Dhawan

FIFTH LALA KARAM CHAND THAPAR MEMORIAL LECTURE

PROSPECTS FOR A SPACE INDUSTRY IN INDIA

By

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PREFACE

The Patiala Technical Education Trust had instituted Lala Karam Chand Thapar Memorial Lecture in memory of its founder and first Chairman which is delivered periodically by eminent persons.

Lala Karam Chand Thapar was one of those rare individuals blessed with natural ability for leadership, who pioneered in a single life-time one of the largest business groups in India - the Thapar Group of Industries.

In pursuance of his vision that only through development of human resources that other resources can be converted to wealth, Lala Karam Chand Thapar founded in 1956 the Patiala Technical Education Trust for the establishment of Thapar Institute of Engineering & Technology at Patiala. The Institute was recognised by the Government of India as a Deemed University in 1985.

The last Memorial Lecture was delivered by Prof. C.N.R. Rao, Director, Indian Institute of Science, Bangalore, in November 1984. This year the Memorial Lecture is being delivered by Prof. Satish Dhawan, Member, Space Commission. Prof. Dhawan is an eminent academician and an outstanding engineer. He had been Chairman, Space Commission and Chairman, Indian Space Research Organisation besides Secretary to Government of India, Department of Space, between 1972 and 1984. He was earlier Prof. and Head, Department of Aero Engineering and subsequently Director of the Indian Institute of Science, Bangalore.

The Memorial Lecture is being published for wider circulation and for the benefit of those who may wish to have a copy of Prof. Dhawan's Lecture for reference and record.

February 5, 1988.

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1. Introduction and Background

Thirty years ago a startled world was ushered into the Space Age by Sputnik I - the world's first artificial satellite. Since then there has been a phenomenal growth of space activities. Over 3000 satellites of varying size and complexity have been launched into orbit since October 1957.

The early years were monopolized by the USSR and USA and the driving forces of scientific exploration and discovery were mingled with international rivalry and military competition. With the passage of time the emphasis has shifted towards the exploitation of outer space. Several new members have joined the exclusive Space Club.

The World's Space activities have grown many fold in magnitude and diversity. The new frontier continues to beckon the romantics with vision of Space Colonies and Interplanetary travel, and the scientists with new discoveries about the universe. However, economic and other considerations have increasingly forced a more pragmatic utilization of Space. This utilization has retained two dominant elements. The first is economic benefit and commercialization and the second military use of Space. The Commercial drive has evolved from civilian and scientific urges to profitably use Space for practical application. These urges are often mingled with perceptions of national prestige. Inevitably this trend - spearheaded by satellite communications - has drawn in many civilian users of Space services and products from industry and many other walks of civilian life. With a multi-billion dollar global turnover the world market for Space technology and its applications has now emerged as a reality.

The second element i.e. military use has also been active from the outset. The military and intelligence services of the two major Space Powers have been deeply involved in the exploitation of Space. Militarization of Space began early, leading to an extensive range of military communications, navigation, reconnaissance and surveillance satellites. These have made the U.S.A., and to a lesser degree the USSR, increasingly dependent on Space platforms for the conduct and support of military operations on earth. The military Space budgets of these countries now far exceed the civil expenditure. This trend, coupled with the development in large numbers of nuclear weapon tipped inter-continental and other ballistic missiles which are second cousins of Space launchers, is threatening to degenerate into the weaponization of Space and Star Wars. This extremely dangerous and economically ruinous trend if not halted and reversed soon may not only threaten civilian satellites of all nations but also destroy all life on earth.

This talk is based on the optimistic premise that the people of the world will not allow man's venture into Space to be subverted towards world disaster. The perspective therefore exclusively focuses on civilian peaceful uses of Space with the central theme being the opportunities for India and Indian Industry.

The Indian Space Programme was organised in 1962. The goals were to achieve, as rapidly as practicable, the application of Space technology to assist national efforts in telecommunications and mass education and in the timely survey and management of our natural resources. Beginning with the development of scientific payloads and sounding rockets twenty five years later India has in space INSAT-I a National Satellite System. Since going into operation in 1983, INSAT has dramatically changed the countrywide telecommunications, television, radio and meteorological services - the mass education potential has, however, yet to be realized.

The first satellite launch from Indian soil took place from the Sriharikota launching range in July 1980 when SLV-3 placed Rohini in a near-earth orbit. Currently an active programme is on to operationalize a national Space service for survey and monitoring of natural resources. This service will be based on an Indian built spacecraft IRS-IA due for launch in the first quarter of 1988. Replacement of the INSAT-I Space segment by Indian satellites of advanced design, currently under development, will take place in the early 1990's.

Parallel developments of the ISRO launchers PSLV & GSLV, seek to provide full Indian launch capability for Polar orbiting (IRS) as well as geo-synchronous (INSAT) operational spacecraft in the 1990-1995 time frame. By then the nation-wide services provided by the INSAT and IRS systems would be fully stabilized and integrated into the Indian economy and national life. Subsequent improvements and extensions would need to be systematically introduced through replacement and renewal of the life-expired Space segment elements every 2 to 5 years with corresponding expansion of the ground segments for utilization.

During the last decade ISRO/DOS activities have seen a steadily increasing involvement with and growing dependence on Indian Industry. The annual flow of funds to Indian Industry has increased nine fold to about Rs. 120 Crores in 1987. From the supply of relatively straight forward materials and hardware for the Space Centres Indian industrial establishments are now undertaking more complex assignments for hardware, machines and system elements for ground test and development equipment and in some cases flight hardware. Through corporate level arrangements the aircraft, electronics, chemical and mechanical industries are beginning to make longer term commitments to the Space Programme.

