holistic look at the solutions to the water problem. Most of the media with some exceptions would like to highlight only scenarios water wars, or flood or drought or drying lakes or pollution by industries or romantic solutions of rain water harvesting or issues of water rights etc. We get excited at the news of finding some water on Moon! Very little attention has gone in terms of available engineering solutions in terms of maximizing efficiency in the use of water, conserving existing water resources, recycling the waste water for repeated reuse and above all continual maintenance of water related engineering systems which is crucial for the sustainability. The latter requires a lot of awareness and training of the users – ordinary citizens to households to farmers to industry persons, as well.

In order to have a clear perspective of the dimensions of the issues relating to water, true to the scientific and engineering traditions, let us look at some numbers. I have drawn them primarily from two excellent reports / books.

i. Integrated Water Resource Development – A Plan for Action, Report of The National Commission for Integrated Water Resources Development, Government of India, Ministry of Water Resources, New Delhi, September, 1999

ii. State of the Indian Farmer, A Millennium Study, Volume 3, Water Resources, K.V.Raju, A.Narayanamoorthy, Govind Gopakumar, H.K.Amarnath Ministry of Agriculture – Government of India (2004), New Delhi.

Major sources of water are rain, and surface water supplemented by ground water. Some data on them are as under. (From Report (i) above)

(a) All India average rainfall is 1,170 mm, but it varies respectively from 100 to 11,000 mm in Western deserts to North Eastern region. More than 50 percent of precipitation takes place in about 15 days and less than 100 hours altogether in a year. The rainy days may be only about five in deserts to 150 in the North East.

(b) Average annual precipitation in India including snowfall has been estimated as 4,000 km³. We have estimated the total annual water resources of the country (including both surface water and ground water) as 1,953 km³. Some of this originate beyond our borders, and in turn some of it cross our borders on its way to the sea and goes into downstream countries.

Another Factor in terms of per Capita Utilization:

India, which has 2.45 percent of the world's land resources, has roughly 4 percent of the world's fresh water resources, whereas the country's population is 16 percent of the world's population.

Total availability as per Report (i) above is:

"It has been estimated by this commission that as against a total annual availability of 1,953 km³ (inclusive of 432 km³ of groundwater), approximately 690 km³ of surface water and 396km³ from groundwater resources, making a total of 1,086 km³, can be put to use. So far, a quantum of about 600 km³ only out of this available water, has been put to use. However, pollution problems have been growing, posing a serious threat to availability for use. Municipal sewage (often untreated), urban and rural wastes, industrial effluents, chemical fertilizers and pesticides, have all contributed to the pollution of both surface water and groundwater. At the same time, the demand for water will grow with population growth and the processes of economic development. It has been estimated that the available supplies on certain premises will be matched if not exceeded by demand by the year 2050. Water – stress conditions will be experienced in many parts of the country unless remedial measures are taken in time."

There are some marginal differences of number between the two reports.

From report (ii) let us look at the sectoral utilization of the water. Of the 180Mham of surface run – off, 15Mham is stored in reservoirs and various tanks: The loss due to evaporation is about 40% in shallow storage places and 20% in deep reservoirs (on the whole about 5Mham is lost). About 15Mham of the river flow is utilized directly or by pumping. Remaining 150Mham flows into sea or adjoining countries. Ground water resources that are periodically replenished amount to 67Mham of which 13Mham are utilized for various sectors.

Of the total utilization of water resources (described above) amount to 38Mham of this.

- 35Mham goes for irrigation (11Mham from ground water and 24Mham from surface water)
- 3Mham are utilized for other purposes, predominantly domestic, industries, and power generation.

There are variations in these estimates see table below from the Report (ii), (Units Mham)

Year	Domestic	Irrigation	Industries	Miscellaneous	Total	Source
1985	1.7	47	1.3	4.1	54.1	CWC, 1995
1990	2.5	49.3	3.4	-	55.2	Reddy, 1992
1995	3.3	63	3.3	5.4	75	CWC, 2000
1998	4.4	52	5.7	4.1	66.2	CWC, 2000

One thing is clear even amid these variations. Irrigation is the bulk user. Domestic and industrial uses are almost equal.

Intersectoral projection of water demand for coming years from Report (ii) is in table below. Units of water in km³.

Projections	Domestic	Agricultural	Industrial	Misc.	Total
2010					
NCIWRDP	48	557	51.1	54	710.1
World Bank	-	-	-	-	-
IWMI	-	-	-	-	-
2025					
NCIWRDP	67	611	100.1	70	848.1
World Bank	52	770	228	NA	1050
IWMI	39.6	525	33.4	NA	598
2050					
NCIWRDP	117	807	150.2	111	1185.2
World Bank	-	-	-	-	-
IWMI	-	-	-	-	-

Source: MoWR, 1999a; World Bank; Seckler et al., 1998.

Having looked at some of the above macro – data let us look at the percentage of the Net irrigated area to Net sown area taken from Report (ii)

Size Class	1970–71	1975–76	1980–81	1985–86	1990–91	ACGR (%)
Marginal (< 1 ha)	33.8	37.5	40.2	42.8	43.6	1.28
Small (1-2 ha)	27.9	30.6	32.7	34.3	35.7	1.24
Semi-Medium (2-4ha)	25.2	26.6	29.3	30.7	32.8	1.33
Medium (4-10 ha)	20.4	20.3	24.2	26.1	29.7	1.90
Large (> 10 ha)	13.0	12.4	16.3	18.8	22.5	2.78
All Size Class	21.4	23.2	26.9	29.4	32.6	2.13
CV	32.64	37.74	31.46	29.38	23.61	

It shows the continuing gross inequity in use of water for agricultural use. No wonder most Indian farmers are abysmally poor and therefore India is poor (since about 65% of Indian s depend upon agriculture – we need to change this figure drastically. That has been dealt with by me elsewhere and I won't talk about it here).

The total availability of water resources, per capita possibility etc indicate the challenge to eradicate this inequity and make available good irrigation (i.e. enough water to the plants at right times) is not expansion as usual but it is an engineering challenge. Engineers have to work with agricultural experts and local communities to make them learn and use water saving systems, use the recycled water, maintain the facilities, and to keep a vigil on new polluting sources and give solutions for them, etc.

It is difficult to cover comprehensively all aspects of engineering / technology / project management tasks required for this Mega Task – 3. If one considers locale specific aspects then the complexity becomes more. For example water conservation aspects relating to agriculture in Punjab will be different from that required for Rajasthan. Hence the engineering considerations will be different. So with different sectors and sizes of industries etc. Therefore we will attempt to have a broad profile of various critical aspects of this Mega Task – 3 on Water. Engineering professionals can expand on these elements when they actually get into action mode.

AVAILABILITY OF WATER:

As discussed earlier the source can be from static surface water, flowing surface water (run off, rivers, canals etc), ground water, rain water collection and recycled water.

Of the water sources, the ones which are monitored well are the 81 major reservoirs; as of the first week of September 2010, the water in these 81 reservoirs was about 103 billion m^3 (32% more than last year). A good news for the Ministry of Power as the hydroelectric power will be good this year. Some places may have threat of flooding, when the reservoirs cross danger levels!

But when we consider the water sources for most of India monitoring these 81 is not enough. One needs monitoring of river flows and importantly many small – medium – large lakes. On paper we have a system in the country. Many of you will know the inadequacy.

A project to have a regular monitoring of surface water, their quantity and quality will be a great engineering challenge. One element of NEWARS described earlier can help putting such a system into operation. A combination of remote sensing and data collection platforms which can be accessed by local mobile telephones or by satellites, can form an effective monitoring system. Such a data available on a national portal can be of great help. I am not unaware of security concerns that can be raised by some persons. In the current period with high resolution satellite imagery available globally and mobile phones which can take pictures and transmit globally, such worries are at best naïve or paranoid.

Well, it is not just enough to record and to monitor all of them, though it could be a first parallel step.

All the major and minor reservoirs, rivers, lakes etc require serious attention in terms of desilting. That will conserve precious water resources.

Let us not for a moment waste our attention on reducing the evaporative losses. May be in future after we finish the simpler and large quantity tasks.

An important issue in conserving the water resources is to keep them clean. Most lakes are full of algae, hyacinths and other plants if they have not dried up already. Many others become easy places to dump solid wastes or the sewage and waste water. This is so even in rural areas. Even the "lost" (due to human apathy) lakes need to be recovered, as much as possible.

Engineers in local areas (under a major project catalyzed and spearheaded by IE's several chapters in India) can very much help in this process.

Similarly one needs to monitor all the ground water usage points. With local help and modern communication (mobile, telephone and satellite) technologies, it is not a difficult task.

Then there are other areas like wetlands, marshy lands etc. they need preservation too, for ecological balance.

Rain water harvesting is another useful water source. But this needs to be done with some caution. Somehow in our country we seem to have an implicit faith in things which were used several centuries ago. While rain water harvesting is good, in the distant past we had very little human and cattle population. Also other newer technologies were not available, not even deep ground drilling.

Indiscriminate rain water harvesting in rain scarce areas may stop downstream flows and affect the ecology at a distance. (Remember how oasis in a desert gets formed). More importantly the indiscriminate decentralization of rain water harvesting to the household levels in big cities like Delhi etc. are one of the cause of spread of mosquito borne diseases. In bigger cities we need to rethink rain water collection strategies. We need to use the storm – water flow channels to aggregate in a local area and have good engineering practices to store and re-use. It is sad that in many housing layouts and also in cities, the storm water channels are being converted into sewage channels.

Again coming back to water sources, their use and reuse are vital to conserve their use. It is possible to use the existing resources to give sufficient per capita water for all Indians for various uses listed before. Let us examine some of the water use technologies.

WATER USE TECHNOLOGIES

In its simplest form, they are micro irrigation systems mostly operating in villages – often not even constructed by govt. agencies. Most of these areas belong to the unirrigated part of agricultural statistics quoted earlier.

Due to the drinking water mission, some of these areas may have a ground water hand pump – some working, some defunct. Otherwise traditional wells, small ponds etc are there. During rains they fill better especially helping the cattle. The fields of the marginal and small farmer receive rain directly and through micro – irrigation channels.

Due the costs involved, it is difficult to imagine that all these unirrigated areas are covered through good water supply and irrigation systems as in the "green revolution" areas of agriculture (about 1/3rd of the total irrigated area).

This is where the real first challenge to the Indian engineer lies. Use of modern plastic liners can reduce wasteful leakages; also drip or sprinkler systems can reduce the need for water to the minimum but capital costs can be higher; some govt. funds are available. Also single local pump systems can be used... many more ways to reach water; I am not unaware of the poor electricity supply in most areas.

In recent USAID conference titles "Transforming Development through Science, Technology and Innovation" (July 13 – 14, 2010) held at Washington D.C, for which I was a special invitee, the background papers indicated that a Grand Challenge in Development at a global level to fight against poverty is as under:

Reduction of agricultural water consumption in non – arid and semi – arid regions of Africa by 70%, with an increase in agricultural yields over 5 years.

