INDIA'S SPACE PROGRAM

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CERTIFICATE

Certified that the dissertation entitled "INDIA'S SPACE PROGRAM" submitted by Mr. S. KALYANARAMAN in partial fulfilment for the award of the degree of Master of Philosophy has not been previously submitted for any other degree of this or any other University. To the best of our knowledge, this is a bonafide work.

We recommend that this dissertation be placed before the examiner for evaluation.

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GRAM : JAYENU TEL. : 667676, 667557 , TELEX : 031 ...

to my parents

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CONTENTS

PREFACE

Human thoughts on space exploration can be traced to all ancient civilizations. The motives behind these were varied. According to Geoffrey Pardoe, it was the curiosity to understand the meaning of life among philosophers, the desire to know more about the Universe among scientists, while to others space represented another "realm of exploration." It was only after the advent of the Space Age in 1957 that scientists began exploring the possibilities for utilizing space technology for practical purposes. And the first application was for military purposes in the form of missiles.

Unlike the programmes of the developed countries, the Indian Space Programme did not evolve either out of military programmes or because of the compulsion created by the autonomous development of technology. The Indian programme was conceived for the purpose of utilizing space technology to achieve practical benefits in the social, economic and industrial spheres.

This study is an attempt at a) understanding the reasons behind India's decision to develop space technology and, (b) evaluating the Indian Space Programme. While the first chapter deals with the Indian perceptions on space technology, the second chapter discusses the policy measures initiated by the Government of India to achieve the goals of the Programme. Chapter III gives the details of the projects undertaken as part of the programme and, Chapter IV enumerates the benefits derived from the programme.

CHAPTER - I

INDIAN PERCEPTIONS ON SPACE TECHNOLOGY

PERCEPTIONS

The initial efforts towards mastering space technology were made by the United States and the Soviet Union in the field of rocketry with the purpose of using missiles for military purposes. The American and the Soviet space programmes developed "out of explicitly military programs designed to create ballistic missiles for the delivery of nuclear weapons."[1] This was the case with France and China also.

Hence, science analysts have generally viewed space programmes as being "directly linked to the destructive system of reliance on force and violence in the international arena ...",[2] and civilian applications as representing spin-offs from military Research and Development and not the objectives of policy.

This has not been the case in the development of India's

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1 William Schauer, The Politics of Space : A Comparison of the Soviet and American Space Programs, (New York, 1976), p.41.

2 Baldev Raj Nayar, India's Quest for Technological Independence : The Results of Policy, (New Delhi, 1983), Vol. 2, p.391.

Space Programme which has been "deliberately linked to the productive, rather than the destructive, system ..."[3], with the priority being assigned to socio-economic objectives.

This divergence in India's approach to the development of space technology can be said to have arisen largely due to the problems which the Indian leadership had been confronted with in the years after independence.

India, ranked among the poor developing countries of the world, has been beset with the problems of poverty, mass illiteracy, frequent natural disasters, etc.... As a solution to these problems, the planners, under the leadership of Prime Minister Nehru, decided to embark upon a policy of rapid industrialization using the latest techniques in the field of science. The goal was to improve the socio-economic conditions of the people.

Much emphasis was laid on the role of science and technology in national development. As Prime Minister Nehru stated : "I do not see any way out of our vicious cycle of poverty except by utilizing the new sources of power which science has placed at our disposal."[4]

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3 ibid,

4 Quoted in F.A. Long, "Science and Technology in India: Their Role in Development", in John W. Mellor, ed., India: A Rising Middle Power, (Colorado, 1979), p.221.

In accordance with this view, a Scientific Policy Resolution was adopted by the Government of India in March, 1958. The Resolution stated that the key to 'national prosperity' lay in the effective combination of technology, raw materials, and capital. And, among these three factors, it identified technology as the most important, since the adoption of scientific techniques " can make up for a deficiency in natural resources, and reduce the demands on capital."[5]

The Resolution also asserted that "reasonable material and cultural amenities and services can be provided for every member of the community" only through the adoption of the scientific approach and the use of scientific knowledge.[6] In general, the Scientific Policy which the Resolution enunciated aimed at securing "for the people of the country all the benefits that can accrue from the acquisition and application of scientific knowledge."[7]

Thus, the evolution of science policy in India was largely determined by the social and economic needs of the country. At the same time, as Possony and Pournelle point out, "technology has a momentum of its own."[8] So, the evolution of Science Policy

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5 Government of India, <u>Scientific Policy Resolution</u> (New Delhi, 1958).

6 ibid,

7 ibid,

8 Stefan T. Possony and J.E. Pournelle, <u>The Strategy of Technology : Winning the Decisive War</u> (Massachusetts, 1970), p.8.

can be said to have been the result of the interaction of these two factors. It was due to this interaction that" a major thrust was provided, right at the beginning, to such areas as atomic energy, electronics, space, etc ...." [9]

The Indian planners believed that space technology would provide significant contributions "to the solution of problems such as overpopulation, mass illiteracy, frequent natural disasters and poor exploitation of resources." [10] So, the major aim of India's space programme has been to utilize space technology for the cause of social and economic development with major applications in the areas of satellite-based telecommunications, satellite remote sensing and satellite- based weather forecasting.

The Indian scientific leadership has felt, according to Nayar, that given India's size, diversity and backwardness space technology is, in the long-term, a cost-effective solution for her problems in these three areas. [11] This view is also shared by other scientists in the world who view space technology as "an

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9 "Science and Technology:An overview of Achievements," Indian and Foreign Review (New Delhi) vol .23, no.3 (Nov.1984), p.20.

10 Stephen F. Von Welck, "India's Space Policy : A Developing Country in the Space Club," SPACE POLICY (Kent) vol.3, no. 4 (1987), p.326.

11 Nayar, n. 2, p.435.

ideal tool for modernization of the underdeveloped areas of the world", especially in the fields of telecommunications, remote sensing and meteorology.[12]

For example, it has been estimated that 75 percent of the villages involved in the Satellite Instructional Television Experiment (SITE), conducted in 1975-76 using the American ATS-6 satellite, can be covered through a ground-based system only at three times the cost of SITE, which was about Rs. 13 crores.[13] Sharma notes that if the entire country were to be covered through a ground-based television system, it would take many years and would, moreover, involve a heavier financial burden and also the requirement of trained manpower on a large scale.[14]

This is also the case for the provision of a telephone system for the country. According to Yash Pal, India would have

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12 Lani Hummel Raleigh, "Space Technology and the Developing Nations," in U.S.Congress, House of Representatives, Report of the Subcommittee on Space Sciences and Applications of the Committee on Science and Technology (Washington,D.C., 1977),p.542.

13 Quoted in L.K. Sharma, "After the End of SITE : The Costs of Interruption, "Times of India (New Delhi), 6 Aug. 1976.

14 ibid,

to invest about a trillion dollars (U.S.) for the provision of the same number of telephones per capita as obtains in the United States or Canada, which works out to a total of 300 million for a population of 680 million. This, he further notes, is nearly six times the Gross National Product of India.[15]

This is also the case with respect to remote-sensing. According to U.R.Rao, while ground-based methods cost about Rs.53 per square metre, satellite remote sensing costs only about Rs. 14 per square metre.[16] Moreover, it enables the coverage of a larger area in a short time when compared with ground-based or aerial remote sensing.

According to U. R. Rao, space technology also offers unique solutions to India in the areas of mass communications and management of natural resources. For a vast country like India, "nation-wide television, through a geostationary satellite, can be used as a most powerful tool for imparting education to the bulk of our rural masses in health, hygiene, family planning and agricultural practices."[17]

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15 Quoted in Edward W. Ploman, Space, Earth and Communication (Connecticut, 1984), p.65.

16 Quoted in R. Ramachandran, "An Eye in the Sky," FRONTLINE (Madras) vol.5, no. 7, (April 1988), p.4.

17 U.R. Rao, Space Technology - Its Relevance to the Development of the Nation (Bangalore, 1976), p.4.

Citing the example of how a few days of satellite imagery can cover the entire forestry of India, which would otherwise take years, Rao insists that there is no alternative to space technology "for quick generation of complete information on our resources."[18]

He concludes that techniques like remote sensing, observation of natural phenomena, etc ..., "can really bring about a total revolution in our knowledge and optimal utilization of our resources."[19] Referring to the Indian space programme, he asserts that it is based on the belief that "through purposeful, selective and imaginative utilization of advanced technology, we can provide unique inputs into the process of national development enabling us to leap-frog some of the stages."[20]

The idea of 'leap-frogging' or skipping stages in development by utilizing high technology "has had a powerful attraction for both the political and scientific leadership in India."[21] Another exponent of this concept was Vikram Sarabhai, according to whom, India's national goals "involved leap-frogging from a state of economic backwardness and social disabilities - attempting to achieve in a few decades a change which has historically

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18 Ramachandran, n.16, p.4.

19 Rao, n.17, pp. 4-5.

20 Nayar, n. 2, p.435.

21 ibid,

taken centuries in other lands.'[22] To achieve these goals, he suggested the development of competence in advanced technologies like space, atomic energy, electronics, etc..., and their utilization for solving the problems faced by the country.