The International Space scene has also rapidly transformed. In spite of the early and continuing domination of the scene by the USSR and the USA, through concerted efforts - in which national governments and the aero Space industries have played a crucial role - Europe, Japan, Canada, China and India have also established visible beach heads in Space. Australia, Brazil and several other nations have an increasing tempo of Space related activities. About a hundred and forty nations - among them nearly 50 developing ones - regularly use Space services. The world wide success of Satellite Communications and weather services and the ripening markets for satellite imageries for a wide range of uses for resource survey and management has created increased awareness among the active technologists and industries of the expanding market for Space based and related services. The parallel revolution in information technologies caused by the marriage of digital communications and computer systems has also been strongly fuelled and influenced by the growth and use of advanced Space systems.

2. Features of the Civilian Space Enterprise

Space systems, when operational in orbit, have a global reach. Transmissions from a geostationary satellite cover approximately one third of the globe. A polar satellite can survey the entire surface of the earth in about 20 days. Coupled with this inherent and unique feature of large scale area coverage, a single Space platform can carry a combination of payloads and provide multiple sevices to large numbers of ground users. Thus the number of spacecraft and the launch services necessary to place them in the desired orbit for a set of widely distributed services on earth tend to be concentrated and relatively small in number. The industrial operations for construction and manufacture of Space systems do not fully lend themselves to be organised on the normal mass production lines of automobiles or civil aircraft. On the other hand in Space projects, the extra-ordinary pooling of scientific/technical/system management knowledge from a large array of disciplines lends itself to wide-spread application and diffusion into other commercial areas.

The manufacture of hardware for rocket launchers and satellites and of the stations which launch and control them, tends to be highly capital intensive with high labour costs. An important economic feature of civilian Space projects is that the earnings to be made from the provision of ground services derived from Space systems often greatly exceed the returns from the manufacture of Space hardware while requiring a much smaller capital base.

Thus Space industries engaged in the manufacture of Space hardware have to recognise special economic imperatives for applying and diffusing complex technologies gained in the process to areas other than Space. It is equally important that government Space policy should be cognisant of the fact that in view of the nature and degree of complexity, the capital investment involved and the relatively restricted scope of the market, Indian industry cannot be expected by itself to make the primary investments for Space projects.

The main elements recognised by the industrial establishments of the industrialized countries - especially the aircraft and electronics people - and supported by their governments, was the vital process of technological innovation coupled with new concepts of systems engineering, reliability and quality control, project management and organisational structures which Space projects brought to the industrial enterprise. Many of the important elements of advanced industrial activity such as entering new markets, diversification, cost reduction and increased reliability - which are the basis of the competitive edge in the market-are concentrated around the innovation process which, in the modern world, relies heavily on new scientific knowledge and in the ability through information and man-machine management, to systematically and successfully translate this into product design and production technologies.

This feature which is absolutely critical for Space projects is of course generally true to a greater or lesser degree of many other modern industrial enterprises. The question is whether Indian Industry - public and private - has been able to seriously address and understand the nature of this complex element and practice the imperatives which flow from it. With a few exceptions, Indian Industry by and large in the past has followed the pathway of licence agreements, import of machinery and technology from firms abroad who have already mastered aspects of the innovation process. While it cannot be said that nothing worthwhile has resulted and no lessons learnt, the Indian Industrial scene does not present a picture of technology innovators. On the contrary those who imported technology some 10, 15 or 20 years ago have found themselves again and again in the same predicament - such has been the nature and pace of scientific advance and growth of new technologies and the mismatch with the absorptive capacities of Indian Industry.

A quick overview of the aircraft, electronics and materials industries would show that in India they have not shown the dynamism and mastery of the processes of technological innovation which characterizes them elsewhere. A measure of the lacunae is provided by the meagre investments made by the corporate managements of these industries in research, design and development. Company reports now-a-days do show an R & D heading but fail to substantiate the nature and more importantly the output from that investment.

Space technology depends very heavily on a combination of advanced technologies and only those organisations who have invested some effort and funds in understanding this can translate these into the industrial strength that the technologies represent. The engineering sciences of aero and thermo-dynamics, propulsion engineering, light weight and high strength structures, micro-packaged avionics and inertial navigation systems combined with advanced control systems theory, orbital mechanics and the physics of Space - all play a crucial role in the design of Space systems and the hardware involved. The aircraft industry typically represents an example of such disciplines combining to produce a commercially viable flight system with extraordinary standards of safety and operational efficiency. Space systems in some respects are natural extensions of aeronautical technology. Thus - except in India - it is natural to find the aeronautical industries taking the lead in developing active and strong links with Space activity.

The spin-offs from Space activity extend into many aspects of the manufacturing industry as a whole and the technologies created in designing and achieving Space systems show great capabilities of inter-sectoral transfer into manufacturing processes, computer and sensor systems and environmental control devices as well as increased potential of value added services. As mentioned earlier this diffusion is an economic imperative for manufacturers of Space hardware.

It is useful to recall the time scales involved in the execution and sustenance of Space missions. A major Space based service - e.g. for telecom or remote sensing-takes 3 to 5 years to be conceptulized and evolved in detail. After service assessment and definition the design and development of the Space segment may take 4 to 6 years. Development of new launchers takes a decade or more, while stage and propulsion module modification and qualification need 2 to 5 years to be accomplished. Thus the designers and manufacturers of spacecraft and launching systems and their support equipment and the industrial suppliers of the hardware and value added services have to begin their dialogues and assessments and responses to participation opportunities many years before the actual firm orders materialize. Such preliminary actions invariably cost some effort and investment of funds. Failure to recognise this usually means missing the bus. This lesson of longer term planning and flexible professional response has yet to be firmly rooted in Indian Industry.

The prime role of government in Space everywhere has been to lay down the Space industry's foundations and determine the overall direction of the Space effort. Public and private industry in India active in the aircraft, telecommunications, electronics, computers, chemicals, scientific instruments, materials and fabrication areas can see in the growth of the Indian Space programme that in spite of different historical conditions from the advanced countries, an equivalent situation is now emerging. Industry must now consciously make decisions on the manner and extent of participation in the Space effort and gear itself up to meet the challenge. A sustained government policy of providing the requisite incentives to industry would be in the national interest.