What is told here for Africa is applicable to most parts of rain fed, unirrigated arid and semi – arid agricultural regions for India.

The engineering challenge would need work with farmers, agricultural experts, technology developers, energy source providers, NGO's etc.

I have placed it first because it affects most people of India (about 40 to 50%) and the challenge is to work with water sources available nearby and at a low cost, which can be used productively and cost effectively.

USE IN HIGH END AGRICULTURE

Major use of water is in the upper end agriculture – irrigated 1/3rd of agricultural area. (We have seen the statistics earlier). In these areas, water use is often extravagant so much so it makes the soils go saline along with the fertilizers and chemicals which float upwards. It is essential to devise engineering methods against such a water – wastage. In addition, such an agriculture which takes away almost 70% of used water in India, waste water not recycled. It is sent away from the fields along with agro – chemicals which further pollute many downstream water bodies.

It is necessary to work with farmers and local governments, convince them and have recycling plants set up near their village. Also reuse the recycled water. In Israel about 80% of water used for agriculture is recycled and used. They are increasing the percentage. In Spain it is about 35%.

A bigger sociological challenge is because water is given free or practically free to most of these farmers, who are relatively rich and influential.

I am reminded of the experience of India's greatest engineer Bharat Ratna Sir M.Visvesvaraya in the Poona Irrigation District, when he was posted in April 1899. Among many books by him and on him, I will refer to one: Memories of My Working Life (written by him 1951) published by Karnataka Engineers Association and Karnataka Engineering Service Association (2001). It has 158 pages. I am amazed at the range of water works he has done all over India (even the present areas of Pakistan)! It is a book worth reading by all engineers interested in water works. It will inspire them to go through the variety of challenges successfully. His works post retirement were huge and immense. So those who are retired or nearing retirement may look at such major possibilities around water.

USE OF VILLAGE PONDS:

Most villages in India have about two ponds. Punjab has about 13,000. Dr.R.Venkataraman former Chief Engineer, ISRO and who is a part of the fraternity of IE, had taken up a major task for advising the then Punjab Govt. (2000 – 2001) on many water related issues referred to the office of Principal Scientific Adviser (then Dr.Kalam) and TIFAC(Technology Information, Forecasting & Assessment Council). I being the chief executive of TIFAC and Scientific Secretary PSA office, had been closely associated with them. The village ponds which existed for centuries had to support about 5 times more human population and also much bigger sized cattle. Naturally the sewage and the cattle wastes find their way to the ponds. BOD (Biological Oxygen Demand) levels (we had them measured for several of them) were intolerable.

A plan for central sewage collection, recycling and reuse of water and clearing up the ponds initially etc were drawn up. It was also for reuse in agriculture. About to be launched. People supported the project and were ready to give free manual service and their land for establishing the treatment plant free of cost. (They asked us to reduce the labour cost from the Project Estimate.) Alas! The state assembly elections were announced and all new works came to a halt! Govt. changes, priorities change .... Well that is India.

But it has given us a rich experience.

It is a great engineering challenge to clean up all village ponds including use of recycled water for continued reuse on sound engineering principles and hand them over to the villagers to manage.

They will!

Their health will improve. Cattle will be better. It will be a great boost to economy, society and people in terms of income increase and quality of life.

There are several other items in terms of use of water in rural India and in agricultural sector. Due to limitations of time, let us move to urban domestic and industrial use.

URBAN DOMESTIC USERS:

When we consider the big metros, and over 5000 cities and towns, domestic water supply is a serious problem – not just in terms of quality but also in terms of regular availability. Delhi the capital city is no exception. Reasons are manifold: from poor planning to mindless designs to callous maintenance. The so called treated water to the lawns of the palacious buildings in the Lutyen Delhi, will be an illustration as to how primitive we are in waste water recycling and reuse.

In a metro city, typical use of a 5 members household would be about 20,000 litres per month. In cities and towns it will be much less. In the metros the same municipal water or the municipal water or the pumped ground water from the apartment complexes are used for cooking, bathing, toilets, house cleaning and car washing. Assuming the corporation supplied water is really of a potable standard, is it the way to waste it, when most of the city dwellers struggle for water? Now a days I find year round movement of private water supply trucks in most cities. So much is the shortage.

Now what happens to the used water? They are discharged as sewage, either in open channels or in buried pipes. There are often over flows of sewage from the buried sewage pipes, year round, through manholes.

Most households are ill-equipped to use stored rain water, as they were not originally conceived in the house design. Best use of them without treatment would be for gardens or washing outside the houses. Where in metros and cities can we find houses with lawns, plants or trees? There is a pressure for land and space, understandably due to rocketing prices of real estates.

As far the drinking water, middle class is resorting to water purifiers. Low cost purifiers have been launched by Tatas recently. Also there is an increasing resort to bottled water (costly imitation of the developed countries). For those who talk about climate change issues from the podiums studded with bottled water, I would like to quote some statistics:

- Worldwide, nearly 2.7 million tons of plastic is used to bottle water each year.
- Making plastic bottles to meet demand for bottled water requires millions of containers of oil annually.
- Burning used plastic bottles releases toxic chlorine gas in air and leaves toxic ashes containing heavy metals which pollutes the soil and ground water

Real environmental friendly solution would lie in providing a good quality potable water in the taps, if necessary by a separate plumbing line and use another plumbing line for the supply of clean recycled water for other domestic uses.

In addition the amount of leakages in domestic taps, garden taps in apartment complexes etc is a huge waste. Engineering solutions for reduction of consumption right from the time people open the tap in the morning for brushing their teeth to the time when they go to sleep, are required. Engineers may also take into account the sad fact that we Indians in general lack a civic or public good sense. Of course all solutions cannot be from engineering and technology. There has to be public education through celebrities and also through 'micro economic' measures of water charges. Of course, a government can acquire the moral right to charge more for water only when it gives regular, dependable and quality water supply: that primarily comes in the domain of engineering in terms of meticulous planning, design, foresight, quality implementation and above all maintenance which should be built into planning, design, and foresight exercises.

URBAN PUBLIC USE

In addition to domestic use, in the urban areas there is a considerable use of water in the public domain. Parks, shopping areas, hotels, restaurants, public toilets, bus stations, railway stations, places of worship etc.

What happens in a typical city has been described beautifully and professionally in a recent article in Hindu, September 11, 2010 by S.Viswanath under the title "Treating the sick water". It is worth looking at some extracts from the concluding part of the article:

"We need urgent steps to rectify this problem in urban India. Unless a vigilant citizenry demands that their local self – governments take up sewage collection and treatment on high priority we will pay through epidemics such as dengue, chikungunya and malaria, taking lives and debilitating a populace.

Islands of excellence exist. Some apartments and some layouts have very good functioning waste water treatment and reuse plants. But many are simply 'garbage-in-garbage-out' systems.

At a larger scale the wastewater treatment plants at Cubbon Park and at Lalbagh in Bangalore are almost state–of the–art and one simply cannot make out the treated wastewater as sewage.

The need of the hour is to invest enough attention in collecting every drop of sewage generated from the city, convey it to decentralized wastewater treatment plants, treat them to high standards and release or reuse them as appropriate".

Wastewater recycling and repeated reuse alone can solve the water and health problems of urban India.

At this point I would like to mention a few words about the Cubbon Park and Lalbagh in Bengaluru referred to above. The engineering expert deeply involved in these projects is Dr.R.Venkataraman former Chief Engineer ISRO. He did them post – retirement from ISRO, at Bengaluru and several plants at Hyderabad.

But the linkage to these plants was way back to his ISRO days. When Prof.Dhawan was Chairman, ISRO, the ISRO Satellite Centre (ISAC) needed (during 1984) additional water of about 0.5 MLD than allotted to them by the water supply authorities, who had released the quota for ISAC as per norms. Instead of trying to use governmental pressures (as is the usual mode we all adopt even today!) ISRO chose a method of engineering solution. Dr.Venkataraman gave the design for recycling the waste water from ISAC and the reuse was primarily for use in gardening, landscape maintenance etc. Mr.R.D.John, Chief Engineer supported it. ISRO top management agreed to the novel idea. Water use goes up as organizations grow. So it was expanded to 1 MLD during 1988, with some additional design features of secondary treatment with pressure filters, disinfection etc. To get the water source, additional sewage water from NAL (then National Aeronautics Laboratory) in whose campus ISAC was located, was obtained! The recycled water was used for several other internal uses in ISAC including toilet flushing and cooling water for central AC plant. . The plant is functioning even now. ISRO adopted such systems for a few other ISRO centres as well.

It is the outgrowth of these experiences and of course continual learning and application by Dr.R.Venkataraman, led to his building the state – of – art Lalbagh and Cubbon Park plants which are about 1.5 mld.

Many of you present here and not present here can make wonders to urban India, if you all and IE crusade for proper urban water planning: for separating storm water channels and sewage channels and more importantly by establishing several sewage / wastewater recycling plants and facilities for the repeated reuse of the water.

City should almost be self – sufficient with only about 25% of fresh water coming from surface and ground water sources and the rest coming from recycling. Not a difficult target for our capable engineers.

INDUSTRIAL USE

Many of the huge water consuming industries need to bring down their consumption. Compared to the international standards of water consumption, we are very poor in most industries. This is an urgent task.

Simultaneously wastewater recycling and reuse is a must.

Even those who cannot reuse for various reasons have to let out only the clean recycled water (either collectively – a few small medium industries together or individually). May I suggest that some of you approach the management of big industries located in and around Bangalore to help them audit their water use and also their recycling capability.

Let us not get into escapism of saying that there are pollution control boards etc. We all know the reality. As engineering professionals we should avoid the cynical acceptance of a situation for which there are sound and cost effective engineering solutions.

MAJOR USERS

If we tackle the above mentioned areas described above such as rural use, agricultural users, urban domestic users, urban public use and industries, we would have solved the immediate water problems of India and also improve health of people. And also the income levels of many rural Indians will increase, thus giving a special boost to the Indian economy. The real market size can go to 1.2 billion unlike the present one which is half of it or less as rest of them are just subsisting.

OTHER ISSUES

There are many more items, I cannot cover here. Therefore I would mention some of them. There are areas of India which have brackish water, or water with arsenic, fluoride etc. There has been a lot of talk on them, R & D papers etc. for several decades. But ground solutions are eluding. Many of you know the reasons. They require practical and urgent solutions. People living in such areas suffer.

Desalination is another area which is talked about, sometimes hyped. If waste water reuse on the lines suggested above is adopted on a large scale, pressure for desalination will not be high even for coastal cities. It may be needed in select places where other solutions may not be easily implementable. Also in terms of ecological balance including marine life, I am not sure whether a large scale resort to desalinated water from sea can be sustainable solution.

Interlinking of Rivers is another complex issue. To adopt it as a panacea is ridden with many engineering, sociological and ecological issues. Small scale interlinking locally may be attractive for a few areas.