Sarabhai envisaged space activities and space research to be an engine to the process of industrial and technological development. According to him, an annual investment of 40 million U.S. dollars, in a five-year period, for the provision of community television to all the villages in India, would generate 'a strong industrial base in electronics providing employment to about 120,000 qualified scientists engineers, technicians, managers and other administrative personnel.'[23]

Regarding the applications of space technology, he refers to the importance of weather forecasting in India, where the major economic activity is agriculture. According to him, space meteorology can play an useful role in this sphere since it permits the acquisition of valuable data from satellites as well as through the use of sounding rockets.[24] He also identifies the other uses of space technology, like telecommunications and

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22. Kamla Chowdhry, ed., Vikram Sarabhai : Science Policy and National Development (Delhi, 1974), p.3.

23 ibid, p.35.

24 ibid, p.26.

remote sensing, which can be, in his view, "of immense benefit to developing nations wishing to advance economically and socially."[25]

To sum up, the Indian perceptions on space technology can be said to be guided by the following considerations :

a) that space technology can be productively applied to help solve the major socio-economic problems facing the country;

b) that a space programme, involving the development of the requisite technology, can play an important role in the development of industrial capabilities;

c) that space technology is more economical than other conventional methods in the areas of telecommunications,, remote sensing, mass communications etc.; and,

d) in general, space research and space activities play an important role in the overall development of the country.

Given these considerations, the Indian perception is summed up by the following comment made by Sarabhai: "It was not a question of whether a developing country such as India could

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25 Rao, n.17, p.21.

afford to go in for space technology, but whether it could afford not to."[26]

ORIGINS AND DEVELOPMENT

The Indian space programme can be said to have had its origins in space sciences in the form of research by scientists at various research and academic institutions. Some examples are: Meghnad Saha, who studied the spectra of the sun and the stars; Homi Bhabha, who conducted cosmic ray research at the Indian Institute of Science, Bangalore; Vikram Sarabhai, who worked with C.V. Raman in Banglore and later set up his own research laboratory for the study of cosmic rays at Ahmedabad in 1947.[27]

After independence, the Government of India set up the National Physical Laboratory at New Delhi for conducting studies on ionospheric physics. And, when the Space Age began, the Tata Institute of Fundamental Research initiated studies on Cosmic rays using high altitude balloons, which according to Nanda-

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26 Quoted in Y.S. Rajan, "Benefits from Space Technology - A View from a Developing Country," SPACE POLICY vol.4, no. 3 (Aug. 1988), p.221.

27 Mohan Sundara Rajan, Indian Spaceflights (New Delhi, 1983), p.2.

Kumar, marked the first attempts within the country at studying space phenomena through modern methods.[28]

It was only in August 1961 that the Government of India took an active interest in space research by allocating the subject to the Department of Atomic Energy. And in 1962 was set up the Indian National Committee for Space Research (INCOSPAR) under the chairmanship of Vikram Sarabhai "to look after all aspects of space research in India."[29]

INCOSPAR's first major project was the setting up of a sounding rocket range at Thumba with the aim of studying problems in aeronomy in the region upto 200 Km. The range became operational on November 21, 1963 with the launch of a U.S. Nike-Apache sounding rocket. This marked the formal beginning of the Indian Space Programme.

Three phases of the development of the space programme can be identified. Phase one was marked by the setting up of the infrastructure facilities, and Phase two by "a series of planned experimental missions in the development of satellites, launch

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28 P. Nanda Kumar, "Space Research in India," <u>INDIAN AND FOREIGN REVIEW</u> vol.15, no.2, (1 Nov.,1977), p.15.

29 Government of India, Department of Space, <u>ANNUAL REPORT</u>, 1972-73, p.1.

vehicles and applications of space technology, and the third phase by the operationalisation of the space services.[30]

During the first phase, a number of facilities were established which were to form the infrastructure for the space programme. These include :the Space Science and Technology Centre, Trivandrum (1965); the Experimental Satellite Communications Earth Station, Ahmedabad (1967); the Rocket Propellant Plant, Thumba (1969), etc .... Efforts were also made during this phase to build up a cadre of scientific and technical personnel who were to be engaged in research on space science and technology. By 1969, according to Nayar, some 2000 technical and scientific personnel were involved in space research within the country.[31]

Phase Two was marked by a series of projects in the development of satellites, applications, and launch vehicles on an experimental basis. These include; the Satellite Instructional Television Experiment (SITE), using the U.S. ATS-6 satellite (1975-76), the Satellite Telecommunications Experimental Project (STEP), using the Franco-German 'SYMPHONIE' satellite (1977-79); the launch from the Soviet Union of the indigenously developed 'ARYABHATA' satellite (1975), BHASKARA-1 AND 2 satellites (in 1979 and 1981 respectively); the launch by the European Space

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30 Parliamentary News and Views Service Compendium of Policy Statements Made in the Parliament (Budget Session) 1987, (New Delhi), p.51.

31 Nayar, n. 2, p.438.

Agency's 'ARIANE' rocket of the indigenously developed geosynchronous satellite - the Ariane Passenger Payload Experiment (APPLE) -in 1981; and the SLV-3 launch vehicle project in which four of these launch vehicles were launched between 1979 and 1983.

The third phase of development, the operationalization phase, aims at providing tangible benefits to society through the utilization of space technology. The three major areas where space technology was applied were telecommunications, remote sensing and weather forecasting. The projects undertaken during this phase include; the Indian National Satellite system, designed to provide services in the areas of telecommunications and weather forecasting; the Indian Remote Sensing Satellites; the Polar Satellite launch vehicle (PSLV) project for the purpose of placing remote-sensing satellites in polar sun-synchronous orbits; and, the Geo-synchronous Satellite launch vehicle, for the purpose of placing INSAT-II class of spacecraft in geostationary transfer orbits.

GOALS

The basic goal which was envisaged by the Indian leadership for the space programme was the utilization of space technology for national development. This was sought to be achieved through the application of space technology, especially in the areas of telecommunications, remote sensing and meteorological observations.

So, the immediate objectives of the Indian space programme was to achieve competence in developing the appropriate technology systems viz, satellites for the various applications and the launch vehicles for placing them in the appropriate orbits, and the ground systems for supporting the space missions and utilising their services.

CHAPTER - 2

POLICY INITIATIVES

A major feature of the Indian policy for national development has been 'self-reliance'. This policy has been adopted, according to Nayar, because of the realization that : (a) no industrial system can be sustained over the long run on the basis of imports alone; and, (b) no advanced industrial system can exist without the firm back-up of its own scientific research and development.[1] This has also been the case with the Indian Space Programme.

The major thrust given to the policy of self-reliance in the case of the space programme is evident from the goals assigned to it which includes the "development and operationalisation of indigenous satellites, launch vehicles and associated ground segment" for the provision of space-based services in the areas of telecommunications, resources survey and meteorological applications.[2] This covers the development of the entire range of technologies required for an integrated space programme.

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1 Baldev Raj Nayar, India's Quest for Technological Independence : Policy Foundation and Policy Change (New Delhi, 1983), vol. 1, p.241.

2 Council of Scientific and Industrial Research, Status Report on Science and Technology in India, 1988 (New Delhi, 1988), pp.35-36.

The pursuance of a co-ordinated and integrated space programme in a self-reliant manner would require :

(a) an administration which would formulate and implement policies and decisions ;

(b) the building up of an infrastructure base;

(c) the building up of the scientific and technical manpower;

(d) the allocation of appropriate resources;

(e) the forging of cooperative relationships between the space programme and other national agencies and the industry; and,

(f) the building up of cooperative relationships with space agencies and industries in other countries.

ADMINISTRATION

Initially, the Government of India (GOI) entrusted the responsibility for carrying out space research to the Department of Atomic Energy (DAE) in 1961. The Indian National Committee for Space Research (INCOSPAR) set up in August, 1962 and later the Indian Space Research Organisation (ISRO) set up in 1969 - both under the DAE - were responsible for carrying out the programmes related to space research.

In 1972, the GOI carried out a major administrative restructuring by setting up a separate Space Commission and a Department of Space (DOS) under the direct jurisdiction of the Prime Minister. At the same time, ISRO was reconstituted as a Research and Development Organisation under the DOS.

The Space Portfolio has been held, from the beginning, by the Prime Minister who operates through a Minister of State responsible for the Ministry of Science and Technology under which the DOS falls. The Minister of State operates through the Space Commission and the Department of Space - the planning agency and the executive agency, respectively of the space programme.[3]

The GOI resolution of June, 1972 which established the Space Commission, assigned to it the responsibility "in the entire field of Science and Technology of Outer Space and their Applications."[4] The specific responsibilities of the Space Commission include :

(a) the formulation of the policy of the DOS for the consideration of the Prime Minister ;

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3 For Organisational Chart, See Appendix 1

4 GOI, DOS, <u>Annual Report</u> 1972-73, p.1.

(b) the preparation of the budget of the DOS for the approval of the Government; and,

(c) the implementation of the Government's policy in all matters concerning Outer Space.[5]

The Department of Space is the executive agency of the space programme. Its activities cover three broad areas :

(a) Space Sciences, which involves research in agronomy, Cosmic rays, plasma physics, etc ...;

(b) Space Technology, which includes the development of launch vehicles, satellites, etc ...; and,

(c) Space Applications which represent the applications of space technology in the fields of telecommunications, remote sensing, etc ... [6]

It operates through the Indian Space Research Organisation (ISRO), the INSAT-1 space segment project (INSAT-1 SSP), the National Natural Resources Management System (NNRMS), the National Remote Sensing Agency (NRSA), and the Physical Research Laboratory (PRL).