To summarise, the key features are :

- Technological
  - —Space system are highly complex
  - —They require mastery over a wide range of disciplines
  - —There is extraordinary potential for transfer to many civilian areas.

- Economic
  - —High costs to enter Space
  - —High cost of R & D and technology development
  - —Market risks high and technology diffusion a must.

- Policy
  - —Government control over access to Space inherent
  - —Long term Space Policy essential
  - —Harmony of Government and Industry endeavours crucial for both.

3. The Nature of Space Hardware, Services and Industrial Facilities

Typically Space products, hardware and services require four basic activities :—

1. The design, development, manufacture and testing of satellites which tend to differ according to their functions. These may be : Television and radio relay and networking, telecommunications, earth observation and remote sensing, weather services and scientific missions, etc.

2. The design, manufacture and launching of launch vehicles to place satellites in the desired orbits. The launchers may use solid and/or liquid propulsion modules and need inertial guidance, telemetry systems and launching ranges.

3. The construction of ground stations to control and communicate with satellites and/or receive information from them.

4. Value added services such as communication and computer networks, data and information analysis and image processing facilities and software to support the communication and television services, data display and processed information for weather forecasts and resource managers.

Industrial production processes for each of the above involve manufacture and testing of sub-system assemblies, components and often major systems. Systems engineering, reliability and quality assurance along with cost control procedures are integral part of the process.

Building a Space segment - one or more satellites - involves complex telecommunication modules, transmit and receive chains, multiplexing and microwave equipment, on-board control systems, special power supply systems composed of silicon solar panels as well as chemical batteries - all packaged for very low weight and qualified to withstand the extreme thermal, hard vacuum and radiation conditions of Space. All such functional components and systems are assembled and integrated into a platform—usually a light alloy metallic structure, along with the on-board fuel containers, apogee/perigee and altitude control propulsion motors and the passive or active thermal conditioning equipment. The structure itself uses advanced honeycomb and composite technology and some components may need special materials such as titanium and beryllium.

The design and development of Space systems undergoes a series of phases in each of which a "model" or concept of the final system is progressively "tested" and moved towards realization. These include analytical studies of systems and sub-systems derived from the 'mission' and progressing to the design and development of hardware and software. In order to check theoretical calculations and design and quantitatively assess the performance, several iteration loops may take place in the "breadboard" or "mock up" phases before a design is debugged, frozen and prototype development undertaken. This in turn is subjected to mechanical, electrical, thermal, vacuum and other environment tests in special facilities to establish satisfactory performance in flight or in orbit. The final Space flight system then emerges through a detailed integration and qualification sequence both at the sub-system as well as the fully integrated levels. Many aspects of this process have been absorbed in the aviation and professional electronic industries which are now reasonably familiar with the type certification, demonstration, validation and qualification procedures of professional high performance equipment. In the Space environment the extreme requirements of reliability, performance within closely specified limits and guarantee of lifetime makes these much more severe. Actually the whole process is not so formidable as it may appear. Given a basic understanding of and respect for the unforgiving nature of Space operations, skilled personnel and the requisite tools the process converges relatively fast to the desired goals. Nevertheless inherent problems including failures associated with such complex systems have to be contended with.

The earth stations and the ground utilization network has much potential for industrial work. Since the days of the first INTELSAT Satellite Earth Station which was established in 1967 near, Poona, many earth stations ranging from the fully steerable large antennae controlling the INSAT satellites to the small dishes for community TV sets as well as transportable terminals have been designed, engineered and built in the country. What is required now is an Industrial Structure for undertaking turnkey jobs.

Building a rocket launcher capable of orbiting a satellite requires the development, testing, integration and assembly of rocket motors (solid and liquid) with their metallic casings, fuel storage systems, nozzles, combustion chambers, pumps and compressors, etc., into rocket stages. The construction and assembly of the inertial control and guidance packages along with the vehicle telemetry and structure and protective nose cone which shields the spacecraft from the friction heating during the rapid flight through the atmosphere form an integral part of the manufacture of launchers. Formulation and manufacture of the special propellants - solid and liquid, constitutes another area of industrial activity. Here again ISRO has built up within the country virtually all the basic launcher technologies and step by step sought to associate Indian Industry to produce and supply as much as possible. During the SLV-3 Project some 57 industries were involved. Some of the industrial infrastruture built and experience gained is currently being further enhanced for the larger launchers now under development. An area which needs attention is tool design, engineering and metrology for the close tolerance manufacture of rocket hardware.

Apart from the launcher hardware there is a great deal of advanced industrial activity involved in the ground tests and propellent handling stations. Typical examples are the rocket test stands, the very special ground handling and mobile transport equipment for rocket stages, the cast and cure ovens for large solid propellent grains, the radiography and other test installations, etc. In the case of special high energy liquid propellents it was possible for ISRO to induce the Indian Chemical Industry through firm long term buy back arrangements to actually establish bulk manufacture and supply of the fuel and oxidiser to ISRO specifications.

The Space sector also includes many ancillary services required for technological applications. These include the launching stations for rockets which include specially engineered and erected launch pads, mobile service towers, radar, telemetry, tracking and data reception networks and range safety communications and data display equipment. Primarily under control of the Space agency, here again there is increasing scope for industry. For example the launch pad installations at Sriharikota with their specialized launch towers, flame deflectors, auxiliary power and service supplies and material handling equipment, all have been executed by Indian structural and other engineering industries through ISRO subcontracts. The possibilities are now emerging that except for the conduct of the actual vehicle integration and launch operations much of the servicing, maintenance and operation of auxiliary ground equipment at the launching range could be undertaken by engineering service contractors.

Such experience, if succeseful, can spillover to other operations.

