Space and Industry

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SHRI RAM MEMORIAL LECTURE

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ON this occasion we pay homage to Lala Shri Ram, a pioneer not only in the industrial development of India, but also in many facets of its socio-economic welfare. The spirit that he infused in all his endeavours has left us a legacy in industry, research, education, community service — indeed, in a large sphere of national life.

I am honoured to give this lecture in his memory and to affirm his faith in the future of India.

1.0 Introduction

The technologies of the 18th and 19th centuries were comparatively of a simple mechanical kind. In the 20th century, especially after World War II, a profound change has come about and today technology occupies a pivotal role in the economic and social life of nations. Advanced technology grows out of and intimately interacts with scientific discoveries especially those relating to the nature of matter, energy and living organisms. A characteristic feature of modern technology is its intimate and dynamic interaction between scientific discovery and in forcing technological innovation.

1.1 No doubt even today there is some debate among people about the beneficial and harmful effects of technology and industrialisation. However, the fact of the matter is that no nation can afford to deny for its population the benefits of modern medicines, transport or communications. Neither can nations with large and growing populations fend for and defend themselves without the products of industry which are based on modern technology and the application of advanced scientific knowledge.

1.2 To be sure many human problems — especially in the developing countries — have yet to find solution. In India although much has been accomplished, we have yet to adequately feed, clothe and house millions of our countrymen. Some people have apprehension that development programmes using advanced technology are depleting non-renewable natural resources and damaging the environment. However, a little serious thought will show that these ills cannot be laid at the door of technology but are rather due to deficiencies in the choices of technology and the manner in which these were introduced and the products distributed. Social wisdom and the application of modern technology do not automatically come together. Choices have to be exercised and these require, apart from scientific knowledge, social, political and economic judgement.

1.3 The new technologies of Space, nuclear and genetic engineering have created new opportunities to solve old problems, opened new pathways for a better life on earth but their application is not simple. We have to learn to carefully choose the best pathway for our country — maximising socio-economic returns for the mass of our people while minimizing the new problems which are bound to arise in a period of change. To do this, we have to have faith in ourselves and learn to take calculated risks. The benefits of the new technologies do not come second hand. Industry has to learn to look ahead and to cope with the risks of ventures. If modernization and improvement is not undertaken competition and the market does not forgive the enterprise which lags behind. On the other hand, if public interest has to be served and governments must take a guiding hand, this should not make the controls and regulator processes stifling and neglect the promotional aspects.

2.0 The Nature of Space Technology

At the beginning the exploration of Space and development of Space technology were fuelled by a combination of scientific and military objectives with national prestige playing an important role. Economic forces were, at first, not the determining factors for the Space programmes of the pioneer nations.

2.1 Today, some 25 years after the first Sputnik went into orbit, economic applications of Space technology are already widespread and all advanced countries regard their Space programmes as a vital component in the industrial health and ability of the country to compete in international markets. Apart from Defence, the economic objectives have become a vital part of Space efforts. Satellite communications, meteorology, survey and mapping of natural resources, navigation are now regularly used in one aspect of national life or another by over a 100 nations — among these there are at least 50 developing countries who regularly use one aspect or another of services derived from satellites — the most common being telecommunications and weather information.

2.2 Space flight is primarily a matter of technology rather than science. It is true that the design and development of rockets and spacecraft draw heavily upon the knowledge of many sciences. But this complex combining of technical knowledge from many disciplines to achieve a set task in a very inhospitable environment is essentially an engineering systems job with management techniques which have evolved to deal with the large scale, complex and high risk ventures in which a large number of individuals and institutions are interlinked.

2.3 The characteristic features of Space missions are:

a. They are complex and large scale : Launch from one location but circling the Earth.

b. Scientific/technical knowledge from a very large number of disciplines is pooled along with systems, management.

c. There are special procedures to design, validate, test, qualify and fabricate spacecraft and rockets to extreme reliability.

d. The inherent complexities of man-machine and information management utilize new concepts of systems engineering — reliability and quality control, project management and organisational structures and processes.

In each Space mission attention has to be paid in detail to:

* The launcher — the rocket system and the range from which the launch takes place;

* The spacecraft — which contains the instruments which must survive and work in an accurate and controlled manner in the hostile environment of hard vacuum, where extreme temperatures, radiation and electro-magnetic fields are encountered;

* The ground control systems which track and control the spacecraft and rockets through radio-telemetry links; and
* The Data/Utilisation Centres which receive the information and transform it into useful form and disseminate it to the users, who may be located countrywide or in different countries.