The Indian Space Research organisation (ISRO) is the major research and development agency of the DOS. It is responsible for carrying out the programmes of the DOS in the areas of

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5 GOI, DOS, Annual Report 1977-78, pp.7-8.

6 GOI, DOS, n.4, p.2.

Space Technology and Space Applications, which it does through its Centres/units located around the Country. The overall guidance and direction for carrying out the various scientific, technological , and managerial tasks of the ISRO is provided by the ISRO Council and the ISRO Headquarters at Banglore.[7] The composition of the ISRO Council include : the Secretary of the DOS who is also the Council's Chairman, the Directors of the ISRO centres, the Director of the PRL, and the Joint-Secretaries in the DOS.[8]

The INSAT system is a joint venture between the DOS and the Department of Telecommunications, the India Meteorological Department, and the Ministry of Information and Broadcasting, designed to provide space-based telecommunications and meteorological services. The overall coordination and management of the system rests with the inter-ministerial INSAT Coordination Committee (ICC), whose secretariat is in the DOS.[9] While the DOS is responsible for the space segment of the INSAT system, the Department of Posts and Telegraph, the India Meteorological Department, Doordarshan and All India Radio are responsible for the telecommunications ground segment, the meteorological ground-segment, the television ground-segment, and the radio ground-segment, respectively.

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7 GOI, DOS, Annual Report 1988-89, p.7.

8 GOI, DOS, n. 5, p.7.

9 GOI, DOS, n.7, p.10.

The DOS is the nodal agency for the establishment of the National Natural Resources Management System (NNRMS). The NNRMS, set up in 1983, "is conceived as a system to facilitate optimal utilization of the country's natural resources through a proper and systematic inventory of the resource availability and reducing regional imbalances through effective planning."[10] A Planning Committee was constituted in 1982 to guide the evolution of the NNRMS.

The major components of NNRMS include :

(a) ensuring the supply of remote sensing data and facilitating its integration with the conventional system through appropriate collaborative application studies;

(b) establishment of infrastructure and generation of trained manpower; and,

(c) application studies as building blocks for generation of data base for the Natural Resources Information System (NRIS).[11]

The activities of the NNRMS are "coordinated at national level by the Planning Committee of NNRMS (PC-NNRMS) and the Standing Committee set up with the user ministries/departments" in various areas.[12]

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10 DOS, Satellite Remote Sensing (ISRO, Bangalore, 1991), p.3

11 GOI, DOS, Annual Report, 1989-90, p.22.

12 GOI, DOS, Annual Report, 1990-91, p.27.

The National Remote Sensing Agency, Hyderabad, is an autonomous registered society established by the GOI in 1975, and brought under the Department of Space in December, 1980. Its aim is to utilize remote sensing techniques for "the survey, optimum planning and management of the country's natural resources."[13] The Agency is equipped with facilities for the classification and monitoring of earth resources using aerial and satellite data. At its earth station at Shadnagar, NRSA receives data from the Indian Remote Sensing Satellites, the French 'SPOT' and the American LANDSAT and NOAA satellites, and routinely processes and disseminates data products to user agencies throughout the country.

The Physical Research Laboratory, Ahmedabad, is also an autonomous institution mainly supported by the Department of Space. It is responsible for carrying out the DOS programmes in the field of Space Sciences. It is mainly engaged in studies connected with "the structure and dynamics of the earth's atmosphere, solar-terrestrial relationships, astrophysical problems, investigations using meteor samples and lunar samples, laboratory studies of plasma for understanding ionospheric phenomena, etc ...."[14]

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13 GOI, DOS, Annual Report, 1980-81, p.37.

14 P. Nanda Kumar, "Space Research in India, "INDIAN AND FOREIGN REVIEW vol.15, no.2 (1 Nov. 1977), p.15.

INFRASTRUCTURE

It was during the initial phase of the development of the space programme that the GOI established most of the infrastructure for supporting the space programme. For example, the space Science and Technology Centre set up at Thumba in 1965, the Rocket Propellant plant commissioned in February, 1969, the Rocket Fabrication Facility commissioned in January, 1971, the Space Applications Centre formed in 1972, etc .... These units have been grouped under various Centers which are discussed below:

VIKRAM SARABHAI SPACE CENTRE

ISRO units situated at Trivandrum were grouped together into a single entity in July, 1972 and named the Vikram Sarabhai Space Centre (VSSC). VSSC is ISRO's major research and development establishment working on the development of sounding rockets, satellite launch vehicles, and ground and vehicle-borne instrumentation. These include Rohini and Menaka sounding rockets, the SLV-3, the ASLV, the PSLV, avionics and mission dynamics, solid propulsion, propellants and chemicals, materials and mechanical systems, and computers and information systems.[15]

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15 CSIR, n.2, p.39.

VSSC carries out its activities through its various units : the Space Science and Technology Centre (SSTC), the Rocket Propellant Plant (RPP), the Rocket Fabrication Facility (RFF), the Propellant Fuel Complex (PFC) and the Thumba Equatorial Rocket Launching Station (TERLS).

The Space Science and Technology Centre (SSTC) was established in 1965 as a research and development unit on the Veli Hill. It is divided into the following functional groups - Aeronautics, Avionics, Chemicals and Materials, Composites, Propulsion and Systems Reliability - which share the responsibility for research and development in propellants, propulsion systems, rocket hardware, design, on-board and ground electronics and Control systems for application in launch vehicles, payloads and spacecraft systems and for their test and qualification.[16]

The Rocket Propellant Plant (RPP) was commissioned in February 1969 for the production of solid propellant blocks.

The Propellant Fuel Complex, Thumba, was set up for the purpose of producing a variety of polymeric fuel binders for high energy solid propellants, special polysters, formaldehyde, polyurethane resins, etc ....

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16 GOI, DOS, Annual Report, 1979-80, p.32.

VSSC also has extension centres at Valiamala for the PSLV project and at Vattiyoorkavu for the development of Composites. And, it has an experimental plant to manufacture homonym perchloerate at Alwaye.

ISRO SATELLITE CENTRE

This centre was established in 1972 at Bangalore as a part of the VSSC and was named as the Indian Scientific Satellite Project (ISSP). its purpose was to design and fabricate India's first scientific satellite - ARYABHATA. In November, 1976, it was reconstituted as a full-fledged ISRO Satellite Centre (ISAC) with responsibilities for designing, fabricating, integrating and testing of Indian spacecraft for scientific, technological, and application missions. It is ISRO's main centre for the development of satellite technology. It is organized into five main groups : the Spacecraft Electronics Group, the Altitude and Orbit Control Systems Group, the Mission Planning and Development Group, and the Technical Support Services Group.[17] ISAC includes a 'Large Space Simulation Chamber'.

SPACE APPLICATION CENTRE

The Space Applications Centre, Ahmedabad, was established in September, 1972 with the aim of applying the benefits accruing from the space programme in the areas of socio-economic importance. In this connection, the Centre "conceptualizes plans and

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17 GOI, DOS, n.7, p.81.

executes Research and Development Programmes and projects leading to practical applications of space technology."[18]

Its activities are covered by various functional groups which "execute and manage programmes relating to telecommunications and television-broadcasting via satellites; use of remote sensing techniques to survey earth resources; space meteorology and satellite geodesy."[19]

The Centre is made up of the following units :

(a) The Experimental Satellite Communication Earth Station, set up in August, 1967 at Ahmedabad, with the aim of establishing contacts with communications satellites. It also provides training facilities in satellite communications technology to students from both within and outside the country;

(b) The Satellite Communications Systems Division, responsible for the design, installation and Commissioning of satellite communication earth station systems ;

(c) The Remote Sensing and Meteorological Applications Division (RSMD) whose main objective is to utilise

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18 CSIR, n. 2, p.39.

19 GOI, DOS, n.5, p.8.

space technology for the collection of data relating to the earth's surface and its atmosphere and use them for applications in various fields like agriculture, forestry, meteorology, etc ... [20]

(e) The Microwave Division, responsible for meeting the requirements in microwave systems for satellites, launch vehicles, and ground systems operating at microwave frequencies, and,

(f) The Audio-visual Instructional Division (AVID), formed in June, 1971.

LIQUID PROPULSION SYSTEMS CENTRE (LPSC)

The Liquid Propulsion Systems Centre (LPSC) was formed during 1987-88. It was initially set up as the Auxiliary Propulsion System Unit with the responsibility for the development of auxiliary propulsion systems for satellite and launch vehicles. In 1985, it was merged with the Liquid Propulsion Project of ISRO, and the new unit was named the Liquid Propulsion System Unit (LPSU). It was to be responsible for the development of the Cryogenic engine and rocket for the Geosynchronous Satellite Launch Vehicle (GSLV) project, in addition to its earlier responsibility for the development of auxiliary propulsion systems.

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20 GOI, DOS, n. 4, pp. 6-7.

During 1987-88, the resources and expertise of the LPSU was consolidated and the LPSU was formed.[21] LPSC has its development wings at Bangalore and Trivandrum (the Valiamala Campus), with the former concentrating on satellite control systems and the latter on launch vehicle control systems. The Centre also runs a Liquid Propulsion Test Facility in the Mahendragiri Hills of Tamilnadu, and a precision transducer manufacturing facility at Bangalore.