Use of big rivers for internal Water Ways can be attractive proposition as it is very energy efficient. There is a full fledged study by TIFAC as a part of its Technology Vision 2020 exercise.

These are some of the engineering challenges. Also there are a number of areas attractive for R&D both in terms of commercial prospects as well as social good. Amongst the several pragmatic and immediate – to – implement items mentioned in this brief address, R & D in select topics will also require attention, as future new engineering ventures will emerge out of them.

In the world governed by Word Trade Organisation (WTO) regimes, engineers need to be aware of the legal issues of Intellectual Property Rights (IPR).

IN CONCLUSION: I have galloped through three mega engineering tasks for the engineering community as a whole. They will touch the lives of our people very positively and help the society in many ways. Also most of them will make good business propositions as well, thus contributing to the growth of the economy. Professional commitment and pride are crucial for these to be implemented. May the dreams and actions of Sir M. Visvesvaraya (whose 150th birth anniversary falls this month) and the visionary and practical wisdom of Prof.S. Dhawan (whose 90th birth anniversary falls this month – a unique September) be our guiding lights and inspiring forces.

Engineers have to wake up and jump out of their routine grooves to create a positive dynamism all rounds.

Thank you.

Some units used relating to volume of Water:

1. 1 Cubic Metre equal to 35.315 cubic feet; 1 Kilolitre; 1000 litres
2. 1 Hectare metre (ha m) equal to 8.10 Acre ft; 10,000 Cubic metre
3. 1 Cubic Metre equal to 1 Billion Cubic Meter (BCM); 109 m3; 0.1 million ham (M ham)

22.09.2010

***Y.S.Rajan** is Dr.Vikram Sarabhai Distinguished Professor, ISRO, Bangalore. Views are personal.*
E-mail Id: ysrajan1944@gmail.com Visit website www.ysrsjan.com

Key Current Positions of Prof. Y.S. Rajan:

- Dr Vikram Sarabhai Distinguished Professor at ISRO Headquarters
- Member of the Court of Jawaharlal Nehru University
- Adjunct Professor, Birla Institute of Technology & Science (BITS), Pilani, India, an internationally reputed institution
- Vice President, All India Dayanand Anglo-Vedic (DAV) College Managing Committee, a network of high quality schools (615) and colleges (60) throughout India
- Member Senate, BITS, Pilani and Adjunct Professor
- Vice President, Forum for Global Knowledge Sharing [http://knowledgeforum.tifac.org.in]
- Member, Executive Council, Doon University
- Member, Academic Council, Guru Ghasidas Vishwavidyalaya
- Advisory role and Membership of Apex Boards or Councils for several other Institutions

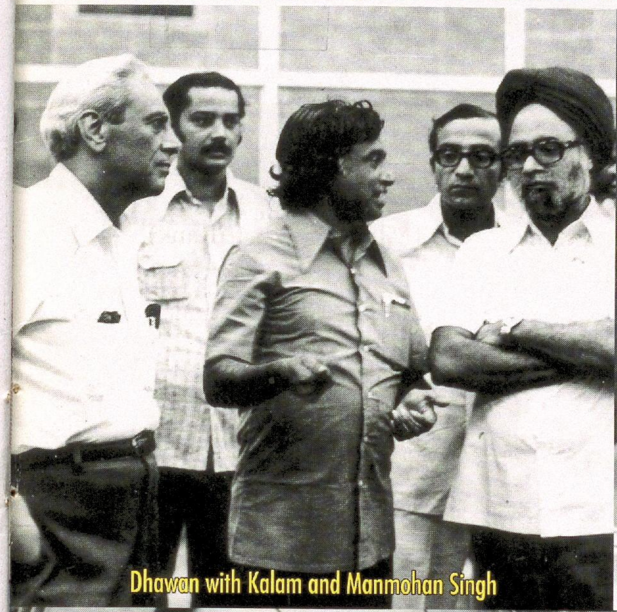
Key Academic Qualifications and Professional Affiliations:

- Masters in Physics from Bombay University (1964), a top Ranker
- Doctor of Letters (Honoris Causa) had been conferred by Jain Vishva Bharati Institute in recognition of dedication to humanity, human values, creativity and literature in the presence of H.E. the President of India on 20 October 2005.
- Life time fellow of Indian National Academy of Engineers, an Apex Academy since 1998.
- Life time elected member of International Astronautical Academy, Paris since 1986.
- Member of International Law Association, Indian Chapter.

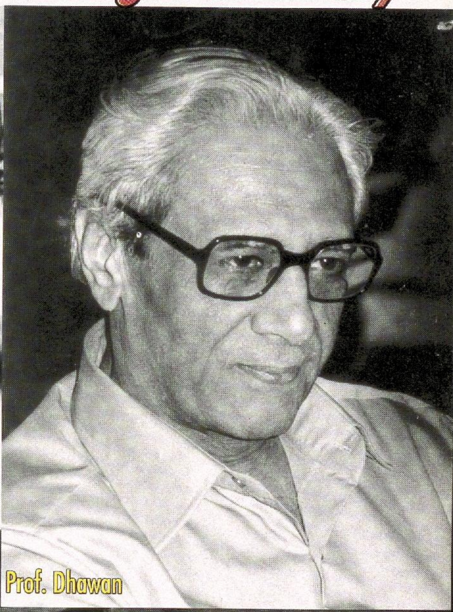
Positions held by Dr. Y.S. Rajan Earlier:

- Principal Adviser, Confederation of Indian Industry (CII) (2004-2010)
- Chairman, Nalanda Board
- Scientific Adviser to Punjab Chief Minister (Minister of State Rank) from Oct 2002 to March 2004.
- Vice Chancellor & Chairman, Board of Governors, Punjab Technical University (PTU) from Oct 2002 – Feb 2004).
- (Founder) Executive Director TIFAC (Technology Information, Forecasting and Assessment Council) from July 1988 to November 2002. India Vision 2020 and many other Missions came from this Institution.
- Scientific Secretary to Principal Scientific Adviser to GoI (Secretary to Govt of India level post) from March 2000 to Oct 2002, Member – Secretary Scientific Advisory Committee to Cabinet etc.
- Senior Adviser (Technology), CII from Sept 1996 to March 2000.
- Advisor, Dept of Science & Technology (DST), Govt of India (Addl Secretary level position), from July 1988 – Sept 1996.
- Scientific Secretary, ISRO from 1976 to 1988.
- Director, Earth Observation Systems & several other senior positions in ISRO till 1988.
- Secretary, NNRMS (National Natural Resources Management systems) - Founder Chief Executive Officer) from 1983 to 1988.
- Responsible for programme management at senior corporate headquarter level for many projects of ISRO like SITE, SLV-3, Aryabhata, Insat, IRS, PSLV decade profiles in ISRO etc. from 1970 to 1988.
- ISRO Engineer at NASA ATS – F Project Goddand Space Flight Centre (USA) from 1970 to 1973.
- Member, ISRO – MIT Study on INSAT 1970.
- Development Engineer IN COSPAR/ISRO from 1966 to 1970.
- Research Scholar at Physical Research Laboratory, Ahmedabad from 1964 to 1966.

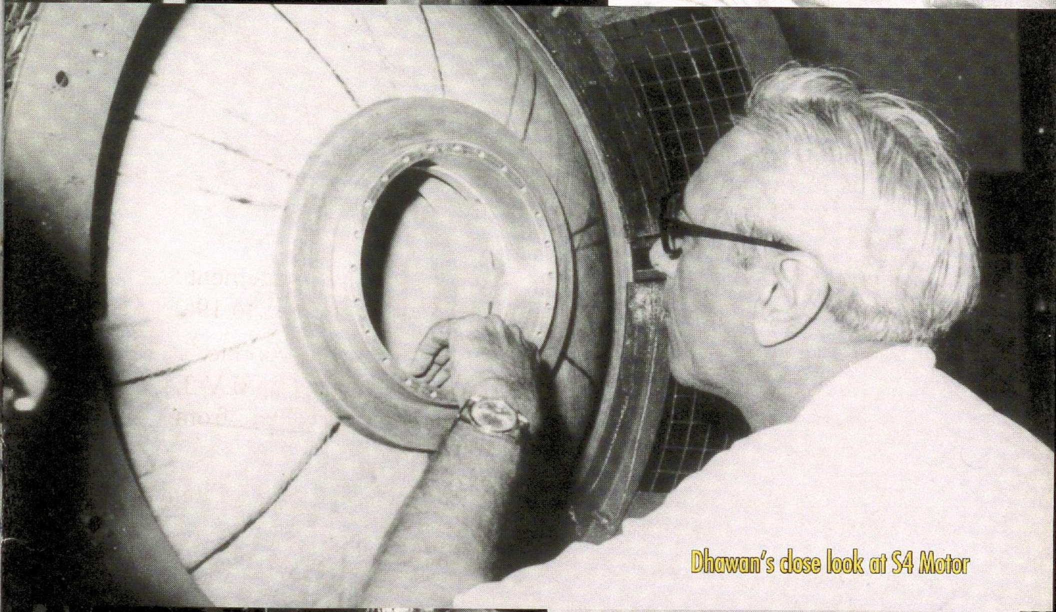
Prof. Satish Dhawan from the Pages of History



Dhawan with Kalam and Manmohan Singh



Prof. Dhawan

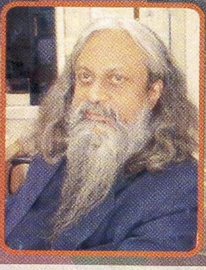


Dhawan's close look at S4 Motor

Dhawan with Manmohan Singh

Dhawan + 560

Prof. Y.S. Rajan
Dr. Vikram Sarabhai Distinguished Professor
Indian Space Research Organisation
Bangalore



Prof. Y.S. Rajan has a proven track record of excellence as a Scientist, Technologist, Administrator, Organisation Builder and Leader, Diplomat, Academic, Writer and Poet. He combines a unique ability for original and innovative thinking with strong implementation skills. He has capability to network with multi–disciplinary and multi–cultural groups.

He has made key contributions to space research, technology and applications since 1964 and continues to be an important expert on space matters. As Scientific Secretary, Indian Space Research Organisation (ISRO), he was responsible for a combination of scientific, technical, administrative, planning, policy and international cooperation matters. His contributions in shaping ISRO from its initial experimental phases into a major service delivery organisation have been remarkable. In the process, he has also been a creator of many institutions and sustainable mechanisms between ISRO and its end-users. He has worked with Massachusetts Institute of Technology (MIT), USA and NASA for about three years.

He is also a well recognised authority and thought leader on technology development, business management and society linkages. While holding various positions of responsibility related to science and technology (S&T) between 1988 and .2002, he has shaped key policies and implemented several successful R&D projects with industry participation. He has been responsible for creating a series of documents related to Technology Vision 2020 for India, which culminated in a book on a roadmap for socio-economic development for India called "India Vision 2020". He has practical ground level experience in developmental issues and has founded and built organizations like Technology Information Forecasting and Assessment Council (TIFAC), which he has led for about two decades. These organizations have helped to bring relevant technologies to improve productivity for the agricultural, manufacturing and service sectors.