An overview of the major facilities for industrial Space activity can be obtained by a visit to some of the facilities built-up by ISRO at its Centres at Trivandrum, Bangalore, Ahmedabad, Sriharikota and the National Remote Sensing Agency at Hyderabad. These are now generally familiar to many Indian industrial organisations and associations of Indian engineering industry.

Highly qualified scientists and engineers backed by experienced and skilled technicians form the core of Space related design, development, fabrication and qualification activity. Compared to other industrial operations the ratio of scientific and technical staff to administration/auxiliary manpower tends to be high. The proportions would vary depending upon the degree and nature of repetitive work content and the element of development undertaken. The proportion of engineering staff in system and sub-system development, qualification and delivery tends to be relatively higher. A sensible way for Industries undertaking Space activities is to assemble a core of qualified staff covering the key elements and disciplines for the selected area and depend upon consultancy and other arrangements to utilize the services of specialists from outside as required. This is a very effective way to maintain a trim high quality team which keeps close professional contacts with research personnel in government labs, academia as well as other industrial establishments.

The management, monitoring and providing career development for such teams needs unusual understanding and handling by corporate management. Indian Space Industry would need to pay special attention to this aspect. Such teams once assembled work best in an atmosphere of challenge and innovation. These are difficult to sustain without forward planning and insights into emerging areas. Project Directors with professional leadership qualities, technical grasp and commitment to maintain quality, schedule and cost are not easy to find and retain. It is not usual to find the emergence of new ideas and new way of doing things during the course of accomplishing a specified job. Managements have to be alert to spot the innovators and without diverting the concentration required to complete the job on hand, find appropriate mechanisms to encourage development of bright new ideas which may result in new follow-on activity or in improving the performance of whatever is on hand. The importance of establishing technical documentation and a well identified rigorous review system laid down before any job is undertaken cannot be over emphasied. These are important not only to maintain quality but also to avoid purely subjective judgements on performance and assignment of responsibility and credit among the members of the project team. A systematic review system, based on documentation and conducted in the open, with the participation of the reviewers and the project team is a powerful antidote to slipshod work. It also helps in assigning the due degree of credit to each member of the team against his job assignment and performance.

To recapitulate : For Industry to successfully participate in Space activity some basic requirements are :

(1) Infrastructure and experience in handling elements of high technology - typically this would be related for example to aircraft, electronics and precision machining areas and/or advanced chemicals and materials.

(2) The existence within the company of a "critical mass" of highly qualified scientists and engineers who are or can remain abreast with the theory and practice of conceptualizing engineering designs from stated specifications, and then realizing the actual complex systems and subsystems with their performance and quality assurance aspects fully understood.

(3) A management and financial structure which is able to support the design and production of relatively small numbers of very high value added products and cognisant of the essential role of R & D in Space related hard and software in which personnel development plays a key role.

(4) Willingness to cooperate with Government in promoting joint ventures in an organised manner.

Clearly these elements do not exhaust the attributes of a successful hightech industry but are only indicative of features without which successful participation in Space projects would hardly be viable. With some modifications these elements are equally applicable to small, medium or large Industry.

All in all while one cannot say that India has, as yet, a clearly identifiable and vigorous Space Industry, the Space effort of the last two decades and ISRO's consistent policy to develop technology and utilize Indian industry to the maximum has energised over 250 major, medium and small industrial firms. The back bone of this process has been the placing of firm procurement orders on Indian Industry which have ranged in value from 45 to 60 per cent of the annual Space budgets. The process has received a special boost since 1977 by ISRO's organised scheme of technology transfer to and utilization of industrial capacities. ISRO consultancy services have proved most useful for realizing these goals and in fact in creating engineering entrepreneurs. The industrial base needs further expansion and consolidation. This would require synergetic efforts between Government and Industry.

4. Scale and Scope of the Space Market

During the last decade approximately a 100 to 140 Space launches have taken place every year throughout the world. Of these nearly 70% were launched by the USSR, about 20% by the USA and the remainder by the rest of the world. Communications satellites currently provide telephone, telegraph, facsimile, data and TV relay to more than 140 countries and generate an annual business exceeding $ 1 billion. Table-1 summarises the level of civilian Space expenditure* being incurred during the mid 1980's by the world's major Space programmes.

*The figures are approximate and given only as an indication of the relative magnitudes. Data for China was not available. European estimates place Chinese Space expenditures to be of the same order as Japan or France.

TABLE—1

Civilian Space Expenditures*

COUNTRY	Annual Civilian Space Expenditure Rupees in Crores	As percentage of GNP	GNP Per Capita Rupees in 1000	Space Expenditure: Per Capita in Rupees	Space Expenditure: Percentage of World Total	Turnover of Space Industry as percentage of Space Budget
USA	7875	0. 2	180	312	42.20	39
USSR	7760	0. 3 to 0. 5	63	262	41.60	—
EUROPE	1925	0.05	125	62	10.32	89
JAPAN	672	0.03	126	56	3.60	80
CANADA	169	0.05	154	72	0.90	137
INDIA	126	0.07	3	1.75	0.68	55
OTHERS	125	—	—	—	0.67	—

Total Rs. 18,652 CR ($ 15 billion)

Of the approximately Rs. 19,000 Crores ($ 15 billion) annual world expenditure on Space, the US and USSR expenditures account for over 83%. Europe accounts for about 10% and Japan just under 4%. France leads among the European countries, spending about 0.11% of its GNP on Space which amounts to about 3.6% of the world total. India's expenditure can be seen to be relatively modest but appears substantial in terms of its GNP and the per capita income. As the table shows, the expenditures of the Space agencies provide a sizeable turn-over for industry even in the case of India. It is interesting to note that industrial turn-over for UK, Italy and Canada exceed the Space budgets indicating an efficient economic spin-off and boost to industrial activity not only for Space but also other sectors.