DEVELOPMENT AND EDUCATIONAL COMMUNICATION UNIT

The Development and Educational Communication Unit (DECU), Ahmedabad, was established during 1983-84 for the purpose of consolidating the various audio-visual software activities of the ISRO since the Satellite Instructional Television Experiment (SITE) was carried out. The unit maintains close cooperation with Doordarshan/Ministry of Information and Broadcasting and is responsible for "the production of development and educational programmes, related research, training, etc...., especially in support of INSAT services."[22] It also provides technical consultancy services to various users in planning equipment selection and installation operations of television studios.

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21 GOI, DOS, Annual Report, 1987-88, p.83.

22 GOI, DOS, Annual Report, 1983-84, p.8.

This is in addition to its involvement in the conception, planning and socio-economic evaluation of space applications programmes. DECU also conducts national and international training programmes on communications research and video programme production.

ISRO INTERNAL SYSTEMS UNIT

The ISRO Inertial Systems Unit (IISU) was established at Trivandrum during 1990-91 with the purpose of consolidating and promoting the "efforts put in so far in the inertial systems for satellites and launch vehicles."[23] Facilities at this unit are being set up for producing Inertial Sensor Systems.

SHAR CENTRE

This Centre has developed into a major Centre of ISRO with "test, assembly and launch facilities for large multi-stage rockets and satellite launchers, and tracking, telemetry and telecommand stations for Indian spacecraft."[24]

The Centre's major responsibilities include: the provision of rocket test and launch facilities, the management of ISRO's nation - wide tracking network, and, the production of solid propellants for sounding rockets and launch vehicles.

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23 GOI, DOS, Annual Report, 1990-91, p.72.

24 Kenneth Gatland, THE Illustrated Encyclopedia of Space Technology (London, 1981), p.59.

It is composed of five units - the Rocket Sled Facility, the Static Test Evaluation Complex, the Solid Propellant Rocket Booster Plant, the Sriharikota Computer Facilities, and the Sriharikota Launch Complex, which is part of the ISRO Range Complex (IREX).

The Rocket Sled Facility (SLED) consist of a 4 km long rail track on which rocket vehicles, carrying test specimens are propelled to supersonic speeds. The facility is used for testing the performance of spacecraft during their launch.

The Static Test Evaluation Complex (STEX) was set up for the purpose of providing the following facilities : (a) for ground-testing large propulsion systems and sub-systems used in sounding rockets and satellite launch vehicles; (b) for simulated high-altitude testing of rocket motors used in the upper stages of launch vehicles and control rocket motors; and, (c) static test stand for spin and vibration tests and a multi-purpose test stand.[25]

The Solid Propellant Rocket Booster Plant (SPROB) was commissioned in 1977 with the purpose of processing large-sized propellant grains for the satellite launch vehicles and the stage motors.

The SHAR Computer Facilities (SCOF) serves ISRO's needs for

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25 Mohan Sundara Rajan, India in Space (New Delhi, 1976), p.30.

real-time computing and data processing during satellite operations and rocket launches. It also provides support for other scientific and management oriented applications.

The ISRO Range Complex (IREX), a part of the SHAR Centre, has launch ranges at Sriharikota, Balasore and Thumba. It consists of block houses, launch pads, control centre, vehicle telemetry, telecommand and tracking systems, Computers, data links, closed-circuit television, range timing, intercommunication, and range safety facilities at all the three launch ranges.[26]

The Sriharikota Launch Complex is the most important launch facility of the IREX. Its facilities include: the sounding rocket launch facility, the SLV-3, ASLV and PSLV Launch Complexes, the liquid booster complex, range instrumentation for telemetry and tracking, range engineering, etc....

The Balasore Rocket Launching Station (BRLS) was set up in January, 1979 as part of ISRO's contribution to the International MONEX programme. This range can launch rockets from latitudes which are higher compared to those from Sriharikota and Thumba.

The Thumba Equatorial Rocket Launching Station (TERLS) was the first launch facility to be established in India. In 1965,

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26 GOI, DOS, n. 13, p.30.

the United Nations recognised it as an international facility open to any member of the United Nations. This range was established for purpose of developing and maintaining a fully-equipped range for the purpose of supporting "scientific experiments with necessary launch instrumentation and other back-up facilities for carrying out investigations in the equatorial upper atmosphere."[27]

ISRO TELEMETRY TRACKING AND COMMAND NETWORK

The ISRO Telemetry Tracking and Command Network (ISTRAC), with its headquarters at Bangalore, controls the ground network facilities which support ISRO satellite and launch vehicle missions by providing Tracking, Telemetry and Command (TTC) support. ISTRAC's responsibilities include "the development and operation of interface, software packages and the network stations."[28]

ISTRAC's network stations are located at Sriharikota, Ahmedabad, Trivandrum, Lucknow, Car Nicobar and Kavalur. They provide ground support for tracking, data acquisition and spacecraft control operations.

MASTER CONTROL FACILITY

The Master Control Facility (MCF), at Hassan, is the major Control Centre for the INSAT series both during the launch and

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27 GOI, DOS, Annual Report, 1978-79, p.27.

28 GOI, DOS, n. 21, p.84.

the operational phases. It was set up for undertaking the following functions for the control and management of the INSAT-1 series : (a) satellite commanding and ranging; (b) satellite health-monitoring and on-orbit testing; (c) reception and processing of satellite telemetry ranging and test data; (d) reception and processing of very High Resolution Radar Data for quick-look evaluation, and, (e) orbital analysis.[29]

At present, MCF has four earth stations and an integrated Satellite Control Centre. While two of the earth stations have catered to the INSAT-1 series, two more have been added to support the INSAT-2 series.

MANPOWER

The aims of the Scientific Policy, enunciated by the Scientific Policy Resolution of 1958, included, among others, ensuring an adequate supply of research and technical personnel.[30] Accordingly, the GOI established a number of institutions for education and research in various scientific disciplines.

Thus, the 1960s marked the GOI's attempt to build a Cadre of Scientific and Technical Personnel in all fields of science and technology, including space science and technology. This led to

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29 GOI, DOS, n. 13, p.11.

30 GOI, Scientific Policy Resolution (New Delhi, 1958).

an almost twenty-fold increase in the number of scientific and technical personnel involved in space research within the country between 1965 and 1969. While there was only 110 scientific personnel engaged in space research in 1965, this number went up to 2000 by 1969.[31]

During the 1970s and the 1980s, the number of personnel involved in the space programme steadily increased, but at a more moderate pace. By the time of the launch of India's first satellite, ARYABHATA, in 1975, the number of scientific personnel engaged in the space programme had more than doubled since 1969 to 5,137. This number had increased to 6,200 by March, 1981 and upto 8,835 by March, 1985. And, by March, 1992, some 10,527 scientific and technical personnel were involved with the Indian Space Programme.[32]

Between 1975 and 1992, the number of administrative staff engaged in the space programme increased from 2765 to 5395.

FINANCIAL OUTLAYS

The DOS, being an agency of the GOI, is solely dependent on the latter for its financial resources. The Government decides the allocations to be made for the space programme on the basis

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31 GOI, DAE, Atomic Energy and Space Research : A Profile for the Decade 1970-80 (New Delhi, 1970), p.31.

32 See Appendix 2.

of the projections contained in the Space Research Profile which covers a ten-year period.[33] The allocations are made as part of the plan outlays on an yearly basis.

The first Space Profile projected a cost estimate to the tune of Rs. 165 crores for the ten-year period 1970-80, with Rs. 62 crores to be provided during 1970-75 and Rs. 103 crores during 1975-80. The actual provisions made during the Fourth and Fifth Plan periods (1969-70 to 1978-79) was Rs. 31.10 crores and Rs. 128.27 crores respectively.[34]

The second Space Profile (1980-90) projected an estimate of Rs. 851 crores, with Rs. 377 crores to be allocated during 1980-85 and Rs. 477 crores during 1985-90. Actual provisions made during the Sixth and Seventh Plan Periods (1980-81 to 1989-90) was Rs. 392.72 crores and Rs. 1075 crores respectively.[35]

A study of the area-wise distribution of funds during the Fourth Plan period indicates that Research and Development on Space Technology,, Space Applications and Space Sciences received the largest share with about 34 per cent annually, on an average.

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33 Three Profiles have been drawn up so far for the 1970s, 1980s, and the 1990s. Cost Projections made by the first two Profiles are given in Appendixes 3 and 4.

34 GOI, DAE, n. 31, p.41 and CSIR, n.2, p.10.

35 CSIR, n. 2, p. 10.

This was also the case during the Fifth plan period when Research and Development received about 39 per cent annually, on an average. This was followed by the infrastructure facilities grouped as 'Ranges and Facilities' with an average of 33 per cent of the allocations per year. Projects received 24 per cent and Direction and Administration 3.6 per cent every year.[36]

During the Sixth and Seventh Plan periods (1980-90) the Operationalisation phase of the space programme, allocations were made under the following categories: Rocket Development , Satellite Development, Space Applications, Space Sciences, INSAT-1, and Direction and Administration. During the ten year period represented by these Plans, Rocket Development received the highest share of the annual allocations with 41.27 per cent on an average. This was followed by Satellite Development, Space Applications, Space Sciences, INSAT-1, and Direction and Administration with annual averages of 22.75, 9.56, 3.43, 18.91, and 3.44 respectively.