After a 30 year stint with the Government of India (GOI), he joined the leading industry association In India, Confederation of India Industry (CII) in 1996. As Principal Adviser (2004-2010) he created unique mechanism at CII for University-Industry collaboration.

He has wide international experience and was responsible for a large number of cooperative projects between India and other countries. He has led Indian delegations to United Nations (UN) and has visited about 40 countries in all continents as a part of cooperative efforts in science, technology and business. He is an expert in environmentally sound technologies, satellite meteorology, remote sensing, mapping systems and Intellectual Property Rights (IPR) related matters.

His engagement with academic world began since 1976 and over a decade was responsible for funding basic research and introducing courses relating to space science and technology in several institutions. He was visiting professor in Anna University for four years (1984–88). As Vice-Chancellor, Punjab Technical University (PTU), he introduced key initiatives to improve the internal processes and the external interfaces of the university. He continues to be visiting faculty, board member and advisor to various renowned Indian academic institutions.

He is also a prolific writer and has written on a variety of subjects, including on science, technology, business, youth, leadership, social and ethical issues. He has written seven books of poetry in Tamil, which has been critically acclaimed by eminent Indian poets. He has also written three books of English poems which have received very good reviews.

THE HINDU

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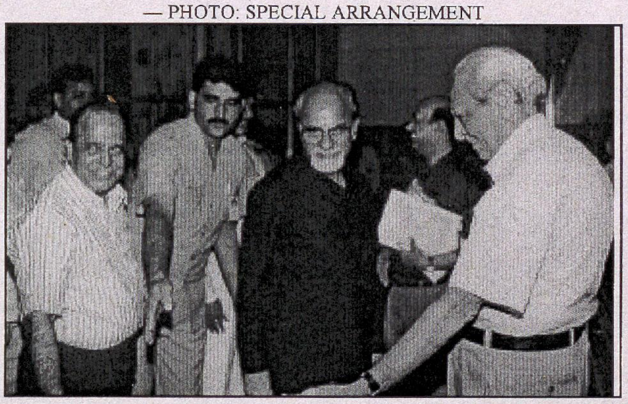
Opinion - News Analysis

Satish Dhawan — the gentle colossus

P.V. Manoranjan Rao

Today is the 89th birth anniversary of Satish Dhawan who lent substance to Vikram Sarabhai's vision and built the Indian Space Research Organisation into a vibrant body.

— PHOTO: SPECIAL ARRANGEMENT



***HISTORIC:* Satish Dhawan (extreme right) with the former Prime Minister, I.K.Gujral. Also in the picture are U.R. Rao (second from right) and K. Kasturirangan (extreme left), both of whom later headed the space programme.**

The recent launch of Chandrayaan-1 has inspired many young people and given the nation a sense of justifiable pride in the achievements of the Indian space programme. Amidst the euphoria surrounding such glamorous events, let us recall the gentle colossus who made it all possible — Professor Satish Dhawan. Though Vikram Sarabhai was the visionary, it was Dhawan who lent substance to this vision and built the Indian Space Research Organisation (ISRO) into the vibrant body that it is today.

One of the first and possibly the most important things that Dhawan did was to bring Brahm Prakash from the Department of Atomic Energy to head the newly-formed Vikram Sarabhai Space Centre (VSSC) at Trivandrum (now Thiruvananthapuram). At that time, activities at VSSC were fragmented, with different groups working independently on a variety of problems and projects — some of them even competing with each other. Brahm Prakash restructured and welded these amorphous entities into a dynamic structure capable of producing results time and time again. Working in tandem, Dhawan and Brahm Prakash created one of the great technology centres of modern India. VSSC became the birthplace of many subsequent ISRO centres and activities. It was the same Dhawan-Brahm Prakash duo that picked A.P.J. Abdul Kalam to lead the project that developed SLV-3, India's first launch vehicle, and U.R. Rao to head the team that made the country's first satellite, Aryabhata. When the SLV-3 put a small 40-kg Rohini satellite into orbit in 1980, India truly entered the space age.

Soon after he took over, Dhawan realised that for ISRO to grow and to deliver on its potential, it was necessary to restructure its links with the government. Against great opposition, he brought ISRO under the Government and created the Department of Space. He also realised that a different structure for the functioning of this new department was necessary. The creation of the Space Commission, a separate book of financial powers and a direct link to the Prime Minister were the specific mechanisms through which Dhawan sought to address the challenges that ISRO faced. The practice of combining the offices of Chairman of ISRO, Chairman of the Space Commission and Secretary for the Department of Space in one person also ensured seamless integration between conceptualisation and funding of programmes with delivery of technologies, launchers, satellites and applications. The setting up of ISRO Headquarters, staffed by young, bright and dedicated professionals hand-picked by Dhawan himself, completed the process of linking ISRO programmes and projects with decision-makers and sources of funds. This particular architecture that Dhawan designed was original and innovative. ISRO's continuing success is visible proof of the robustness of this design.

Under the leadership of Dhawan and Brahm Prakash, ISRO pioneered a new way of managing complex projects. In this system, the project director presided over a small team of experts whose job it was to coordinate and channelise efforts of independent R&D groups towards realising a common goal, be it a launch vehicle or a satellite. Dhawan also ensured total transparency in project management by involving leading professionals from outside ISRO in the technical reviews of its projects.

From the beginning, Dhawan insisted on a significant role for indigenous industry in the projects of ISRO. Today, hundreds of industrial units, both in the public and private sectors, manufacture a wide range of space-quality hardware for ISRO.

The early days saw many failures. Through all those difficult times, Dhawan never lost faith in ISRO's capabilities. He took personal responsibility for failure but when success came, he always attributed it to ISRO and his colleagues. Thus, when the first flight of SLV-3 in 1979 failed, Dhawan faced the press. When the second flight succeeded, Dhawan kept himself in the background while Kalam spoke to the press. With this kind of leadership, engineers and scientists in ISRO were never afraid to face honest failures.

As ISRO's capabilities matured and grew, Dhawan felt the need for a stronger link between the programmes and the development needs of the country. The operational Indian National Satellite (INSAT) and Indian Remote Sensing Satellite (IRS) systems were therefore designed jointly with the users. If the user agency was not clear about what it wanted, a programme of joint experiments and studies ensured that the agency's requirements were defined as clearly as possible so that the technology and its use were closely coupled. Most of what ISRO does so well today – the IRS and INSAT satellites with their associated Polar Satellite Launch Vehicle (PSLV) and Geostationary Satellite Launch Vehicle (GSLV) systems — are outcomes of these carefully thought out processes.

Handsome and elegant in appearance but simple in nature, Dhawan never seemed to realise the impact his personality had on others. He respected and worked closely with workers and technicians in the pursuit of his research interests. Many of them reciprocated his feelings by adoring him and by doing whatever he wanted them to do.

He had a great interest in issues of war and peace, and the role that science and technology could play in resolving conflicts between nations. At ISRO, he set up one of the earliest think tanks in the country to deal with such issues.

Dhawan took an occasional break from the high-tech business of space to study the flight of birds. The Pulicat Lake, Nelapetu and other bird sanctuaries near ISRO's Sriharikota Range were his natural laboratories. The result was a classic monograph called 'Bird Flight'. In the preface, Dhawan wrote : "I lay little claim to originality and acknowledge my debt to the many distinguished researchers on animal flight who have made the subject a new branch of science. I am no less indebted to the birds…" Many of the drawings of birds that appear in this monograph were sketched by Dhawan himself.

Dhawan loved teaching and research. He often said that he spent his most productive years at the Indian Institute of Science (IISc), Bangalore. He always modestly described himself as a teacher and said that the IISc was his first and greatest love. In an interview he gave a few months before he passed away, he was asked about the origins of all the organisational and managerial knowledge that he had used so effectively in ISRO. His reply was that he had learned everything at the IISc. In his eighteen year tenure as director, Dhawan transformed the institution, slowly replacing a feudal academic structure with a modern, democratic departmental system. His idealism and commitment influenced his colleagues in substantial measure. He also brought in fresh blood and set about creating new areas of multidisciplinary research.

What sort of a person was Dhawan? "If I have to choose one word that would define his personality, it would be integrity," wrote Yash Pal, former chairman of the University Grants Commission. This is how Abdul Kalam and Roddam Narasimha, former director of the National Aerospace Laboratories in Bangalore, sum him up: "Professor Dhawan in his professional career has been engineer, teacher, research scientist, technologist, manager, leader and adviser — often all at the same time! His great human qualities, combining intense personal charm with a deep commitment to social values and an extraordinary objectivity in management, have led several generations of students, colleagues and administrators to efforts that they would otherwise not have taken."

Today, the 25th of September, is Dhawan's 89th birth anniversary. It is nearly seven years since he passed away. It is only proper that we remember him and the values he stood for.

There is perhaps no better description of him than what Shakespeare wrote:

"His life was gentle, and the elements

So mix'd in him that Nature might stand up

And say to all the world "this was a man!"

(P.V. Manoranjan Rao was a scientist at the Vikram Sarabhai Space Centre for many years.)

S K SAHNI
Executive Secretary

ML
ACTION
Enuf -

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No. PB-BM-146/ 990
Dated: 29th Dec., 2004

Sub: Biographical Memoir on Late Prof. Satish Dhawan
Specialization: Aerospace Engineering, Fluid Mechanics, Atmospheric Sciences

Dear Professor Rajan,

In its endeavour to preserve for posterity the memoirs of the inspiring lives and achievements of scientists, the Indian National Science Academy publishes the Biographical Memoirs of its deceased Fellows. Twenty-four volumes have already been published and the Current Volume No. 25 covers the memoirs of many deceased Fellows who had specialized in Physical Sciences like Mathematics, Statistics, Physics, Chemical Sciences, Earth Sciences & Engineering & Technology.

We take the privilege of approaching you for writing a Biographical Memoir on Late **Prof. Satish Dhawan** either by yourself or by any other scientist who had been closely associated with his/her scientific contributions. The memoir may be prepared broadly covering the following points:-

(a) Family Background & Early Education (Personal Life, Date & Place of Birth, Death; Marital Status/Number of Children etc); (b) Professional Career; (c) Scientific Contributions; (d) Membership, Awards & Honours & Association with National & International Societies; (e) Extra Curricular Activities; (f) Last Days; (g) Acknowledgement & (h) Bibliography arranged chronologically.

A good photograph and a specimen signature of the Fellow are to accompany the memoir which can run up to 20 pages in A4 size neatly typed in double space preferably within a period of **Four Months** along with a detailed bibliography of the works of the Fellow in Floppy form (MS Word). The memoir should be concisely written by avoiding the shortcomings and redundancies however highlighting the scientific knowledge, interesting experiences and wonderful events occurred in the life of deceased scientist.