While it is inherently difficult to accurately forecast the demand for Space services and products in the future it should be recognised that apart from the countries

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with organized Space programmes some 140 countries - virtually the entire world routinely utilize satellites services for their communications and weather information needs. An increasing number are also actively using satellite remote sensing data. This implies a degree of stability and continuation of at least the existing level of activity and expenditure in support of it. Considering trends of the last decade, the current Space activities and plans of various Space agencies, reasonable projections can be made for the next ten years or so. A word of caution is in order here As noted earlier Space business is risky, highly capital intensive and directly depends on Government policy.

The projections for future Space activity are also subject to major unforeseen upsets caused by technological, economic and political events. The Challenger disaster and other recent failures of rocket launchers underscore the inherent element of risk and uncertainty in Space ventures and the need for long range planning which include plans for such contingencies. The presently booming area of satellite communications has already led to an over supply of transponders and is likely to be affected and influenced by the rapid growth of fibre optics. Similarly the rapidly developing area of satellite remote sensing is subject to political issues of national sovereignty over natural resources and dissemination of information relating to national security. Notwithstanding these sobering concerns there remains no doubt of the enhancing scope of Space activities world wide.

Apart from the USSR and USA - countries which can be expected to continue to dominate the Space scene not only through expanded projects for planetary exploration, communication and earth observation services but also because of geo political reasons - the enlarging scope of peaceful civilian uses of Space of special interest to the developing countries and India, may be seen from the plans of Europe, Japan and the countries of Asia, Africa and Latin America. The estimated number of satellites to be launched by countries other than the USA & USSR for Satellite Communications, Weather Services and Earth Observations is expected to exceed 100 during the period 1985-95. Inclusive of related launch services, this implies an expenditure of about $ 15 to 20 billion over the period. Considering the expanding world wide interest in business, air, sea and land mobile communications and the growing demand for value added products for image and resource analysis a further investment of $ 20 to 25 billion can be expected on the ground utilization facilities and services. Even on a conservative estimate the implied annual turn-over for industry could be of the order of $ 4 to 5 billion.

Of special interest to Indian industry would be the expected domestic Indian investments in Space which determine the scope for them. Here we can make estimates based on the ongoing and known programmes of ISRO and the Department of Space. As noted earlier the lone INSAT-IB satellite will soon be joined by IC in mid 1988 and towards the end of its seven year life be replaced by ID in 1989. The Indian Remote Sensing Satellite IRS-IA is expected to be in orbit in the first half of 1988. This will usher in the National Natural Resource Management Service with organised and regular use of satellite data by nearly twenty departments and agencies of the Central Government and practically all the States of India. Preparations for using the data have been on for the last seven years or more. IRS-IA will be followed by IB & IC at approximately two years intervals. The scale of these two Space based national services and the investments that have gone into operating them up to 1990 can be seen from Table-2. The table, incidentally, shows that for every rupee spent in Space it needs two or three on the ground to make use of the satellite.

The revenue from the Telecom and TV components alone of the INSAT-I system since its operationalization in 1983 will by 1990 amount to approximately Rs. 1000 crores. The benefit/cost ratio for the IRS-I based NNRMS system is expected to be even better as the remote sensing survey costs per hectare of area are estimated to be about one-third of the conventional methods and are accomplished on an order of magnitude faster in time. Thus the Space services, in time, can be expected to pay for themselves.

TABLE—2

SERVICES		Outlay in Rs. Crores upto 1990 SPACE SEGMENT	GROUND SEGMENT
	Telecom, TV/Radio :		
INSAT	Weather Observation :	370	760
SYSTEM	Disaster Warning :		
	Survey Inventory :		
	& Monitoring of :		
IRS	Resources :		
SYSTEM	*Agriculture & Forest :		
	*Water Management :	95	345
	*Geology & Minerals :		
	*Environment :		
	*Marine resources :		
	Total	Rs. 1570 Crores ($ 1.2 billion)	

Conservative estimates based on the current Space services and the increasing demands on them indicate not only their continuation but significant expansion. The INSAT-I Space segment will get refurbished by the larger INSAT-II satellites which are currently under development. In the latter half of the 90's this will consist of two co-located INSAT-II satellites plus a third active in-orbit spare. Since the meteological services may not need more than two met. payloads for redundancy, it is quite likely that the 3rd INSAT-II and subsequent spacecraft would carry additional communications or meteorological services. One can also surmise that after about a decade of operation the multi - service INSAT system would undergo a transformation, perhaps calling for separation of existing services or a new combination of Space services on the Space segment. One may also expect the IRS-I based resource survey system to rapidly grow - especially through significantly increased ground investments by the utilization sector. Indian Industry has special opportunities opening up in this area. The demand for improved resolution from 35m to 10 or 5m, would call for improved sensors on the IRS-C and subsequent spacecraft. Equal or even greater pressure for day and night capability and the ability to acquire data through cloud-cover - very important for Indian agriculture during the monsoon - will require the development of active microwave sensor systems in later spacecraft of the IRS series. Taking into account the required launch services for the INSAT and IRS systems by Indian launchers, one can also foresee special investments into cryogenic propulsion systems which would raise the PSLV launcher capabilities to place INSAT class satellites into geo-stationary orbit and the heavier active radar equipped IRS satellites into polar orbits. The cryogenic industry dealing with the production, supply, storage and transporation of liquid Hydrogen, Oxygen and Helium is just beginning in India and has much leeway to makeup.

Obviously the developments mentioned above would also call for the necessary R & D investments by ISRO. Taking all these features into account one can assess the expected Space expenditure during the 8th and 9th plans.

As against the planned expenditure of about Rs. 3,000 Cr. during the 10 year period covering the 6th and 7th plans, national Space investments of approximately 800 to 1200 Cr. annually would probably be required to sustain and develop the Space services. Thus over a ten year period a total expenditure of about Rs. 10,000 Cr. ($7 billions) can be foreseen. Even at the current level of involvement the industrial turnover can be expected to be at least Rs. 5,000 Cr. but there is no reason why this cannot be doubled - provided of course industry gears itself up in time and receives due support from Government.