These statistics indicate that the thrust of the Indian Space Programme during the 1970s was on Research and Development in an effort at mastering the basics in space technology, space applications and space sciences. This period saw the carrying

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36 See Appendix 6.

out of several experimental projects for the purpose of testing the various technologies acquired and developed by Indian Space Scientists - the Satellite Instructional Television Experiment, the development of the ARYABHATA and the two Satellites for Earth Observation, the launch of the SLV-3, etc...., are some examples.

During the 1980s, the thrust was on the development and operationalisation of the applications satellites, utilisation of the services provided by them, and the launch vehicles required for placing them in oribit. E.g., the Indian Remote Sensing Satellites and the Polar Satellite Launch Vehicle.

INTERNAL COOPERATION

In accordance with the goal of overall national development which was sought to be achieved through the space program, the Indian Department of Space made it a policy to involve as many national agencies, institutions, and industries as possible in the execution of its various projects. Initially, this took the form of "sub-contracting of specific jobs, participation of scientists from other agencies in technical review of the elements of the space programme and exchange of scientific information."[37]

However, the increasing complexity of the technologies involved in the space programme led to a more formal mechanism

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37 GOI, DOS, n. 16, p.38.

for involving external agencies in the space programme. This took the form of the establishment in 1976 of the ISRO sponsored Research Programme (RESPOND), and the decision taken by the DOS in 1978 to make the maximum use of capabilities of Indian industry in carrying out all space projects.

This policy results in the improvement of the technological capabilities of Indian industry, while at the same time, benefiting the space programme. For example, in the case of the development of the satellite programme, this policy not only "paid dividends in terms of a much shorter gestation period for the satellite programme but also served to distribute the philosophy of exacting quality among all the agencies concerned."[38]

RESPOND

This programme was initiated by ISRO in 1976 with the purpose of establishing "a strong interaction between ISRO and the academic institutions in the country to carry out jointly, research, developmental and educational activities of relevance to the Indian Space Programme."[39] The aim was to support the space programme through the development of a large base in space research at academic institutions, training of the manpower to be

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38 N.N. Sachitanand, "Making Our Own Satellites," THE HINDU(MADRAS), 28 May 1979.

39 GOI, DOS, n.7, p.66.

involved in space research, building-up of the infrastructure facilities for space research and, nurturing of indigenous capability.

The major activities supported by RESPOND are :

(a) research projects in space science, applications and technology areas;

(b) the Space Technology Cells (STC) at academic institutions for carrying our research in advanced technology areas; and,

(c) educational activities, Conferences/symposia, seminars and publication activities.[40]

These activities are carried out by ISRO on the advice of the RESPOND Programme Board, comprising of members drawn from the academic community, representatives from ISRO Centers and from the Physical Research Laboratory.

The three Space Technology Cells, established as part of the RESPOND programme, are located at the Indian Institute of Science, Bangalore, and the Indian Institutes of Technology at Bombay and Madras. They carry out research and development activities in select space technology areas.

ISRO, through RESPOND, has supported 210 research projects at 80 institutions till March, 1992.[41] The institutions include

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40 GOI, DOS, n. 11, p.55.

41 GOI, DOS, n.12, p.66.

universities, IITS, national laboratories, regional engineering colleges, and public sector industries with the involvement of about 1,200 scientists and engineers.[42]

INDUSTRY

The Department of Space has, over the years, made concerted efforts to promote cooperation with the Indian industry in the execution of the various projects of the space programme. The policy has evolved from "an informal sub-contracting level to a more formal collaborative partnership made necessary by the increasing complexity of the programme."[43]

Accordingly, a two-way partnership has been evolved between the space programme and the industry in order to build up a sustainable relationship which would be advantageous to both. It involves "the transfer of advanced technologies developed in the Space programme to industry and the provision of technological consultancy from the space programme to industry on the one hand, and the utilisation of industry's own technological potential on the others."[44]

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42 GOI, DOS, n.7,p.66.

43 Anita Bhatia, "India's Space Programme - Cause for Concern?", ASIAN SURVEY (Berkeley) vol.25, no.10 (OCT. 1985), p.1021.

44 GOI, DOS, n.7, p.68.

Technology transfer, carried out through the Technology Transfer Group, serves three major purposes: (a) it meets the requirements of the Space Programme through buy-back arrangements of products for which technology was transferred earlier to industry; (b) it caters to the market for space applications within the country which has been generated by the Space progrmme in the areas of satellite communications, television and radio broadcasting, remote sensing for natural resources, and meteorological services; and, (c) it exploits the full potential of the space technologies developed indigenously for various spin-off applications.[45]

In 1982, ISRO launched its Technology Consultancy Services for the purpose of offering its expertise in a wide range of technologies and engineering disciplines to industries and other Research and Development institutions.

Till March, 1992, ISRO has transferred 181 technologies to the Indian Industry in the areas of Electronics and Computer Based Systems, Optics and Opto-Electronic Instruments, Mechanical and others, Chemicals and Materials, and Telecom, Meteorological and television hardware.[46]

Apart from technology transfer, the other modes of ISRO's cooperation with industry are fabrication contracts, development contracts, joint design and development, and, supply to industry of special items.

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45 ibid, p.68.

46 GOI, DOS, n. 12, p.69.

The space programme has also been benefited by the technological potential and expertise of the Indian Industry which has provided "crucial support in developing indigenous capability for the production of specialised systems such as precision inertial sensors/systems for navigation and guidance, liquid propulsion engines/stages, etc..."[47] It has also played an important role in the supply of rocket fuels, in the augmentation of the tracking network and in the supply of systems and components for ISRO's satellites.

The demands on industry made by the space programme have also resulted in the establishment of divisions and units within private and public sector industries which cater exclusively to the needs of the space programme. One such example is the Space Electronics Division of the Bharat Electronics Limited.

NATIONAL AGENCIES

The Indian Space Programme has also co-opted various national agencies in pursuance of its objectives. ISRO has established a formal link with the University Grants Commission in an effort at fostering linkage at the policy level with the national education system. The purpose was to develop a strong academic base within the country which could be made responsible to the needs of the Space programme in the areas of space sciences, applications and technology.[48]

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47 GOI, DOS, n. 21, p.73.

48 GOI, DOS, n. 5, p.70.

The Satellite Instructional Television Experiment involved, besides the Department of Space, the Ministries of Information and Broadcasting, Health, Communications, Agriculture, Family Planning and Education.

The INSAT system is a joint venture of the Department of Space, the Department of Telecommunications, the India Meteorological Department, All India Radio and Doordarshan. While the DOS is responsible for the establishment, operation and maintenance of the space segment, the other agencies are responsible for the various ground-segments of the system - telecommunications, meteorological, radio and television.

Similarly, the Indian Middle Atmosphere Programme (IMAP) - involving the DOS, the Department of Science and Technology, the Department of Agriculture, the Department of Education, the Council of Scientific and Industrial Research, the University Grants Commission and MTCA - is a multi-agency programme for the investigation of the physical and chemical phenomena and processes taking place in the Earth's atmosphere between 10 to 100 km.

The Physical Research Laboratory (PRL) has conducted several analyses on the lunar rock samples, provided by the Soviet Academy of Sciences, in a multi-agency research programme which involved the Bhabha Atomic Research Centre, the Geological Survey of India and the Indian Institutes of Technology, Bombay and Kanpur.[49]

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49 GOI, DOS, n.5, p.68.

The National Natural Resources Management System was established by the Department of Space with the participation of number of Central and State departments.

The National Aeronautical laboratory (NAL) has played an important role in India's Space Programme. It fabricated the dynamic balancing machine used for ARYABHATA and also the satellites notation chamber. It has also conducted wind-tunnel tests for sounding rockets and the SLV-3. It is also involved in specialised fabrication, materials development, and testing and evaluation.[50]

INTERNATIONAL COOPERATION

India was initially dependent on the expertise and services of other advance countries to a large extent. Even though indigenisation has been achieved to a good degree, the country is still dependent for certain key components on the advanced countries. These include: high-speed momentum wheels for the INSAT-2 series, light-detecting CCDS used in remote sensing cameras, cells for the satellites batteries and solar array, titanium tanks for fuel and helium, Kevlar fibers used for the upper stage solid motor casing, - etc .... [51]

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50 ibid, p.70.

51 N. Gopal Raj, "Future Shock. The Implications for ISRO, "FRONTLINE vol.9, no. 11 (5 June, 1992), pp 9-12. For a list of items imported along with their suppliers, see Appendix 7.

India has also been dependent on other countries for the launch of its applications satellites.

Its major partners in the field of space technology have been: the United States, the former Soviet Union, France and Germany (formerly West Germany). India also maintains a cooperative relationship with the European Space Agency.

USA

It was the United States which formally began the Indian Space Programme by launching a Nike-Apache sounding rocket from the Thumba Equatorial Rocket Launching Station in November, 1963. The United States had, earlier, helped India in designing the Thumba range, and it also trained the first group of Indian engineers in rocket launching and range operation.[52]

According to Milhollin, NASA, the U.S. space agency also provided ISRO with technical reports on the U.S. Scout rocket's design. He further asserts that India's SLV-3 is virtually identifical in design to the Scout.[53]

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52 Gary Milhollin, "India's Missiles : With a Little Help from Our Friends," Bulletin of the Atomic Scientists (Chicago) vol.45, no.9 (Nov. 1989), p.32.