The Academy will be happy to provide **honorarium** up to a maximum of **Rs. 5,000/-** to the author to meet the incidental expenses like stationery and typing for preparing the memoir. In case you are unable to write the memoir for any reason, we need your help to suggest suitable persons who are closely associated with the Fellow and who could be approached for authorship for writing this memoir.

We shall very much appreciate if you will kindly acknowledge this letter and soon write to us as regards your confirmation in taking up this noble task. On receipt of your confirmation, we will send a sample copy of the printed memoir for your guidance.

With the best wishes and warm regards:

Yours sincerely,
Sd/-
(S K Sahni)

Professor Y S Rajan,
Principal Advisor
CII, Sector 18, Udyog Vihar
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Gurgaon (Haryana)

1) Photo
2) Specimen Sign
? Satish Dhawan
T 5.1.05

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PB-BM-146
Dated:29th Dec. 2004

Sub: Biographical Memoir on Late Prof. Satish Dhawan
Specialization: Aerospace Engineering, Fluid Mechanics, Atmospheric Sciences

Dear Sir,

Thank you very much for agreeing to write the above Biographical Memoir. As advised by our Editor Prof. V Ramamurti, I am happy to enclose herewith the sample printed memoir for your guidance and style-sheet purpose which I think may be useful to you for the preparation of the memoir.

If you need any more assistance, please do not hesitate to write to us.

With warm regards,

Yours sincerely,
M Ranganathan
(M. Ranganathan) 29.12
Section Officer

Professor Y S Rajan
Principal Advisor
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NB: Our ES may write to you soon and send formal letter as he is out of Stn. today.

M Rang
29.12

Sample copy

VISHNU MADHAV GHATAGE

(1908-1991)

Elected Fellow 1950

VISHNU MADHAV GHATAGE passed away on 6 December 1991. He was truly the first, and perhaps for some time to come, the last, great aeronautical design engineer that India has produced. Another doyen of aeronautical science, the late Professor KAV Pandalai, wrote thus about Professor Ghatage in 1987:

> *Greatness sits lightly on the shoulders of Dr. VM Ghatage, the doyen of aircraft design and development in India. Like all truly great people, he is extremely modest, easily approachable and accessible. He is a rare combination of a scholar in Sanskrit, a person who is highly knowledgeable about and lover of both Hindustani and Carnatic music, an accomplished painter whose many one-man shows have attracted a large number of visitors, a keen Golfer who has won a number of tournaments at the Bangalore Golf Club where he is treated by all with great regard and affection, and an exponent of Gita and Upanishads.*

FAMILY BACKGROUND, EARLY EDUCATION & PERSONAL LIFE

Professor Ghatage was born on 24 October 1908, in a small village called Hasur in Kolhapur, Maharashtra, as the eldest son of Madhav Venkatesh and Radhabai Madhav Ghatage. He had three brothers and one sister. His father was a writer in Marathi and was a Sanskrit scholar in the orthodox fashion. His father was also a great student of Indian Philosophy, particularly of the Upanishads, and had written a poetic rendering of the Upanishads in Marathi, which was published privately after his death. A younger brother, Dr AM Ghatage was the main editor of the Sanskrit dictionary prepared by Deccan College, Pune.

His maternal grand father had taken him when he was only 2½ years old and he was brought up by him and given a sound vernacular education in Marathi in the old classical village style at Mahagoan. He returned to his parents and had his first four standards at Gadhinglaj. No English was taught up to 4th Standard, and the teaching of English commenced only from 5th Standard onwards, as school education was of eleven (4+7) years duration, in those days.

He went to the Rajaram High School in Kolhapur for the last 4 years of school education. He passed the Matriculation in 1926, from Bombay University. The first year of college was spent at

Rajaram College in Kolhapur. Dr. Ghatage went to second year of college at the Deccan College in Pune. Education was imparted in English. The subjects taught were Mathematics, Physics and Chemistry (the Intermediate Year). Then he went to S P College, Pune for B.Sc., which was a two year course with Physics (Main) and Mathematics (Subsidiary) as his subjects of study. He took the B.Sc. in 1930 and got married as was a custom of those days. Then he went to Royal Institute of Science in Bombay for M.Sc. in Physics and his thesis work for M.Sc. was done at the Kolaba Observatory on the topic of Vortex Formation. He secured M.Sc. with distinction in 1932. Due to this background, he got a scholarship for study abroad when he applied for it at the Bombay University. It was the Sardar Bhimarao Akbarnawis Research Scholarship, funded by an enlightened philanthropist. The stipend for this was for three years. It could be used for higher studies any where in Europe and UK.

Because of the vortex studies done at Kolaba Observatory, he came to know of the work of Prandtl and so he applied to the Kaiser Wilhelm Institute at Gottingen for admission. On his way from Bombay in 1933 he halted at Geneva where he had an introduction to one Mr. Chatterji who was in the Labour Office of the League of Nations. Mr. Chatterji tried to persuade him not to go to Germany because of the emergence of Hitler. But he did not change his mind, and went to work under Prandtl. The first three months were spent in Berlin for an intensive course in the German language at the Berlin University.

After this exposure, he went to Gottingen. At the first meeting with Professor Prandtl, he was asked what his educational background was as Prandtl was not familiar with the Indian educational system. He described to Prandtl all the courses he had taken and books studied. Prandtl then asked him why he had come to study there. Dr. Ghatage replied that he was not sure that he had very clearly understood or mastered all that he studied which was primarily meant to pass the University examinations. Prandtl asked him to meet him the next day, when he suggested the courses he should take (including Prandtl's courses) and also courses in Mathematics (but none in Physics). Prandtl also asked him to meet him after the first semester was over. He had as instructors well-known persons like Betz and Flugge (who later on migrated to USA and was at Stanford). During this time Dr. Ghatage was also working in the Laboratory of Prandtl getting acquainted with the facilities and the work going on there. Prandtl had two Assistants and many people below them. Dr. Ghatage used to work under Reichardt who was one of the Assistants, the other being Tollmien who was mostly doing analytical work. Tollmien worked later on at Caltech with Millikan.

After the first semester, Prandtl discussed a number of problems with Dr. Ghatage so that he could choose a suitable problem for research. One advice Prandtl gave was: "Do not choose something that is of immediate interest to you or to the industry. This is training for you to learn how to tackle problems, training in R and D".

Finally, the subject chosen was "*Model Experiments for the Relative Motion of Air Columns of Different Temperatures*". It was both an analytical and experimental study. The Ph.D. dissertation was submitted to Gottingen University in 1936. Oral examinations were given in 3 subjects (Maths, Physics and the main subjects which were aerodynamics and thermodynamics). Prandtl used to meet his Ph.D. scholars regularly to guide their work. The work for the Ph.D. took him 2½ years. This study relating to cumulus clouds was funded by the Gliding Society of Germany and their interest in it was because of many accidents that used to occur to the comparative small gliders very common in those days.

During this period, there was a glider group of students in the University. They had to work on glider construction in the evenings and also to give a certain number of hours of gliding training. This was the practical introduction to wooden glider design and workshop experience in construction.

PROFESSIONAL CAREER

He left Gottingen at the end of 1936. On his return to India, he was to find that he could not get a job easily. So he took up jobs as a Professor of Physics and Mathematics in private colleges for the next four years – one year at the S P College in Pune and another three years at the Ramnarain Ruia College in Bombay. The salary was Rs. 150/- per month.

With the onset of World War II, a factory set up by the visionary industrialist, Walchand Hirachand in 1940, primarily for automobile manufacture, was converted into an Aircraft Factory, in association with the Government of Mysore, mainly for the assembly and repair of aircraft. In December 1940, Dr Ghatage applied for and was selected for a job in the Design Office of this factory, Hindustan Aircraft Limited (HAL) as it was then known. He came to Bangalore in March 1941 to begin what is arguably the most illustrious career in aircraft design work in India. The staring salary was Rs.300/- p.m. His first assignment at the HAL was to write the glossary of aircraft parts and write down the drawing standards. A design job he undertook was a 10-seater, troop transport Wooden Glider, during World War II.

The presence of HAL in Bangalore was an incentive for the establishment of a Department of Aeronautical Engineering in the country, preferably in Bangalore, to meet the trained man power requirements. Perceiving this need, the court of the Indian Institute of Science in Bangalore, presided over by Sir M Visveswariah, moved to set up facilities for advanced instruction and research in aeronautical engineering. The Department of Aeronautical Engineering was therefore started at the Indian Institute of Science in Bangalore in December 1942. The services of Dr Ghatage, who was then working in HAL, and who was one of the few trained aeronautical engineers in the country, was lent to the Institute during 1942-47. A one year intensive course in Aeronautical Engg. (post B.Sc. Engineering, i.e. a post graduate course) was started. For the first batch of 14 students who were admitted in January 1943 only Mechanical and Electrical Engineering graduates were taken. It was a one-man faculty, with Dr Ghatage doubling as Faculty member (Assistant Professor), and as Head of the Department, till 1945. He used to handle all subjects, Fluid Mechanics, Solid Mechanics, etc. and had 4 hours of lectures (9.00 a.m. to 1.00 p.m.) everyday and then after lunch, he had to take drawing and design classes and also supervise wind tunnel classes and experiments in the afternoons in the low speed wind tunnel.

In 1945, Professor RG Harris from the Royal Aircraft Establishment joined the Department as Professor and Head. This was when the duration of the course was made 2 years. Professor Ghatage continued till the end of 1947, when he returned to HAL, to head the newly created Aircraft Design Department. From 1948-67, he was Chief Design Engineer at HAL and from 1967 onwards, he was Deputy GM, GM and a Director of HAL till 1971. He was on extension from 1966 to 1971. He always kept the Design Engineer's post with him. The Padma Shri was awarded to him in 1965 by Government of India. After retirement, Dr Ghatage ran his own company, Product Designers Pvt. Ltd., Bangalore, serving as its Managing Director from 1973 to 1990.

SCIENTIFIC CONTRIBUTIONS

Dr Ghatage played a crucial role in the formative years of two great aeronautical establishments in the country, the Hindustan Aeronautics Limited, and the Department of Aeronautical Engineering at the Indian Institute of Science, both in Bangalore. India's first indigenous effort at design and development was a ten seater, "*Troop Carrying Glider*" designed by Ghatage, at HAL, towards the end of the Second World War. It was successfully flown in August 1942.

An *ab initio* piston-engined trainer plane, christened HT-2 was the first aircraft fully designed and built in India, under Dr Ghatage's leadership. This was meant to fulfil the requirements of the Indian Air Force. The prototype was powered by a Gypsy Major 10 engine, but production aircraft were fitted with Blackburn Cirrus Major 3 engines of 155 horse power, the trainer was made entirely of metal, including the control surfaces, designed to operate in tropical conditions by eliminating the use of wood and fabric in construction, and thus guarding against deterioration and the need for frequent replacements (*the Hindu*). By the end of 1953, it was getting into full scale commercial production.