Some remarks may be in order on how these requirements are likely to be met. Considering the government investments in the ISRO Space Centres over the last 20 years or so, the primary definition and development of the Space System would logically remain with ISRO. However considering the desirability of growing the interface with Indian industry - especially the aeronautics, electronics/computers/communications, chemicals, mechanical and structural engineering industries, there is enhanced scope for Indian Industry, which services these sectors, to profitably increase participation, and make a significantly enhanced contribution not only to Space but also to the national technology base.

Industrial groupings, inter-linked especially for Space and leading to the organisation of Space divisions within industry which focus on this activity would appear logical.

Since the primary experience and expertise in spacecraft and Space borne subsystem design, development and testing within the country still resides by and large in the ISRO Centres the proportion of contract work to be performed by Indian Industry in this area may at first sight appear to be relatively small. There are however excellent opportunities for industry to establish a closer partnership with ISRO in performing some of the engineering and service tasks even during the conceptual phases of projects and rapidly graduate to performing some of the primary tasks in the future. An example would be in the running and expansion of the major Space test facilities. These include thermo-vacuum chambers, vibration and acoustic tests, electromagnetic compatibility system, preparation and conduct of rocket motor tests, operation of chemical plants, etc.

As discussed earlier the development of a Space system involves the development of a series of models and mock-ups - mechanical, electrical, etc. - each of which represents a partial realization of the final full system, in which detailed theoretical predictions are closely compared with an actual physical system. ISRO's oncoming tasks in supporting two or three operational Space segments with nation wide services would need several qualified Space systems—satellites as well as launchers to be manufactured and delivered on time with perhaps an equal number of advanced systems in the research and development phase. This can be visualized to be a virtual production line of spacecraft and launchers with their sub systems and it is obviously of considerable mutual advantage that standardized tasks are taken over in a phased manner by industry with a collaborative effort in the related R & D areas.

Industry in India has seldom attempted such technolgically advanced and demanding tasks in a sustained manner, and it should be recognised that there is bound to be a phase of learning and mutual adjustments. There is however no reason to believe that the tasks are beyond the competence of Indian Industry. The technological strength gained by industry would have far reaching impact on its ability to compete in other areas apart from providing a strong under-pinning for the national Space effort.

As noted before an area of some significance where Indian Industry already has competence and experience, is in the ground segment of the operational Space systems. With the oncoming expansion of the INSAT system, especially the use of satellite links for news agencies, business and maritime communications and other special services including search and rescue missions and mobile communications, the Indian market for a whole range of earth stations and terminals - from large tracking systems to small direct receive and mobile or transportable units is emerging. One can expect, on conservative estimates, the requirements to run to several hundreds of terminals and related equipment. The overall budgetary figures may exceed Rs. 2200 Cr. over a five to ten year period.

A similar, or may be even greater, opportunity is emerging for important value added services and equipment for utilization of the satellite data from the IRS system. Here, apart from the electronics, optics and computer system hardware and software there are emerging urgent requirements for enhanced airborne operations to support the Space derived data and imageries. The current civilian aircraft operations are woefully inadequate. With the growing demands for drought and waste land management, rural and urban land use, planning and monitoring of agricultural resources, and the emerging nation-wide NNRMS system, Indian industrial enterprises should explore the growing domestic market for aerial remote sensing operations. There is no reason why the aircraft, and virtually all the survey instrumentation as well their operation cannot be undertaken by Indian Industry organised as a professional, cost effective, efficient and safe service. What is required is a light aircraft of all-up-weight below 500 kg and with about 4 hours endurance and low fuel consumption. The National Aeronautical Laboratory already has such a fully composite structure aircraft flying and ISRO/NRSA can provide all the technology to Industry for the remote sensing instruments. Some of the civilian flying clubs could be most usefully re-oriented to provide flight training for the civilian flight personnel required. The remote sensing aircraft would have several other civilian service applications making the production runs economical and establishing the beginnings of a civil aircraft Industry outside the defence ambit.

It must be noted that overseas manufacturers from Europe, USA and Japan have not been idle and have a significant presence in India in these areas. Indian users and Industry unfortunately have not capitalized on past experience and the emerging opportunities but have either been passive or shown inclination to act as import channels. In fact after the concerted efforts in the late seventies and early 80's there is again a tendency for users of Space services to revert to importing earth station equipment citing non-availability, schedule and performance lacunae in the Indian Industries' products - a familiar tune ! Public and Private Industry in India seems to avoid the consortium approach in which a group of Industries get together with an agreed sharing of the engineering and supply tasks, with one of them acting as the prime contractor. Such cooperative approaches - in which the bulk of the engineering systems and hardware work is performed within India, with very selective component acquisition from abroad, would utilize the expertise and strength of each member of the consortium and avoid unhealthy competition. For the customer it would provide a cost effective supply system with a service back-up. Regrettably if each Industry competes with the other on the basis of tie-ups with foreign manufacturers, and the users of Space services encourage this, the growing Indian Space systems and services instead of strengthening the

Industrial base would end up in channeling scarce Indian resources to Industry abroad. This would indeed be a great pity.

It is worth noting that earth stations and ground station equipment are needed not only for Space systems. The major sub-systems - antennae, sensitive receivers, high-power and low noise parametric amplifiers, tranmit-receive chains, multiplex systems, telecommunication and data transmission and image processing and analysis equipment are also required in large areas of the domestic professional technology market which includes education and scientific research instiutions, R & D Laboratories, news agencies and facsimile transmission users, audio and video equipment and the hospitals and health services as well as defence. It is obvious that were the Indian Industry to seriously gear itself up for the oncoming domestic Space requirements, with some enlightened and sustained help from government, it could also hope to participate in an expanded domestic as well as the international market - especially relating to programmes of the neighbouring developing countries. While Indian Industry seems to have remained somewhat passive, Europe is very active in the 3rd world countries promoting studies of the use of Space systems with the expectation of later sales.