53 ibid, p.32.

In 1975, the United States loaned its ATS-6 satellite to India for a period of one year for conducting the Satellite Instructional Television Experiment. In 1978, the DOS entered into a contract with Ford Aerospace and Communications Corporation (USA) for the supply of four INSATs and also for the supply of equipment for the Satellite Control Centre of the Master Control Facility at Hassan, and other miscellaneous equipment and services.[54]

And, in July, 1978 the DOS signed a Memorandum of Understanding with NASA for the provision by the latter of launch services for the INSAT spacecraft. NASA launched the INSAT-1A in April, 1982, the INSAT-1B in October, 1983, and the INSAT-1D in June, 1990.

NASA has also loaned certain equipment to the Indian Institute of Technology, New Delhi, for conducting laboratory investigations on the 'Mossbauer Effect' for space applications purpose.[55]

Under an Indo-US Memorandum of Understanding, the National Remote Sensing Agency has been receiving data from U.S. Landsat and NOAA satellites.

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54 GOI, DOS, n. 27, p.6.

55 GOI, DOS, Annual Report 1976-77, p.56.

SOVIET UNION

The Indo-Soviet cooperation in space began in the early 1960s when the Soviet Union gave token assistance to India in the development of the Thumba rocket station in the form of a Minsk Computer, a helicopter and a shaketable.[56]

Collaborative research work began in 1970 with the weekly launching of Soviet M-100 rockets from Thumba for joint meteorological and aeronomy studies, which still continues.

The Soveit Union offered its expertise for the fabrication of India's first satellite, ARYABHATA. It supplied the solar and chemical batteries for the power supply system, stablisation systems, on-board computer memory systems, etc... for ARYABHATA.[57]

In 1975, ISRO and the USSR Academy of Sciences signed an agreement for the supply of equipment for the ISRO Satellite Tracking and Ranging Station (STARS) at Kavalur, which included an AFU-75 Camera and laser equipment.[58]

The Soviet Union has also provided launch services for a number of Indian satellites - ARYABHATA (1975), BHASKARA-1(1979), BHASKARA-2 (1981), the Indian Remote Sensing Satellites IRS-1A

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56 R. Ramachandran, "Cooperation in Space Technology : Indo-Soviet Experience, "THE HINDU (Madras), 19 Nov. 1988.

57 ibid,

58 ibid,

(1988) and IRS-1B(1991). And, the Soveit Union also placed the first Indian in Space in April, 1984.

Indian Scientists have also participated in the Soviet programme for the building and operation of orbital stations.[59]

FRANCE

Cooperation with France dates back to the 1960s when French sounding rockets were launched from Thumba. In 1964, India entered into agreement with Sud Aviation (France) for the licensed production in India of the Centaur rockets.[60]

In April, 1972, ISRO concluded an agreement with the French Centre National d'Etudes Spatiales (CNES) for collaboration in space research and set up a CNES-ISRO Joint Commission.

During the 1970s, ISRO engineers participated in the French 'Viking' liquid engine development program through an agreement with the Societe Europeane de Propulsion (SEP). And in 1974, ISRO acquired the knowhow for the design, development and testing of this engine from SEP.[61]

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59 Vitali Sevastyanov and Vladimir Pryakhin, Mankind's Road to the Stars (New Delhi, 1988), p.32.

60 GOI, DAE, n.31, p.27.

61 Parliamentary News and Views service Compendium of Policy Statements made in the Parliament (Budget Session), 1986, (New Delhi, 1987), p.36.

France has also conducted training programmes for ISRO engineers and scientists in various fields in French space research establishments.[62]

FEDERAL REPUBLIC OF GERMANY

West Germany (formerly) was another major partner of India's Space Programme. Cooperation began with an umbrella agreement signed in 1971 between the two governments. In July, 1973, a training programme was commenced for ISRO personnel at the West German space research establishment.

FRG assisted India in the development of three major technologies - Guidance, Rocket Testing, and Composite Materials. The West German aerospace agency, (Deutsche Forschungsanstalt fur Luftfahrt und Raumfahrt e.v.) DLR, first began its cooperation with ISRO in 1976 on guidance technology. It helped indian scientists in fabricating interferometers which are useful for guiding rockets from the ground. Later, under the Autonomous Payload Control Rocket Experiment (APC-REX) - joint programme between India and Germany - DLR helped India in the development of an autonomous navigation system for satellites.[63]

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62 GOI, DOS, n. 55, p.55.

63 Milhollin, n. 52, p.33.

In the field of rocket testing, DLR tested a model of the first stage of the SLv-3 in its wind tunnel at Cologne - Portz in 1974-75. Later, it helped India in building rocket test facilities by "furnishing a complete facility design and training Indian engineers in high-altitude testing."[64]

DLR trained Indian scientists in composites at Stuttgart and Braunschweig. The subject ranged from glassfibre reinforced plastics via impregnated materials to Carbon fibre reinforced composites, which helped Indian scientists to make rocket nozzles and nose cones.[65] DLR also supplied the documentation for a precision filament-winding machine which would help in using the composites. The plan was commissioned in 1985-86.

ISRO and DLR scientists also worked jointly for developing software for large-scale computer networking.

FRG also helped India to expand the National Remote Sensing Agency through an Indo-FRG Technical Coopoeration Programme. This programme also involved the training of Indian scientists and engineers and joint projects in microwave remote sensing, forestry and vegetation mapping, cartography, agro-meteorology and geology.[66]

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64 ibid, p.35.

65 ibid,

66 GOI, DOS, Annual Report, 1984-85, p.49.

Under a joint programme, DFVLR developed a Monocular Electro Optical Stereo Scanner, which was one of the payloads carried by the second of the Stretched Rohini Satellite Series.

EUROPEAN SPACE AGENCY

The European Space Agency (ESA) has also been an important partner in the India Space programme. Its contribution has been mainly in the area of launch services. In June, 1981, it launched the India Experimental Geostationary Communications Technology Satellite - otherwise known as APPLE. And, in July, 1988, ESA's Ariane launch vehicle placed INSAT-1C in its transfer orbit. The Ariane-4 launch vehicle has also launched the INSAT-2A spacecraft on 10 July, 1992.

ESA has also trained Indian specialities in meteorological satellite data processing and in the area of satellite mission operations and control.

The base on whch ISRO - ESA Cooperation rests is the April, 1978 agreement signed by the two agencies for strengthening their relationship and for establishing mechanisms which would "facilitate the development of Cooperation" between them in the peaceful uses of outer space.[67] The areas of cooperation it covers are: information exchange, exchange of visits by Scientists, award of fellowships to scientific and technical personnel, making available test facilities and tracking and telemetry support.

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67 GOI, DOS, n. 27, p.44.

CHAPTER - 3

PROJECTS OF THE SPACE PROGRAMME

The basic goal of the Indian Space Programme has been to utilise space technology for achieving practical benefits, especially in the areas of telecommunications, remote sensing, and meteorology. Accordingly, the immediate objective has been to develop, in a self-reliant manner, the appropriate technology systems, namely, satellites for the various applications, and the necessary launch vehicles for placing them in the appropriate orbits.

In accordance with this objective, a number of projects were undertaken by the Indian Space Establishment. During the developmental phase of the Indian Space Programme, these projects were on an experimental basis and "focussed on developing the necessary experience to enable the design, manufacturing and operational teams to make best use of the technology available."[1] The projects undertaken during this phase include: the Satellite Instructional Television Experiment (SITE), the Satellite Telecommunications Experimental Project (STEP), the Aryabhata and Bhaskara Satellite projects, the Ariane Passenger Payload Experiment (APPLE), and the Satellite Launch Vehicle (SLV-3) project.

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1 Stephen F. Von Welck, "India's Space Policy : A Developing Country in the Space Club," SPACE POLICY, vol.3, no.4 (Nov. 1967), p.327.

During the operational phase of the Indian Space Programme, the projects undertaken aimed at the achievement of practical benefits. These include: the Indian National Satellite system, the Indian Remote Sensing satellites series, the Polar Satellite Launch Vehicle (PSLV), and the Geosynchronous Satellite Launch Vehicle (GSLV).

The other projects that have been undertaken are: the Rohini Satellites project, the Stretched Rohini Satellite Series (SROSS), the Augmented Satellite Launch Vehicle (ASLV) project, and, the Sounding Rockets programme.

SITE

The Satellite Instructional Television Experiment (SITE), "the greatest communications experiment in history"[2] according to Arthur Clarke, was designed to demonstrate the possibility of transmitting educational programmes through satellites to large segments of rural society. Under the experiment, instructional programmes were telecast to 2,400 villages spread over six states for over five hours every day. For this purpose, ISRO signed a Memorandum of Understanding with the U.S. space agency. NASA, in 1969, for the utilisation of the services of NASA's ATS-6 satellite for a period of one year, beginning with 1 August, 1975.

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2 Quoted in L.K.Sharma, "After the end of SITE : the Costs of Interruption, "TIMES OF INDIA, 6. Aug. 1976.