The *Pushpak,* a piston-engine light aircraft used by Flying Clubs was designed by the team led by Dr Ghatage in 1958. This was followed by the *Krishak*, a piston engine agricultural aircraft, also useful for observation or patrol duties, with the design and development effort spanning from 1960-1974. He also designed a Logistic Air Support Aircraft, a prototype of which was successfully flight tested. One of Dr Ghatage's greatest successes was the HJT-16 *Kiran*, a jet trainer for intermediate pilot training used by the IAF – 1960-74. He was also responsible for the design and development of a jet engine of 2500- Pound thrust suitable for Jet Trainer aircrafts.

HONORS AND AWARDS

He won some of the most prestigious awards during his professional career. These include: Fellow, Royal Aeronautical Society of London; Fellow, Aeronautical Society of India; Fellow, National Institute of Sciences; Member, Institute of Engineers; and Member, USA Institute of Aeronautical Science. He also won the Sir Walter Puckey Prize, the National Design Award and the Padma Shri in 1965. He was the President of the Rotary Club of Bangalore for 1951-52; the President of the Aeronautical Society of India in 1959; and the President of the Indian Society of Theoretical and Applied Mechanics (ISTAM) from 1966-67. The Convention Centre at HAL was named after Dr VM Ghatage in 1998.

LAST DAYS

Dr Ghatage had many varied interests which occupied his attention in his post-retirement days. As a young boy, he was very much interested in paintings and actually hoped to join a school of arts after matriculation. In fact, he admitted that he never dreamed of becoming a scientist or engineer. He was a keen painter and several exhibitions of his paintings were organised in Bangalore. A portrait which he executed of his teacher, Prandtl, was presented to Kusseman. A number of his paintings adorn the Golf Club at Bangalore.

He also had a deep interest in the exposition of the *Bhagavad Gita*. For 10 years there was a study circle where he gave lectures on the Gita, the ten Upanishads, Patanjali's Yogasutras and the Yoga Vashisht. He was passionate golfer, playing since 1955, and was for some time the President of Karnataka Golf Association, which was started by him in 1973.

ACKNOWLEDGEMENTS

This Biographical Memoir is mainly based on the published record of an interview with Dr Ghatage on January 31, 1987 by the late Professor KAV Pandalai. The author is also indebted to Shri IR Nagana Goudar, of the Information Centre for Aerospace Science and Technology of the National Aerospace Laboratories, Bangalore, who helped in sourcing old records and to Dr SR Valluri, former Director of the National Aerospace Laboratories, Bangalore for some valuable insights. INSA made available some personal records from which some additional information was gleaned.

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Satish Dhawan (1920–2002)

In this issue

Laser-driven shock waves to probe equation-of-state of gold

Interest in investigation of equations-of-state (EOSs) of materials arises from both fundamental and applied points of view. Properties of materials for pressures between 1 and 100 TPa (between 10 and 1000 Mbar) and temperatures up to a few hundred electron volts are relevant to areas such as hydrodynamics, planetary physics, astrophysics and inertial-confinement-fusion programs. In the higher pressure regime, many new phenomena become apparent.

Static high pressures and shock waves using gas guns have provided precise data up to about 1 TPa (10 Mbar). Static or cold compression experiments are performed using diamond-anvil high-pressure cells, exerting progressively high pressures slowly over many hours or days. The experiments are limited by the insulator–metal transition of diamond which occurs at about 1 TPa. This is in contrast to the gas gun, whose shock experiments get completed in a millionth of a second or less. Such pressure shocks can also occur in detonation of nuclear weapons, in inertial fusion experiments, or when a large meteorite hits Earth. The shock wave travels in the target material with a supersonic velocity, taking the material to a new state with higher density, temperature, and pressure. The relationship amongst the target's pressure, density, and temperature, together constitute the material's EOS.

Direct illumination of metals by a terawatt laser can produce pressures of 10 TPa or greater, albeit a transient one. To perform this type of experiment in the pressure range of 1–5 TPa requires laser intensities of nearly 10^{13} to 10^{14} W/cm^2.

In shock physics experiments, the set of new compression states that can be reached are not along thermodynamic or equilibrium paths. The resulting curve of loci of the new states is the material's characteristic Hugoniot. The straight lines joining the initial condition to each of the points in the pressure–volume plane are the Rayleigh lines. The slope of a Rayleigh line is proportional to the shock velocity – higher strength compressions are associated with faster shock velocities. The final shock state can be determined from a knowledge of the initial state and two dynamic variables. The two dynamic variables are (a) the velocity at which the shock propagates through the undisturbed medium u_s, (b) the velocity of the material behind the shock front, known as the mass or particle velocity u_p. The Rankine–Hugoniot relations, which express conservation of mass, momentum, and energy across the shock front relate the pressure P to these variables by the relation $P = \rho_0 u_s u_p$, where ρ_0 is the density of the solid.

H. C. Pant *et al.* describe (**page 149**) experiments (carried out at the Centre for Advanced Technology, Indore) to determine EOS of gold based on laser-driven shock waves. They have used a Nd : YAG laser-based system (2 J/200 ps at 1.06 μm wavelength, peak intensity 10^{14} W/cm^2). By using 'impedance matching technique', they have measured the Hugoniot EOS data points of gold to good accuracy. They have compared their data with experimental and theoretical results available in the literature. Thereby they have 'shown the feasibility of using a simple laser-driven system for conducting shock wave experiments for EOS measurements in gold at moderate pressures of nearly 10 Mbar'.

Over the past three decades, shock physics experiments have provided data about materials at high pressures. Originating in the background of cold war, they were used to improve output from weapon design codes and simulation models. Researchers have been able to predict in detail the behaviour of nuclear weapons. Apart from results related to weapons research, there have been other important fall-outs. The shock physics data obtained at various experimental conditions have provided insight into the material properties in the planetary interiors. Shocks can induce transformations in materials' new properties – for example, it is theorized that hydrogen would become a metal at room temperature in a shocked state. The emphasis in the paper of Pant *et al.* has been on basic high-pressure properties of a 'standard' metal, namely gold. Many properties like electrical conductivity and thermal conductivity of materials and non-equilibrium properties, all at extreme pressures and temperatures, could also be studied with availability of higher power laser systems.

K. R. Rao

Towards mitigating earthquake damages

Many processes related to earthquakes continue to be evasive. Gaps in our knowledge are perhaps the greatest stumbling blocks in our ability to predict what could lie ahead, for example, the location and size of a future earthquake. As efforts in this direction continue, there is an increasing emphasis on the ability to predict seismic hazard; more importantly, how the man-made structures will respond to the expected level of ground shaking at a specific location. Recent experiences have demonstrated that even regions in the outskirts of an active zone are not free from damage. Many of our own cities face threats, the capital city of New Delhi being one of the most vulnerable to earthquakes from the Himalaya. The 1999 Chamoli earthquake caused damages to buildings in some parts of Delhi and most notably, those affected were built on the sediment fill of the Yamuna valley. Damage to multistoried buildings in Ahmedabad, located more than 300 km from the epicentre of Bhuj earthquake, is another grim reminder of such eventualities. Such selective destruction is the result of the increase or decrease of ground motion, determined by the properties of the surface material through which the seismic waves propagate. The modern-day seismic hazard maps are amalgamation of both geologic and seismologic data, giving due importance to the character and distribution of strong ground motion.

Ability to predict site-specific effects of earthquake shaking elevates seismic hazard analysis to a new platform, one that enables the engineers to design structures with an *a priori* knowledge of what may lie in store. This is what is expected from microzonation, which is a block-by-block scale mapping of seismic hazard, based on local conditions. Requiring a variety of data from ground motion to soil properties, microzonation is now being done in many regions of the world facing threat from near or far earthquakes. The paper by Parvez *et al.* (**page 158**) provides an example of first order microzonation in a part of Delhi city. Using the strong motion data from the 1999 Chamoli earthquake, the authors demonstrate that the level of strong motion – both acceleration and velocity – are different for eastern and western Himalaya. For many who live in the alluvial plains of the Himalayan hinterland, possibility of a distant earthquake is a reality that must be reckoned with. That cannot be averted. What can be and should be done is to equip the society to cope up with such disasters. Perhaps, the ability to design structures based on modern-day seismic hazard maps is the starting point. That is the context from which the paper by Imtiaz Parvez and his co-authors must be looked at. There is a long way to go, but this paper marks an excellent beginning.

Kusala Rajendran

CURRENT SCIENCE

Volume 82 Number 2 25 January 2002

EDITORIAL

Transition

I have got my leave. Bid me farewell my brothers! I bow to you all and take my departure.

Here I give back the keys of my door – and I give up all claims to my home. I only ask for last kind words from you.

We were neighbours for long, but I received more than I could give. Now that the day has dawned and the lamp that lit my dark corner is out. A summons has come for me and I am ready for my journey.

— *Rabindranath Tagore*
(*Gitanjali*, Translation by the Author,
Macmillan, 1913)

Life is real, life is earnest,
And the grave is not its goal,
Dust thou art, to dust returnest,
Was not spoken of the soul

— *Henry Longfellow*

Bangalore was a quiet, sedate town in the 1950s and the Indian Institute of Science was tucked away in its northern corner, its existence unannounced even by a signboard. There were no impressive gates at its entrance, no visible sign that the cluster of low-lying buildings housed an institution that already had an international reputation as a centre for scientific research; one that would serve as a centrepiece for the development of science in post-independence India. C. V. Raman had already established the physics department as a major presence, in the tumultuous period between his entry into the Institute as its Director in 1935 and his formal retirement as a professor of physics in 1948. Despite being armed with the Nobel prize, a level of attainment that would have made him invincible today, Raman was removed as Director by the Institute's Council in 1937, moving him from the centre of administrative power to the seclusion of his own laboratory. Homi Bhabha had come and gone, moving to Bombay (now Mumbai) to begin the establishment of the Tata Institute of Fundamental Research and the Atomic Research Centre at Trombay, now named after him. By the mid-1950s the Institute had begun to lapse into middle-aged obscurity. Jawaharlal Nehru and his principal advisors were already embarking on a major program of building India's scientific infrastructure; new institutions, national laboratories and the glamorous Indian Institutes of Technology were already on the anvil. Few would have spared a thought for an ageing and established institute that seemed to be slowly slipping into a comfortable state of academic somnolescence. It was into this ambience that Satish Dhawan made his entry into the Institute in 1951, as a member of the faculty of the Aeronautical Engineering department, rising in dramatic fashion to become its Director in 1962, at the remarkably young age of 42. When he formally retired in 1981, he left an institution that had grown enormously in size and scope and was arguably, the preeminent institute of science in the country, comparable to many in the developed nations of the West. Legend has it that Dhawan entered the Institute as an extraordinarily dashing young man, driving a red sports car; I saw him when he left it, a remarkably handsome and distinguished figure exuding a quiet charm that was uniquely his. In this period he transformed the academic structure of the Institute, moving it from a feudal departmental structure presided over by a single, powerful, and most often, inhibitory professor to a more collegial model which promised the prospect of collective decision making on academic matters.