The sizeable requirements of satellite communications and use of remotely sensed data for the Middle East, the Continent of Africa, South East Asia and Australia provide additional scope and opportunities for Indian Industry and potential avenues for mutually advantageous South-South cooperation.

The Arabsat system is already in place with virtually all elements of the Space and ground segments procured from Europe and USA. For a variety of reasons its full use has yet to materialize. Large areas of Africa remain very poorly linked and served by modern communications. Estimates for an AFSAT system with two satellites carrying 20 to 30 active transponders for telecommunications and TV distribution and covering the whole of Africa indicate expenditures of the order of $ 800 million, of which nearly 75% would be for the ground segment. Africa already receives the US Landsat and the French Spot spacecraft imageries and data but the users are as yet nowhere near using this technology on an operational basis. Here is another potential market for the Indian Space Industry. Indian industrial organisations which actively serve the domestic Space market and also have earlier collaboration agreements with advanced industries abroad should with ISRO's assistance be able to trade the supply of their own Space products to European, Japanese and US prime contractors through sub-system sub-contracts against payment or transfer of new know-how. They would, of course, have to be competitive in cost and performance.

5. Issues of Policy and Industrial Action

The surmise of the preceeding paragraphs is that the scale of on coming national investments to sustain Indian Space Services over the next decade cannot only provide a significant and profitable domestic market for Indian Industry, but also help it to acquire technological muscle to enlarge its capability for increasing the value added component in other areas and so eventually capture a part of the growing international market in high technology applications - especially in the developing countries which are likely to be a target for Space applications.

The achievement of this object has some imperatives. First of all the nature, time scale and sharply tuned objectives of Space projects, necessitate advance actions on the part of industrial establishments - otherwise they will miss the opportunity. This advance action implies an understanding of and familiarity with the broad oncoming areas where Space services would be expanding into. Part of the general information base is available on the basis of the existing Space services and an awareness of the technical and technological trends elsewhere in the world. This however, is not enough and efforts from industry as well as Government are required. When development of existing services or new ones are being planned by public agencies it is wise and important for government as a measure of considered policy in public interest to inform

Indian Industry early enough. For this purpose general, vaguely worded public pronouncements at inaugural and other ceremonial occasions are of little value. These lack the definition and concreteness for professional system engineering assessments from which only can industry derive a clear measure of what may be involved and whether a professionally rewarding and profitable involvement is called for.

The essential mechanism for this is an information system for Indian Industry during the study or conceptual phase of projected Space activities. To be effective these study or concept phase activities in industry have to be rigorous and industry must be prepared to invest in them. What usually happens in many cases is that the public agencies, charged with the responsibility of planning and introducing a new system or developing or modernising an existing one, proceed to "informally" obtain information from interested "parties". In case of advanced technological systems there being few Indian industrial concerns who can meaningfully respond, recourse is taken to firms abroad and their ever present representatives in India. Once this starts the familiar process of requirements getting more or less tailored to what Industry from abroad can offer takes place. Indian Industry seldom exerts or exercises any real professional engineering system analysis, or design assessment but usually hopes to either become the junior partner with licence production at best or at worst act as a procurement channel. The time factor inevitably works against the new comer industry especially in high-risk and expensive areas such as Space. A major departure from this self-defeating and retrograde process can occur only if government and Indian Industry begin a business like, serious process of discussion and professionally clear arrangements at the concept or study phase itself, with the clear knowledge on all sides that the studies would involve some expenditure and may or may not lead to a full development or procurement contract.

The process is familiar in virtually all international industrial contracts for not only Space but also for many other advanced projects. It is also not completely unknown in India. What appears to be lacking is a clearly understood procedure right from the concept to the final phase, openly and fairly conducted in a professional manner with competing organisations undertaking clearly defined engineering and technical work in each phase for which they make some investment and can hope to receive reasonable compensations.

Another issue of prime importance relates to costs. As noted earlier, compared to most other industrial products. Space hardware do not easily lend themselves to quantity production. Nevertheless considering the high investments in research and development and in creating the infrastructure special efforts are called for to fully capitalize on proven designs already developed. In the past there has been a strong tendency on the part of Space scientists, engineers and designers to innovate new technologies for virtually every new project. The trend was probably set by NASA, the US lead Space agency pushing the-state-of-the-art on every occasion. For a cost effective and affordable Space programme India will have to learn to make the best use of its investments by lengthening the production runs of its satellites and consciously find ways of using elements of the sub-systems and technologies in other areas. Government policy in this regard also needs to evolve since, if nothing else, resource constraints will dictate severe limitations and if stop-and-go decisions are to be avoided in the public interest. The issue is complex and will demand serious long range planning and dialogue between Government and Industry.

Among the possible approaches to such issues Indian Industry should be encouraged to make full use of the facilities and trained manpower set up for earlier Space projects. Such actions by Industry would be helped if long term assessments are converted into reasonably firm indications and orders for Industry. Typically in major Space hardware such as satellites and launchers production of the whole, or in sub assemblies, in quantity rapidly lowers the cost and sustains reliability. Ariane Space the French organisation providing the European launch services has assessed that by placing orders for

50 launchers the cost per launch would be lowered by 25% a matter of some $ 10 million per launcher. This philosophy and its variants, is imperative for the PSLV & GSLV launchers leading not only to savings for the national exchequer but also eventually making the Indian launchers more competitive internationally. One can also learn some useful lessons from the conduct of the USSR Space programme in this regard. While not ignoring the technology imperatives world wide for improved systems and not shying away from the related R & D investments the Soviet Government has not allowed these to displace the prolonged use of well-tried systems on the ground of being outmoded. The Soviet launchers in operational use today were engineered in the late sixties—once proven they have been produced in large numbers for the USSR programme and are now emerging in the international scene at prices which no one can beat - except politically !