SITE, according to the Department of Space, was "an attempt at building a total instructional system based on television broadcasting via satellites."[3] The efforts involved ranged from the building up of earth stations, studios and community receivers to planning and conducting research for assisting programme production.

The general objectives of SITE were to :

(a) gain experience in the development, testing and management of a satellite -based instructional television system particularly in rural areas and to determine optimal system parameters;

(b) demonstrate the potential value of satellite technology in the rapid development of satellite technology in the rapid development of effective mass communications in developing countries,

(c) demonstrate the potential value of satellite broadcast TV in the practical instruction of village inhabitants; and,

(d) stimulate national development in India, with important managerial, economic, technological and social implications."[4]

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3 GOI, DOS, Annual Report 1976-77, p.9.

4 ISRO, INDIAN SPACE PROGRAMME (Bangalore, 1989).

STEP

The Satellite Telecommunications Experimental Project (STEP), a joint project of ISRO and the Posts and Telegraphs Department, was designed to provide experience in "operating and utilizing a geostationary satellite for domestic telecommunications."[5] The project was carried out with the help of a leased transponder aboard the Franco-German 'SYMPHONIE' satellite, for a period of two years, beginning with 1 June, 1977.

The entire ground network for the project - Earth Stations and Communication Terminals - were established by ISRO, except for the Earth Station at Madras, which was set up by the Posts and Telegraphs Department.

The objectives of this experimental project were :

(a) to provide a system test of a synchronous satellite for domestic telecommunications;

(b) to enhance India's capabilities in the design, development and operation of various ground systems required; and,

(c) to acquire competence in choosing the right operational system for satellite telecommunications.[6]

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5 Welck, n.1, p.327..lm 10

6 Mohan Sundara Rajan, Indian Spaceflights (New Delhi,1985), p.87.

A number of experiments were carried out under STEP, which include: television with multiple audio channels, radio networking, remote area communications, emergency communications digital communications with multiple access, and Single Channel Per Carrier.[7]

ARYABHATA

ARYABHATA, India's first satellite, was launched by a Soviet booster on 19 April, 1975. The satellite was designed, fabricated, and integrated at the ISRO Satellite Centre, Bangalore.

The objectives of the project were:

(a) to indigenously design and fabricate a spacecraft, and evaluate its performance,

(b) to master the on-orbital management of the satellite;

(c) to set up the necessary ground-based receiving, transmitting and tracking systems;

(d) to establish the relevant infrastructure for the fabrication of such spacecraft systems; and,

(e) to carry out scientific experiments.[8]

The experiments conducted were of relevance for future ISRO projects also. For example, the experiment to determine the range, velocity, and directional parameters of the satellite.

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7 GOI, DOS, <u>Annual Report</u> 1977-78, p.15.

8 U.R. Rao, Space Technology - Its Relevance to the Development of the Nation (Bangalore, 1976), p.8.

Another experiment was conduct to test the feasibility of providing medical help to rural areas, by transmitting electrocardiogram data from Shriharikota to Bangalore via Aryabhata.[9]

BHASKARA

Also referred to as the Satellite for Earth Observation, the first of the two 'BHASKARA' satellites was launched from the Soviet Union on 7 June, 1979. Its goals were :

(a) to conduct earth observation experiments for obtaining data in the areas of meteorology, hydrology, forestry and oceanography;

(b) to evolve a methodology for the reception, processing and dissemination of remotely - sensed data; and,

(c) to conduct experiments in the areas of space technology, applications, and sciences.[10]

The second of the Bhaskara satellites, SEO-2 or BHASKARA-2, was also launched from the Soviet Union, on 20 November 1981. It carried two major remote sensing payloads - a television camera operating in both the visible and the near-infra-red spectrums, and a microwave imaging system called SAMIR. In addition, it also carried two payloads which were designed to evaluate the

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9 ibid, p.10.

10 GOI, DOS, n.3, p.22.

performance of indigenously developed solar cells and thermal coatings, which were of relevance to ISRO's spacecraft technology programme.

The experience gained through this project was an important milestone in the "realisation of an operational satellite-based remote sensing system for the country."[11]

APPLE

The Ariane Passenger Payload Experiment (APPLE) consisted of an experimental, geostationary, communications satellite, designed and developed by ISRO, and launched by the Ariane launch vehicle on 19 June, 1981. The aim of the project was to gain experience in designing, developing, and operating a geostationary communications satellite which would provide telecommunications services to the country.

Experiments conducted with the satellite include: (a) educational television; (b) computer interconnect; (c) remote area and emergency communications; and, (d) teleconferencing using transportable two-way earth terminals and small receive-only communication terminals.[12]

Another experiment that was conducted using 'APPLE' was the transmission by facsimile of the pages of the 'The Hindu' from Madras to Bangalore.

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11 GOI, DOS, <u>Annual Report</u> 1980-81, p.13.

12 GOI, DOS, <u>Annual Report</u> 1981-82, p.6.

ROHINI SATELLITES

The Rohini series of satellites were launched aboard the indigenously-developed satellite launch vehicle, SLV-3. RS-1, the first in the series, was launched by the second experimental flight of SLV-3 on 18 July, 1980, and was mainly intended for the purpose of monitoring the fourth stage performance of the launcher. RS-D1, the next Rohini Satellite to be launched, by the SLV-3, on 31 May 1981, carried a remote sensing device - the landmark sensor.

The last in the series was RS-D2, launched by the second developmental flight of SLV-3 on 17 April, 1983. Its primary objectives were :

(a) to space qualify a solid-state imaging device;

(b) to develop a methodology for identification of major land features viz., snow, cloud, water, vegetation and barren land by an on-board process for utilisation in remote sensing applications; and,

(c) to refine attitude and orbit using landmarks on the imageries.[13]

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13 GOI, DOS, <u>Annual Report</u> 1983-84, p.13.

INSAT

The Indian National Satellite (INSAT) system represents "Indian's first step toward implementing operational' space systems for identified national requirements." [14] These include : nation-wide direct television and radio broadcasting, network broadcasting, and weather forecasting.

The first generation INSAT spacecrafts - INSAT-1A, 1B, 1C and 1D, were designed, developed and fabricated by Ford Aerospace and Communications Corporation (USA). These satellites had three distinct components which provided the services of telecommunications, direct broadcasting, and weather forecasting. The telecommunications component was composed of 12 C-band transponders which provided over 8,000 two-way telephone circuits. The direct broadcasting component consisted of 2 S-band transponders which enabled direct television broadcasting to augmented receivers, national networking of terrestrial television transmitters, and radio and television programme transmission. The Meteorological component consists of : a Very High Resolution Radiometer (VHRR) which provides half-hourly observations of weather systems over Indian territory as well as over the adjoining land and sea

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14 ibid, p.9.

areas; and, a Data Relay Transponder which receives data from unattended and remote land and ocean-based platforms and transmit them to a central facility.[15] In addition, under the Disaster Warning Scheme, warning messages to coastal areas are disseminated in the event of an approaching cyclonic storm.

Only two of the four INSAT-1 satellites were successfully operated. INSAT-1A, launched by a U.S. Delta rocket on 10 April, 1982, and INSAT-1C, launched by the Ariane launch vehicle on 22 July, 1988, failed to function. INSAT-1B, launched by the U.S. shuttle ' Challenger' on 30 August, 1983 was fully functionalised and had successfully completed its seven-year life span. INSAT-1D was launched on 12 June, 1990 by a U.S. Delta rocket and has been operationalized.

Work on the second generation INSAT system was formally started in April 1985. A total of five satellites have been planned for in this series. These are to be indigenously developed and are to have enhanced capabilities compared to the first generation satellites. The telecommunications component consists of 18 C-band transponders, while the other components are the same as in INSAT-1. In addition to these, INSAT-2 satellites are being equipped with a payload for Satellite Aided Search and Rescue (SAS&R) mission which is designed to detect distress signals from land and sea, thus providing instantaneous emergency alert capability.

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15 GOI, DOS, _Annual Report_ 1978-79, p.51.

The first of these satellites, INSAT-2A was launched aboard the Ariane launch vehicle on 10 July, 1992.

The definition of the third generation INSAT system - INSAT-3, has been initiated.

IRSS

The India Remote Sensing Satellites are the next step in the operational stage of the Indian Space Programme. They form the space segment of India's National Natural Resources Management System. The major areas of their application include: crop inventory and forecast; forest mapping and damage detection; land use, land degradation, and land desertification mapping; ground water, petroleum, and mineral exploration; land erosion monitoring in coastal environments ; urban land-use studies and cartography.[16]

The first generation IRS satellites - IRS-1A and IRS-1B, were launched from the Soviet Union on 17 March, 1988 and 29 August, 1991, respectively. Their payloads include: two types of Linear Imaging Self Scanners - LISS-1 and LISS-2, with the former having a spatial resolution of 72.5 metres and the latter 36.25 metres - and operating in four spectral bands. The satellites return to their original orbital trace every 22 days, thus, enabling the repeated collection of data at the same place at the same local time.

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16 Welck, n.1, p.328.

The second generation IRS satellites - IRS-1C and IRS-1D - are to have better spatial and spectral resolutions, more frequent revisit capabilities, stereoviewing and on-board data recording capability.[17] They are also to be incorporated with sensors in the visible, near-infrared, and short-wave infrared bands. The multispectral bands are to have a resolution of 20 metres and the panchromatic bands better than 10 metres. The short-wave infrared,with a resolution of 70 m is being included along with a wide-field sensor (resolution of 180 metres), for the purpose of vegetation monitoring.