During his long innings as its Director, Satish Dhawan gently and at times, unobtrusively guided a transformation of an established academic institution; a formidable task that required a clear vision, a firm resolve and an ability to persuade recalcitrant academics to tread a new path. Experience tells us that in our surroundings when old institutions begin to falter, it is easier to contemplate setting up new ones; the hope is that this strategy sidesteps the difficult problem of effecting reform and change, in institutions with set traditions. Dhawan's administrative achievement at the Institute in Bangalore, has faded into obscurity, dimmed by the lustre of his achievement in building up the Indian Space Research Organization (ISRO) into the formidable structure it is today.

In the period between the late 1960s and early 1970s, Dhawan began a program of expansion at the Institute, which would bring in a very large number of faculty, some of them at the professorial level. The institution was soon to acquire a breadth of discipline that was unprecedented; the influx of new blood hastening the process of democratization. Many new departments, which were later to become pre-eminent, were established during this time, among them were Computer Science and Automation, Centre for Theoretical Studies, Molecular Biophysics Unit and Solid State and Structural Chemistry Unit. The latter two units were to bring to Bangalore two of India's most accomplished scientists, G. N. Ramachandran, already a world renowned figure, and C. N. R. Rao who would very quickly have a major influence not only on the development of the Institute, but indeed on the growth of contemporary science in India. Dhawan's ability to attract men of unique and varied talents and his role in shepherding the Institute during this phase of explosive growth, a period that coincided with the development of mechanisms for large-scale funding of academic science, must surely rank as one of his finest achievements. The Institute's focus on research, nurtured carefully by Dhawan, deepened in later years, providing an institutional ambience that was clearly distinct from other institutes of technology.

Dhawan's love for Bangalore and his attachment to the Institute led inevitably to the choice of this city as the headquarters of the Indian Space Research Organization. Vikram Sarabhai's untimely death in 1971, catapulted Dhawan into a dual role heading both ISRO and the Institute for a decade. The space program has had a wonderfully romantic history, with Satish Dhawan as the guiding force; in times of failure he shouldered responsibility, in the heady days of success he stood quietly by the sidelines. Dhawan's ability to build an organization whose success relied on teamwork, discipline and collective dedication was truly remarkable, particularly when one recognizes that he was simultaneously guiding an institution, where individuality and idiosyncracy were cherished qualities.

My view of Satish Dhawan is necessarily circumscribed by the limited perspective from which I saw him. For a man of many facets, any historical assessment must, of course, come from a scholarly study of his life and times. But, at the distance from which I viewed him, separated by the gulf of age, position and discipline, Dhawan was a man who engendered immense respect by his grace of conduct. There was an engagingly shy air of reticence about him, uncommon in men, who have experienced power and distinction. In thinking about Dhawan, my thoughts drifted, almost inevitably, to some of his contemporaries, whom I have known, who have also departed in the last few months. Just a few days before Dhawan's passing, T. R. Govindachari, an organic chemist of special distinction, died in Chennai at the age of 86. In the months before, two more of India's eminent scientists passed away; V. Ramalingaswami at the age of 80 and G. N. Ramachandran in his 79th year. Govindachari built an extraordinary record of natural products research in the most modest surroundings of Presidency College, Chennai in the 1950s. He moved in the mid-1960s to the Ciba-Geigy Research Centre in Goregaon as its first Director; an unusual step at the time. This was the first major private R&D centre in India, opened by Jawaharlal Nehru in 1963. Govindachari was an amazingly uncomplicated person, interested passionately in experimental work. He managed to work in a laboratory well into his eighties, returning to Chennai to set up two private R&D centres. I have rarely met anyone with such an enthusiasm for experimental detail; he was always completely immersed in the wonderful molecules he coaxed out of nature. Govindachari set standards for scholarship and rigour that few are prepared to emulate today. G. N. Ramachandran, a man of remarkable achievement and distinction, also did his path-breaking work on protein and polypeptide structures in Chennai, before moving to Bangalore in 1971; a transition initiated by Dhawan. Ramachandran, a biophysicist, was brilliant, unpredictable, totally dedicated to his science, leaving behind him an indelible impression on his discipline. Finally, there was V. Ramalingaswami, who more than anyone else influenced the development of medical research in India. He headed the All India Institute of Medical Sciences and later the Indian Council of Medical Research. His work in the area of nutrition brought him great international distinction. Until the end he was a much respected figure in making biomedical research policy. I saw and heard him on many occasions and was always struck by the clarity of his thinking, the elegance of his presentations, the intensity of his committment and above all, the graciousness of his manner. In thinking about this quartet of remarkable men of science, I was reminded of the famous quartet of Indian spinners, who spun us to many a famous victory – Bedi, Prasanna, Chandrasekhar and Venkataraghavan. Here were men of different backgrounds, contrasting styles and distinctive abilities, consistently propelling their team towards success. The four men of science also had their unique styles; Dhawan and Ramalingaswami were men who presided over Academies, rubbed shoulders with Prime Ministers, accepted great responsibilities and challenges, whose dedication is evident in the accomplishment and character of the institutions they built. Ramachandran and Govindachari were academic scientists, focusing intensely on their chosen disciplines, carving for their laboratories a level of international visibility, that allowed their surroundings to bask in reflected glory. These were all men who dedicated themselves to the cause of science in India, as men in the prime of youth in the heady years after independence. They played full and magnificent innings, which bear retelling in the years to come. For those who bemoan the absence of role models in our midst, reflecting on Satish Dhawan and his remarkable contemporaries may be instructive. Many of us must count ourselves as fortunate to have seen them all.

P. Balaram

TRG during his recent illness was exemplary and heart-warming.

I visited the family a few days ago to express my condolences. Rajagopalan was kind enough to show me one of TRG's bequests, his orchid collections, Dendrobiums, Vandas and a few other species. Some were on the ground, while about a thousand were in the climate-controlled terrace. He told me that he would try to preserve this inheritance for which he had trained himself. Natural products chemistry is another bequest of TRG which needs to be preserved and pursued. N. S. Narasimhan at Poona University practised it very ably for several years. I have retained a significant interest in the area, but circumstances took me into synthetic medicinal chemistry. Now the country looks to young, gifted organic chemists to carry on the work of TRG.

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Satish Dhawan

Satish Dhawan, former Director of the Indian Institute of Science (IISc) and Chairman of the Space Commission, and President of the Indian Academy of Sciences during 1977–1979, passed away on the night of 3 January. Although he had been growing physically infirm during the previous half-year, he had remained his usual cheerful self till the very end, and died peacefully within twenty minutes of complaining about difficulty in breathing. With his death the country lost one of its most distinguished sons, and the scientific community a truly unimpeachable representative. He had at various times in his career been teacher, research scientist, engineer, technologist, manager, leader and adviser – sometimes many of these at the same time. And to everything he did he brought dedication, breadth of vision, meticulousness and humanity, which, combined with his remarkable scientific and technological abilities, transformed every organization he worked for or led, and made it achieve what it had often not thought itself capable of.

Satish Dhawan was born on 25 September 1920 in Srinagar, and was educated in this country and the United States. He graduated from the University of Punjab (Lahore) with an unusual combination of degrees: a BA in Mathematics and Physics, an MA in English Literature, and a BE in Mechanical Engineering. In 1947 he obtained an MS in Aeronautical Engineering from the University of Minnesota, and moved to the California Institute of Technology (Caltech), where he was awarded the Aeronautical Engineer's Degree in 1949 and a PhD in Aeronautics and Mathematics in 1951 with the eminent aerospace scientist and fluid dynamicist Hans W. Liepmann (Honorary Fellow of the Indian Academy of Sciences) as adviser. This educational breadth, covering science, engineering and the humanities, and his distinguished family background, appear to have given Dhawan an ability to view the world from many different angles, and may explain in part his unique qualities as a leader.

Dhawan had spent a year on the shop floors of Hindustan Aircraft (now Hindustan Aeronautics, HAL) before leaving for the US on a government scholarship. As a student at Caltech he made an extraordinary impression, and left a glow of fond memories behind him when he left to return home in 1951 – for here was an Indian who was not only ingenious at hooking up new and intriguing experiments but could also play with hypergeometric functions, quote Shakespeare for every occasion, and regale his friends with stories about the camel answering to the name of Greta Garbo in the Khyber Pass (Dhawan grew up as a young man in what is now Pakistan). The charm of his personality overwhelmed everybody that came to know him, especially as it was accompanied by a very Indian sense of grace and modesty.

At the time that Dhawan began his career in aerodynamic research, supersonic flows and shock waves were still rather exotic phenomena; his earliest papers dealt with these subjects, and one of them, which had detailed observations of how a shock wave bounces off a solid surface (such as that of a wing, for example) became widely known for its revealing and defining observations. For his Ph D thesis he

Dhawan laughing away with young scientists at the First Asian Congress of Fluid Mechanics, Bangalore, 1980.

invented an ingenious method of directly measuring the friction drag on a surface by letting a small strip of it – about a millimeter wide – float, and measuring its effective deflection against the resistance of a spring by electronic methods, using a null technique[1]. These results appeared in various books of the time, including the first edition of the English translation (from German, published in 1955) of Schlichting's book *Boundary Layer Theory*, the first on the subject. They have been faithfully reproduced in the many editions the book has gone through over the last fifty years, including the eighth published in 1999 (ref. 2).

At IISc, which he joined as a Senior Scientific Officer in 1951 (he became Professor and Head of the Department of Aeronautical Engineering in 1955, and Director in 1962), he built the first supersonic tunnels in the country. (The very first was a tiny tunnel with a test section of 1 cm × 1 cm or so, running on compressed air stored in two war-surplus oxygen tanks from a Dakota.) I first met him when I joined the Institute as a student in 1953. That is now nearly fifty years ago, but my recollections of early encounters with him are still vivid. I recall a tall, handsome, young man who would jump out of his sporty little MG car, wearing a red shirt and a broad smile, racing across the stair-case in the Department and cheerfully saying 'Good morning' as he stepped into the class room. Dhawan brought to the Institute an element of youth, freshness, modernity, earnestness and Californian informality that captivated the students and many colleagues. In short, he was a star on the campus.

Students liked his classes very much indeed, and for a variety of reasons; the first of these was, as I have already remarked, Dhawan's general cheerfulness in his approach to the subject as well as to the students. He took his teaching very seriously, and supplied his classes with plenty of notes, data sheets, diagrams and so on. He worked hard on all these – one would often see him in his office late at night – and he expected the students to work just as hard – which many of them cheerfully did. Another reason for the great popularity of his classes – last but not least, as they say! – was that he was generous with his grades if the student had got the gist of what had been taught in the classroom.