2.4 Practically all directly useful applications of Space technology viz., satellite communications, remote sensing, navigation, geodesy, etc. are essentially 'information transactions'; that is to say, a space system is uniquely capable of gathering, relaying, and transmitting very large amounts of information from and to large areas of the earth. The technology is such that instantaneous information connections, so-to-speak, are practically possible point-to-point as well as area to area. In this connection it is interesting to note that economic development of nations and societies is even more profoundly linked with 'information transactions' than 'energy transactions' which are often cited as indicators of advancement. This feature has important implications for the future directions for the growth of industries and services. Already the world is beginning to see the physical limitations to industrial growth based on energy and material resource constraints. However, increasingly modern human society is seeing a remarkable relative growth of services which depend on information which is capable of being stored, transmitted and retrieved by electronic means and uses decreasing amounts of energy as well as materials. The spectacular growth of computers, word processors and robotics and the information industries is witness to this. Application of Space technology is central to this feature and there seem to be no natural limits to growth in this direction.

3.0 Space and Industry Linkages

It is clear that like all human ventures Space technology has historically appeared in response to tangible and intangible human urges. Over the years there has been a transformation from scientific exploration (curiosity, adventure, seeking knowledge) and national prestige and defence (pride, desire to dominate and control) to the fulfilment of economic and other needs on earth. We note that modern industry is also basically an organised attempt by society to efficiently meet the complex needs of the large populations of the world. Some industries such as steel, energy and transportation directly enter into economic life while others like the perfume and cosmetics industries are part of human societies since time immemorial and make humans what they are!

3.1 It is therefore not difficult to conjecture that natural linkages would exist between Space technology and industry. First of all the execution of Space missions requires all sorts of hardware. Even though the missions are unique and often outside the experience of a particular industry, the very nature of engineering utilises the existing fabrication, tool and materials industries — often stretched to their limits in the manufacture of the parts which go into rockets and satellites. This is the direct linkage between Space activities and industry.

3.2 Satellite communications is a typical example: Geostationary satellites act as complex relay and switching stations in orbit and provide interconnections — telephone, telex and teleprinter, radio and TV, not only between two widely separated individual fixed points but also between whole geographic areas. They enable area-wide multiple route coverage. Thus one INSAT satellite stationed over India will interconnect all regions of the sub-continent as well as the outlying islands such as the Andaman/Nicobar and Laccadives. Using the Indian Ocean INTELSAT satellite, India is now directly connected to all major countries of the world. Apart from the spacecraft the ground segment or telecommunication network consists of earth stations, switching equipment, etc. Indian industry has already supplied a substantial part of the ground station equipment for the INSAT system. These include :

— the earth stations along with control equipment

— High power amplifiers

— Ground communication equipment such as multiplexers

— Single channel per carrier equipment

— Power supplies

— Cooling equipment

— Low cost TV (direct-from-satellite) receiving stations

— Mobile satellite communication terminals etc.

3.3 Apart from the 'direct' involvement through supply of equipment and services there is the so-called 'spin-off' to industry. Those industries which undertake to work with the Space technologies invariably find that the demands of extreme reliability or complex specifications and performance force innovation. For examble, in fabrication tasks extreme tolerances would be required calling for special tooling and measurement techniques. Similarly high strength and light weight requirements lead to use of special materials such as special steels, titanium or beryllium or composites. The processing of such materials requires changes in metal cutting, heat treatment and forging processes etc. The successful solution of such problems brings into being new industrial technology with wider applicability. In this area we are still in the beginning stages in India, but the process has begun and if industry looks ahead and seizes the opportunity there are many exciting things possible in the coming years.

3.4 In all countries advanced technology and especially Space technology has acted as a growth catalyst to existing industries and through the generation of new technologies created new industrial potential. As an example, the stimulus given by electronics, computers, aviation, new chemicals and special materials to a whole range of manufacturing process industries, has transformed them radically. In Europe the organisation and implementation of the European Space Programme during the last 15 years has resulted in a remarkable strengthening of the industrial base and the ability to compete in international markets. France and West Germany lead in this. Studies have shown that for every dollar invested in Space technology, the industries that have actively participated have already reaped nearly threefold benefit.

4.0 Goals of the Indian Space Programme

The central objective of the Indian Space effort is to achieve as rapidly as possible 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. Such applications are made possible by the unique capabilities of satellites to reach large geographical areas and interlink by telephone, TV and radio, and also gather resource information over the whole sub-continent. The greatest benefits of Space technology accrue when this inherent large scale feature of satellites is recognised and fully utilized.

4.1 The effort in attaining these objects has also to be a large scale endeavour. The designing, building of satellite and launching them means first of all trained manpower, the setting up of special facilities and laboratories, the planning and execution of large scale experiments before launching operational systems on which many national services will come to depend. In this endeavour ISRO has been active for the last 15 years or so. Over this period the Space activities have forged links with many other departments of government and with industry.