The emerging Space industry on its part must recognise the complexity, high cost and risks in the Space markets and organise itself. One important step would be the formation of an Indian Space Industries Association (ISIA). While some preliminary thinking and actions have already taken place during the ISRO-Industry dialogues much more needs to be done. ISIA could constitute a professional forum for cooperation with Government in Space and help minimize for its members the impediments and risks inherent in Space activities. It could also help to evolve acceptable institutional mechanisms for servicing and use of the national Space assets built-up through public investment.

6. Conclusion

Developments in the maturing Indian Space programme and the world wide expansion of Space activities indicate a good opportunity for Indian Industry for greater professional investment and involvement in Space business. If effectively pursued this would strengthen the national technology base as well as contribute to a more efficient execution of the expanding national Space services. While the central role of government, a feature of all Space efforts the world over, is likely to remain, Indian Industry must now receive the requisite incentives for an expanded role in the domestic Space market, thereby lowering costs for domestic Space activities and also qualifying it for competing in the growing international market for civilian Space and other products. Indian experience in tailoring Space hardware to clearly defined service objectives in Space communications, meteorology and application of remote sensing technology to resource assessment and management can prove a valuable asset for cooperation with other developing countries in the Asian and African regions in their effort to utilize Space technology.

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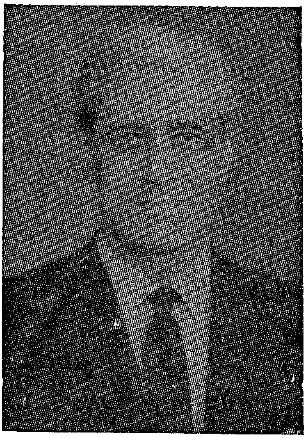

PROF. SATISH DHAWAN

Prof. Satish Dhawan M.A., B.E. (Punjab), M.S., Ph.D (Caltech), D.Sc, (honoris causa) from Roorkee, Bombay, Panjab and Delhi Universities as well as from IIT Madras and Cranfield Institute of Technology, U.K., had been Chairman, Space Commission, Secretary to Government of India, Department of Space and Chairman, Indian Space Research Organisation between 1972 and 1984. During 1984-85 he was Senior Adviser, Department of Space and since 1985 he is a Member, Space Commission. Prof. Dhawan was earlier Prof. and Head of Department of Aero Engineering (1955-62) and Director (1963-1981) of the Indian Institute of Science, Bangalore. He was visiting Professor of Aeronautics, California Institute of Technology, during 1971-72.

Prof. Dhawan had been President of Indian Academy of Sciences as well as President and Honorary Fellow of Aeronautical Society of India. He is a Fellow of Indian Academy of Sciences, Indian National Science Academy and Royal Aeronautical Society, U.K.

Prof. Dhawan has been associated with various important national committees. He had been Member, Scientific Advisory Committee to the Union Cabinet, Member, National Committee on Science and Technology and Member, Science Advisory Committee to the Union Cabinet.

LALA KARAM CHAND THAPAR

Late Lala Karam Chand Thapar, the founder of Karam Chand Thapar & Bros. Ltd., was born in 1895 in a modest Punjabi family at Ludhiana. He was one of those rare individuals who, by their own energy and acumen, built up from the smallest beginnings, a large industrial organisation in their own life time.

After receiving his education at Punjab University, he started his career as a businessman at Ludhiana (Punjab) in 1917, moved over to Calcutta in 1920 and continued the expanded business in the firm named Karam Chand Thapar & Bros.

In 1929 it was incorporated in the name and style it bears today, which formed the nucleus around which the present structure has been steadily growing up. Initially, the firm confined itself mainly to buying and selling coal. Soon afterwards it expanded into coal raising contracts, lease and ownership of collieries. The years that followed witnessed the widening up of business horizon pertaining to coal, paper, textiles, sugar, spirit, starch, radios and engineering goods, forming a large industrial complex in the country.

Lala Karam Chand Thapar was able to foresee industrial potentialities of the country necessary to sustain a developing economy. He applied himself with zeal and energy to the task of setting up industrial units with professional management structure evolved on the pattern of contemporary British firms in India. All this symbolised by the dynamic character of his personality. His pioneering work, in due course, led to the foundation of the Organisation which brought it not only to the rank of sixth biggest industrial house in the country but also has put itself on the way to expansion and development with intensive activities outside India in paper manufacturing, pulp making, glass industry, textile manufacturing, edible oil manufacturing, hoteliering, etc.

Substantial as the achievements of Lala Karam Chand, in the industrial world, were, his contribution to guidance of industry as a whole was no less. In fact there was no sphere of activity in which he did not take part and which did not bear the imprint of his varied and mature experience and bold outspoken personality. Among the various responsible offices held, he was one of the founders of the Indian Sugar Syndicate and its Chairman from 1937 to 1942. He was the President of the Indian Sugar Mills Association, All India Organisation of Industrial Employers, Indian Chamber of Commerce, Calcutta, a Committee Member of the Commerce, Calcutta, a Committee Member of the Indian Mining Association, Member, Central Advisory Council of Industries, Iron & Steel Advisory Council, Standing Committee for Scientific Research and Industry, Direct Taxes Central Advisory Committee & Export Promotion Committee. He was one of the oldest committee members of the Federation of Indian Chambers of Commerce and Industry and its President in 1961.

Lala Karam Chand Thapar was one of the most respected industrialists of the country besides being a philanthropist, educationist and humanitarian. In mid-fifties, jointly with the then PEPSU Government, he created Patiala Technical Education Trust, which established the Thapar Institute of Engineering and Technology at Patiala, a foremost Engineering Institute with Post-graduate, Under-graduate and Diploma level technical educational facilities in Northern India today.

Because of his wide knowledge and experience in business Lala Karam Chand's advice was often sought on vital policy aspects confronting the Industry, coal, sugar, paper in particular. As the CAPITAL wrote, at the time of his death in 1962 :

"The influence of his thinking will continue to shape the policies of the Indian Industry for many years to come."