To anyone who walked into the laboratory that he set up at the Institute, one thing that caught immediate attention was that every thing looked different, and worked well. The laboratory managed to convey an impression of both science and engineering; it had 100 hp compressors running wind tunnels, as well as lenses and galvanometers measuring what was going on in those tunnels. In a very real sense I think Dhawan established, at IISc and – by example – elsewhere in the country, a tradition of scientific research on engineering problems. His laboratory also had a variety of little devices, rigged up by him with great and obvious pleasure, to make things a bit easier for the experimenter. Among these 'gizmos', as he loved to call them, I remember a pretty little thing for electroplating 5 micron tungsten wires with copper, so that they could later be soldered for making hot wire probes – I started my life in the laboratory, like so many students of fluid dynamics everywhere in the world at that time, struggling to make these fragile probes for wind tunnel measurements of fluctuating velocities in turbulent flows. I still recall Dhawan teaching me to make these probes, telling me about the ritual one had to follow – 'like doing pooja', he would say. The fine wires we needed for these probes were not easily available, and Dhawan had obtained from his friends in the United States various bits of platinum and tungsten wire which came stuck on the back of letters written to him: we used to hoard them like misers.

I vividly recall how the 1 inch × 3 inch wind tunnel in the High Speed Aerodynamics Laboratory was calibrated, with the help of all hands that could be mustered at any given time, to open valves, ring bells, take readings, click cameras, etc.: it was all very dramatic to me at the time. (Not that the number of people so mustered was very large: the Department was still small then.) He also led a pilot project for the huge facilities that later came up at the National Aeronautical Laboratory (now the National Aerospace Laboratories, NAL) in Bangalore. The students and colleagues he worked with at IISc went on to establish and run the National Trisonic Aerodynamic Facility at NAL – a facility that now may well be the most well-equipped blowdown tunnel in the world. Simultaneously his research in fluid dynamics continued: he and his students made pioneering investigations in the intriguing phenomenon of boundary layer transition, as the flow goes from a smooth, laminar state to the more common eddying, irregular, turbulent state; they also studied reverse transition or relaminiarization, as the flow (under certain conditions) reverts (to everybody's amazement at the time) to the laminar state. Also studied were wall jets, axi-symmetric bodies, three-dimensional boundary layers, base flows, separation bubbles, transonic flows and so on. It was almost as if Dhawan wanted to set up a base from which any worthwhile or important topic in aeronautical fluid dynamics could or would be studied.

He was the father of experimental fluid dynamics research in India, and indeed was in many ways the first engineering scientist of the country.

He summarized all of this research in a lecture which he gave at the First Asian Congress of Fluid Mechanics, held in Bangalore during 8–13 December 1980 (ref. 3). And these Asian Congresses, growing stronger with each meeting, were again something that would not have prospered without his moral and material support.

There were two outstanding features of Dhawan's philosophy in research. First, it was carried out at low cost, with ingenious development or adaptation of whatever materials, skills and instrumentation were available at the time; second, the basic research areas investigated in his laboratories were all inspired in some way by the problems faced by the newly-born aircraft industry of the country (which he had known from the year he had spent on the workshop floors before he went to the US). In later years he constantly sought to promote the development of this industry at the higher levels of policy and management, and persuaded HAL to start a division for space projects.

In 1972 Dhawan was appointed Chairman of the Space Commission and of the Indian Space Research Organization (ISRO), and Secretary to the Government of India in the Department of Space. It was an inspired appointment. The Indian space programme owes its birth to the vision of Vikram Sarabhai, but the superb technology development organization it has now become was Dhawan's loving creation. In the decade following his appointment he directed the Indian space programme through a period of extraordinary growth and spectacular achievement. Major projects were carefully defined and systematically executed, including in particular the launch of Indian satellites on Indian rocket vehicles. Pioneering experiments were carried out in rural education, remote sensing and satellite communications, and led to operational systems like INSAT that became (and continue to be) a part of Indian life. These projects were all distinguished by their keen sensitivity to the true needs of a developing nation, a confident appreciation of the ability of its scientists and engineers, and the carefully planned involvement of Indian industry, both public and private. It is no surprise that the Indian space programme has come to be seen in the last two decades as a model of technology development and application carried out within the country. Kalam recalls a late evening in Cauvery Bhavan in Bangalore (where ISRO Headquarters were located at the time) with Dhawan, discussing space missions for the next two decades. While many mission options were debated with all the ISRO engineers that had gathered, Dhawan summarized the next morning his plans with graphs prepared in his own hand, bringing out a space mission profile for the next 15 years (1980–1995). These charts, reproduced in a volume dedicated to him[4], became the blueprints for the national space programme, as it grew into a stable of various launch vehicles (including in particular those for polar and geostationary satellites, PSLV and GSLV), the Indian Remote Sensing satellites, the INSAT series, and their current technological descendants.

The principles that Dhawan formulated and applied (but, characteristically, never stated) in running the country's space programme can be easily inferred from the way he operated. First of all he devised a programme that was societally conscious, with objectives that could be widely understood (weather, natural resource-mapping, communications, etc.). He had supreme confidence in the ability of Indian engineers and scientists, even when they did not have degrees from IITs or foreign universities. He kept the technology development work open and transparent to the national scientific community through an elaborate system of reviews (some of them held in the big auditorium in the Vikram Sarabhai Space Centre at Trivandrum, filled to capacity on such occasions; the tradition was quickly established here that the juniormost engineer could ask awkward questions of the big project leaders). He managed his projects through a small group of very able directors, and another small group of bright young whiz-kids in his office (protecting them from the natural dislike of their colleagues). He took the responsibility when there were failures, but let others take credit when there were successes (as Kalam has pointed out). He maintained accountability through peer pressure, but shielded his engineers from blame for honest failures. He developed a promotion and assessment system that had some unique features, enabling the more productive engineers to move ahead of their colleagues but not too rapidly, retaining the confidence of the bulk of the staff in the fairness of the system. And he insisted, successfully, that the national space programme should be a purely civilian enterprise.

And there were some other unusual things about his management style. He shunned publicity, and rarely held forth before the media – so much so that people were often surprised how forceful he could be in private, or within the four walls of Council or Commission.

I think of him as a critical optimist in everything he did.

While running the country's space programme he took only one rupee for doing the job, preferring to be paid by IISc for directing it. (When he was asked by Indira Gandhi to take over ISRO as successor to Sarabhai, he made it clear that he would do so only if he could remain at the Institute that he so loved. And when Morarji Desai took over from Indira Gandhi after she lost the elections in 1977, Dhawan was ready with his resignation from ISRO – but Morarji refused to accept it.)

After his retirement from formal positions in Government, Dhawan continued as a member of the Space Commission, after having already become the Bhishma – the doyen – of the Indian aerospace community. He took time every now and then to analyse matters of public policy in science and technology, and kept egging his colleagues in the scientific community to give more attention to the social demands on science.

While doing all the high technology and big science at ISRO, he never forgot how crucially important 'little' science was, and ceaselessly promoted it, especially with young people. Indeed, he indulged in it himself whenever he could; the only book he wrote (to my knowledge) is a little gem on *Bird Flight*[5], which grew out of a lecture he gave first at the Academy, and then at many other places across the country (especially, by his insistence, at those off the beaten track, like Jammu and Guwahati). I still remember how he took a busy break from running his space empire to work on the Academy lecture, drawing his own diagrams and doing his own sums.

During the 19 years that he was Director of the Institute (beginning in 1962), he retained his interest in fluid dynamics and aeronautics, e.g. carrying out an elaborate evaluation of the airworthiness of the HS-748 ('Avro') aircraft flying for Indian Airlines, pioneering a kind of civil aviation research unmatched then or since. (As he had to run both IISc and ISRO at the time, most of the meetings he held – with the small group of some ten scientists from IISc, NAL and HAL that were assisting him – took place late at night.) He devoted much time to the establishment of many new scientific programmes in the Institute, in such areas as automation and control theory, materials science, molecular biology and biophysics, technology for rural areas, theoretical physics, applied mathematics, solid state chemistry and atmospheric sciences. He persuaded such distinguished scientists as G. N. Ramachandran, C. N. R. Rao and George Sudarshan to join the Institute; and he also persuaded a rather reluctant faculty to reform their educational programme. Indeed, his long tenure at the Institute – a record – transformed it from a rather laid-back campus (with strong traditions in only a few areas like physics), to one humming with new ideas in a wide variety of subjects, from fresh young faculty and a great many new students. At the same time he played a key role in formulating the science and technology policy of the country, through such bodies as the Scientific Advisory Committee to the Cabinet. He also helped mould other organizations whose Councils he headed. Most notable among these were the Raman Research Institute and NAL. As Director of NAL during 1984-93, I must place on record how much we benefited not only from his advice and friendly criticism, but much more importantly from his gentle but unceasing pressure on us to promote civil aviation. Dhawan's encouragement, and the enthusiasm of the late Raj Mahindra, provided the inspiration for the civil aircraft projects that NAL went ahead to pioneer.

But what specially distinguished Dhawan from many other eminent scientists and engineers were his extraordinary qualities as a leader and a human being, his great personal charm, and his keen social conscience. When the Sriharikota Range was being built, he rejected a proposal to fence the range to keep cattle from it, noting that the range had belonged to the cattle and the tribals living there, and making alternative arrangements. He set up a museum housing the artifacts that were found at the site. The mechanics making his pet gizmos for him in the Institute laboratories – some of them highly skilled but hardly educated – felt they were his friends, even as the students and his own class-fellows in India and abroad did. He could be, and was, a tough man many times, but never on personal considerations.

If he sometimes seemed indecisive, that was because he accommodated so many diverse points of view within himself; after knowing him for some time I felt I could recognize the churning that went on in his mind on those critical occasions as he balanced, in his own very rational way, all those competing ideas and forces; and he often shared these thoughts with his close colleagues before he made his decisions.

Although he generally gave the impression that he was not particularly interested in Indian philosophy or religion, he once asked me whether there was some brief account I could recommend to him. In spite of this apparent lack of interest, however, he was actually more deeply Indian in his fundamental attitudes and his value system than most philosophy-lovers: he was a true *karma-yogi*.

Dhawan was honoured widely for his contributions to science and technology by various bodies within India and abroad. When he was invited to deliver the Commonwealth Lecture at the Royal Aeronautical Society[6], he characteristically made a comprehensive review of everything that was being done in the many different aeronautical institutions in the country. He was elected President of the Indian Academy of Sciences in 1977, and awarded the Padma Vibhushan in 1981. He was one of the very few Indians to be elected to the US National Academy of Engineering. He was a Distinguished Alumnus of both Caltech and IISc. Two volumes of scientific papers[4,7] have been published as tributes to him, with contributions from friends and admirers all over the world. Among his numerous other awards, one that deserves particular mention is the Indira Gandhi Award for National Integration, bestowed on him in 1999 with a citation that read in part:

> The award goes fittingly to one of our foremost scientists, teachers, and national builders, Prof. Satish Dhawan, who has made multi-dimensional contributions to scientific education, research, policy formulation and implementation and is deeply concerned with the solution of national problems through the use of science.

He was, most of all, the undeclared but widely accepted moral and social conscience of the scientific community. He was a great man.

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