4.2 Some 5 years ago the Department of Space had taken a policy decision that in all Space projects the maximum use of Indian industry will be made. This is being implemented step by step. The main features of this are:

a. Technology transfer to industry on products and processes developed by ISRO;

b. Placing orders on industry consistent with meeting the specifications;

c. Involving Indian industry in fabrication and development of systems required by Space projects.

We can discern three phases in the evolution of the Indian Space Programme and its interactions with industry.

In the first phase ISRO established the laboratories, collected and trained the manpower by undertaking R & D tasks. Typical of these was the development of sounding rockets for study of the atmospheric regions up to about 300 km above the earth. About 1,500 such rockets have been built. In this phase most of the hardware and equipment was developed by ISRO scientists and engineers and only common materials and chemicals and simple hardware obtained from industry.

4.3 From 1970 to 1980 there was a major change since after planning and conducting the SITE and STEP experiments, ISRO took up the design and development of the satellite launcher SLV-3 and of the satellites Aryabhata, Bhaskara-I & II, Rohini and APPLE. In this phase our collaboration with industry naturally increased especially in the establishment of ground based facilities. Indian industry also undertook some major fabrication tasks for the Space projects. Typical elements were ground electronics, raw chemicals, a range of tools, equipment, jigs and fixtures, testing and transportation equipment.

In these activities ISRO engineers actively worked with industry from the specification stage to the final product. Every effort was made to suit the design to available capability and materials without, of course, jeopardising the performance and reliability criteria. A modest beginning was also made in licensing industries for using ISRO developed technologies to supply ISRO requirements as also needs of others outside the Space programme. However, during this phase only a few industries accepted major responsibilities and committed themselves for the Space projects.

4.4 We have now entered the third phase when plans, production lines and divisions of large industrial undertakings have been set up with ISRO technology or a combination of ISRO R & D and the experience of industry to meet the needs of Space as well as applications of other departments of government. Plants and production lines have also pegun to be established to utilise ISRO licensed technologies for non-Space applications. At least two major chemical plants have been set up by industry exclusively for meeting ISRO's needs. ISRO has also organised technical consultancy services which cover a fairly wide range of technical disciplines so that ISRO's experience can be utilized widely by industry.

4.5 Some illustrative exambles of Indian industry's work for Space and the transfer of technologies to Indian industry from Space are given below:

Typical Indian industries' contribution to Space projects:

* Electronics components packages and computers

* Earth station antennae and control equipment

* Standby power supplies and cooling equipment

* Components and subsystems for special test equipment viz., vibration and balancing machines, thermo-vacuum chambers

* Fabrication tasks — jigs and tools

* 50 industries in 22 cities of India participated in the SLV-3 project

  — Rocket casings and interstage structures

  — Fins and base shrouds

  — Launch pad structure (Launcher)

  — Rocket transporters

* Supply of special propellant ingredients

Typical technology transfer from ISRO to industry :

* Electronics subsystems and packages
* Silver-Zinc cells (for rocket applications, typically)
* Fabrication techniques for special steels
* Communication equipment :
  — Earth stations
  — High Power amplifiers
  — Direct Receive TV sets
  — Digital equipment
  — Radio Networking Terminals for AIR
* Special instruments
  — Pressure, Force transducers
  — Spectro-radiometer
* Special chemicals and process technology
  — Polyols
  — Fire extinguishing materials
  — Phenolic resins
  — Bonding materials

4.6 The new Space projects — ASLV and PSLV launch vehicles and the Indian Remote Sensing satellite — which involve an expenditure of over Rs. 300 crores in the next 6-7 years should bring in the 4th phase of Space-Industry co-operation in India. It is our hope that the bulk of the investments will flow into the Indian economy — especially the Indian industrial and technology sector and create a multiplier effect through a wide range of advanced technologies and help upgrade quality and reliability, technical skills and bring economic benefit as well as technological strength. Active industrial participation not only directly helps the Space activities but also is, technologically and in the long run, economically profitable for Industry. A good beginning has been made but we have a long way to go and together with industry tackle and solve the problems of costs and contracts, schedules and performance standards demanded by the high risk ventures which all Space missions are.

5.0 Remote Sensing and Industry

Finally I would like to share with you the potentials and opportunities held out by a large emerging Space applications area in the coming years. This is the Indian Remote Sensing Programme for the management of the country's natural resources and also help in monitoring the environment. In a way this serves to illustrate what I have said earlier.

5.1 Remote Sensing is the technique used to observe and gather information from distant objects. The entire band of the electromagnetic spectrum, from microwave to the ultraviolet, is selectively used to survey and study the surface of the earth and oceans. Radiations from the target areas are received by appropriate sensors in aircraft and satellites, and the data transmitted back to ground stations. Modern data interpretation techniques are employed along with other sources of information, including data measurements on the ground to yield important information required by scientists, planners and administrators in various disciplines of agriculture, forestry, hydrology, geology, meteorology, etc.

The sensors and ground truth data collectors can be simple cameras or radiometers, or complex high resolution multispectral scanners and active radars. Interpretation equipment ranges from simple optical projectors or complex array processors and interactive computer systems.

5.2 After a series of elaborate consultations with users, scientists, State Governments, national planners and Central Ministries, a National Natural Resources Management System is currently under evolution in India. The utilisation of the Indian Remote Sensing satellite, now under development by ISRO, will be a major component of the resource managing system. A preliminary survey shows that simple opto-electronics ground truth equipment, like radiometers. and interpretation equipment like colour additive viewers will be required to the tune of Rs. 5 to 10 crores over the next 3 to 5 years. A number of these equipment have been indigenously developed in ISRO and NRSA and we will be transferring these technologies to capable manufacturers of electro-optic equipment and instruments.

5.3 The market for computer-based interactive systems including mini-computers, microprocessors, array processors, interactive peripherals, opto-electronic recorders, photographic recorders, etc., may be of the order of a 100 systems in various parts of the country, worth some tens of crores of rupees. The ultimate demand would really depend on how industry nurtures this market in terms of quality products, reasonable prices, timely deliveries, after-sales service and supply of consumables. There would be an additional demand for high quality printing and photographic products for the generation and distribution of data products.

Due to the very nature of remote sensing applications in diverse fields it has a large potential market. If Indian industry does not take up the challenge and act in time to develop and supply these equipment and materials, the user community, which is developing fast, would look outside, and foreign industry would reap the benefits. There is thus a need to establish production lines in India on many items in a year to two from now.

5.4 Here let me digress a little to give a feel for the magnitude of information that remote sensing technology is capable of generating.

The Indian Remote Sensing satellite will operate in a nearly North-South orbit approximately 900 km above the earth. Every day it will pass over India 7 to 8 times — each pass being of a duration of 5 to 10 minutes. In each pass over the sub-continent the satellite instruments will gather information and data over India relating to agriculture, forestry, water bodies, geological features, coastal features, etc. This information will be directly conveyed by telemetry down to the data receiving station at Hyderabad and recorded on digital tapes after several complex corrections relating to atmospheric and other effects.

In each pass over India the data sent down will be equivalent to some 4,000 volumes of 300 pages each — roughly a good sized library of about 10,000 books-each day! In about ten years' time, with actvie microwave sensors which can gather data day and night and in all weathers, the capability to gather data by satellites would increase by an order of magnitude.

5.5 Dealing with such large amounts of data requires quick processing, storage, archival and timely dissemination. This calls for developing and handling a tremendous amount of software and of course use of modern communications. Quantitative information technology is an emerging industry, vital for modern development and the business opportunities are yet to be fully understood. In remote sensing applications it would require team efforts from mathematicians, physicists, agricultural specialists, geologists, economists, computer scientists, and a whole range of engineering and industrial services.

5.6 Before I close, it may be worth relating some international experience based on the Landsat satellites. About one-third of Landsat data products were sold by NASA to the petroleum industry. In the USA and Western Europe many industries are producing remote sensing interpretation and ground truth equipment and software; some companies are even contemplating themselves buying and operating remote sensing satellites as a revenue earning service. Many developing countries in Asia, Africa and South America, have shown keen interest in the use of remote sensing data for their own resource development and assessments and set up Remote Sensing Centres. Some of these countries will also require remote sensing equipment, and Indian industry, if it gears up to meet internal Indian demands, can be in a position to supply equipment and services to these countries.

5.7 I have touched on the potential direct benefits which industry can derive from remote sensing technology. The indirect benefits require a deeper look. Remote Sensing is intended for better management of natural resources in the country. It is these resources which feed and sustain the nation and its industry. A Soviet report estimates that the savings, in studying geological structures in a territory of one million square km from space, would be around three million roubles (approximately Rs. 3 crores).

Some of the newly emerging aspects of Space technology especially in relation to ocean engineering and technology, are also likely to open up further avenues for industries in the coming years.

6.0 Conclusion

In India we have a mixed economy. Political processes and the evolving social needs since freedom have created their own compulsions for technology. In vital national sectors such as health, food, defence, energy, transport and communications, etc. the compulsions to adopt up-to-date technology include the compulsion to achieve this in a self-reliant manner. Space can help all these.

In its struggle to build a better life for its people. India, with its large population, resources and unique social structure and a hallowed tradition, cannot but use advanced technology and science — we must, as rapidly as possible, through education and training and industrial entrepreneurship make our selections, master the new technologies and put them to use.

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