SROSS

The Stretched Rohini Satellite Series is directed towards providing a satellite system "for conducting various scientific and technology experiments using the Augmented Satellite Launch Vehicle, ASLV."[18]

The first two in the series - SROSS-1 and SROSS-2 - could not be operated because of the failure of the ASLV to place them in their orbits. While SROSS-1 carried a technological payload, a Gammma Ray Burst detector, and a laser tracking equipment, SROSS-2 carried a Monocular Elecro Optical Stereo Scanner (MEOSS) and a Gamma Ray Burst detector.

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17 GOI, DOS, Annual Report 1990-91, p.24.

18 GOI, DOS, Annual Report 1991-92, p.46.

SROSS-3 was launched on the third flight of the ASLV on 21 May, 1992. It carried a Gamma Ray Burst detector, and a Retarding Potential Analyser (a payload designed by the National Physical Laboratory) for measuring the fluctuations in the number of electrons in the ionosphere.

The next satellite in the series, SROSS-4 will carry an X-ray astronomy payload which is being jointly developed by ISRO and the Tata Institute of Fundamental Research (TIFR).

SOUNDING ROCKETS

According to Prakasam, "experimentation with sounding rockets is an excellent point of departure for space research," because of the relatively simple techniques and range facilities required. He further adds that a sounding rocket programme effectively stimulates technological interest, study and cooperation.[19]

India's Space Programme had its formal beginning when a U.S. Nike-Apache sounding rocket was launched from Thumba on 21 November, 1963. During the developmental phase of the Indian programme, the emphasis was on developing and using sounding rockets. Initially, before the technology for developing sounding rockets could be mastered, sounding rockets from other countries were launched from Thumba. These include: the U.S. Nike-

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19 K.P. Prakasam, Space Horizons (New Delhi, 1981), p.13.

Apache, the Nike-Tomahawk, the Dual Hawk, the Arcas, and the Judi Dart rockets, the Soviet M-100s, ,the French Dragon and Centaur rockets, and the British Skua and Petrel rockets.[20]

In 1964, India concluded an agreement with Sud Aviation of France for the licensed production of Centaure rockets in India. Later, a number of rockets were developed indigenously, which were termed as Rohini sounding rockets. The first indigenous rocket, Rohini-75, was launched from Thumba on 20 November, 1967.

The launching of Indian sounding rockets is carried out under the Rohini Sounding Rocket programme, which "coordinates the development, production and launch of the Rohini series of sounding rockets and Indian Centaure rockets for research of the Upper atmosphere and meteorological sounding."[21]

The Rohini series comprises the following: RH-75, RH-100, RH-125, RH-200, RH-560. The RH-125 and RH-200 are used for meteorological research and are referred to as Menaka rockets. They measure the temperature, wind velocity and direction, etc .... Apart from RH-200 ISRO produces only RH-300 and the RH-560 on an operational basis.

Sounding rockets were also used "to develop and test several

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20 Kapil Kaul, "India in Space, "STRATEGI ANALYSIS (New Delhi) vol.10, no.7 (Oct. 1986), p.855.

21 GOI, DOS, n.11, p.35.

sub-systems for advanced rockets and evaluate more energetic propellants."[22] For example, RH-125 rockets were used for testing and perfecting techniques like stage separation, destruct system, clustering of boosters to serve as a single large booster, payload recovery systems, and ejection of nose cones.

Under an agreement signed between India and the former Soviet Union, Soviet M-100 rockets have been launched every week from Thumba since 1970. These rockets help in studying meteorological data -atmospheric pressure, temperature, electron density, etc ..., upto a height of 80 to 90 km.

SLV-3

SLV-3 was an experimental project designed to achieve competence in the area of satellite launchers. It was to "serve as a model for bigger rockets, leading to a geostationary orbit."[23]

The first experimental flight of SLV-3 was on 10 August, 1979, which was a failure. The goals of this launch were :

(a) to realise a fully-integrated vehicle;

(b) to evaluate on-board systems like stage motors, control systems, and electronic subsystems; and,

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22 Rajan, n.6, p.6.

23 Mohan Sundara Rajan, <u>India in Space</u> (New Delhi, 1976), p.26.

(c) to evaluate ground systems like check-out, telemetry, and real-time data facilities in launch operations.[24]

The second experimental flight, SLV-3(E)-02, was on 18 July, 1980, which succeeded in orbiting a Rohini satellite. Its goals were the same as that of the first experimental fight.

The first developmental flight of the SLV-3,SLV-3 D-1 was on 31 May, 1981. It was intended for the purpose of evaluating the performance of the vehicle for future operational flights. This launch was a partial failure, for, it deviated from its planned trajectory which resulted in the placement of the Rohini satellite in a lower orbit.

The second developmental flight of the SLV-3,SLV-3 D-2 was on 17 April, 1983. This launch marked the completion of the project.

ASLV

The Augmented Satellite Launch Vehicle (ASLV) is designed to augment the indigenous satellite launch capability, as also to "validate a number of important advanced technologies needed for the larger launch vehicles of the Country such as PSLV/GSLV."[25] Examples are closed-loop guidance system, strap-on mechanisms, etc ...

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24 GOI, DOS, Annual Report 1979-80, p.18.

25 GOI, DOS, Annual Report 1988-89, p.36.

The ASLV is an augmented version of the SLV-3 with the addition of two strap-on motors. It was originally designed to orbit 150-kg class satellites in 400 km orbits. Because of the failure of the first two launches, the design was altered to incorporate some additional mechanisms which has resulted in a reduced payload capacity of only 106 kg.

The first flight of the ASLV on 24 March, 1987 failed due to the non-ignition of the first stage after the separation of the Zero stage. The second flight on 13 July, 1988 also failed because of a flaw in the vehicle design which led to aerodynamic instability and the resultant breakdown of the launcher.

The third launch of the ASLV (ASLV-D-3) on 21 May, 1992 succeeded in orbiting the SROSS-3 satellite. The aim of this mission was to evaluate the performance of the vehicle.

PSLV

The Polar Satellite launch Vehicle (PSLV) is being developed to "achieve indigenous capability to launch remote sensing satellites into polar sun-synchronous orbits."[26] The four stage vehicle, which uses both solid and liquid rocket motors, is designed to place a 1,000 kg satellite in an orbit of 1,000 km.

PSLV's second stage liquid rocket engine is the French 'Viking' liquid rocket, which has been developed within the country under an agreement with France.

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26 GOI, DOS, Annual Report 1989-90, p.35.

GSLV

The Geosynchronous Satellite Launch Vehicle (GSLV) is being planned for the purpose of achieving launch capability for geostationary satellites. The configuration of the Vehicle has been finalised. "It is configured by replacing the upper two stages of PSLV by a single cryogenic stage and the six solid propellant strap-on motors by four liquid propellant strap-ons derived from the PSLV second stage."[27]

ISRO signed an agreement with Glavcosmos, the Soviet space agency (now Russian), in November 1990 for the purchase of cryogenic engines along with technology transfer. The GSLV is being developed for placing INSAT-2 satellites in geosynchronous transfer orbits.

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27 GOI, DOS, n. 18, p.44.

CHAPTER - 4

BENEFITS OF THE SPACE PROGRAMME

As pointed out earlier, the major aim of the Indian Space Programme is to utilize space technology for practical applications in the fields of telecommunications, weather forecasting, and remote sensing, which would help to improve the socio-economic conditions of the people of the country. The benefits that have accrued to India in the three thrust areas of the space programme are discussed below.

TELECOMMUNICATIONS

The experimental projects undertaken during the 1970s - the Satellite Instructional Television Experiment (SITE) and the Satellite Telecommunications Experimental Project (STEP) - indicated the viability of utilizing space technology in the field of telecommunications.

The impact of SITE on the target audience - both children (5 to 12 years) and adults - was significant. According to a survey conducted by the Research and Evaluation Cell of the Space Applications Centre, there was (a) overall improvement in health and hygiene, (b) appreciation for the message of limited families, (c) improvement in the language of the children as well as in their school attendance, and

(d) increased awareness and also eagerness to gain more information on several subjects.[1]

STEP demonstrated the viability of satellite-based domestic telecommunications. For example, the 'SYMPHONIE' satellite was utilized for providing emergency communications between a jeep-mounted mini-earth station at Vijayawada and New Delhi when a severe cyclone struck the coastal areas of Andhra Pradesh.[2] The experience gained through SITE and STEP was further consolidated during the APPLE project.

The full-fledged operationalization of space-based telecommunications services became a reality with the INSAT project. The INSAT system "initiated a communication revolution in the country enabling, for the first time, even remote corners and off shore islands to become a part of the mainstream of the nation."[3]

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1 Mohan Sundara Rajan, Indian spaceflights (New Delhi, 1985), p.97.

2 GOI, DOS, Annual Report 1977-78 ,p.16.

3 U.R. Rao, Indian Space Programme : A Perspective (Bangalore, 1991),p.12.

As of 1 December, 1991, a total of 126 telecommunication terminals were operating in the INSAT network providing 4,514 two-way speech circuits or equivalent over 140 routes.[4] Several rural areas have also been connected through INSAT to the main telecom network by establishing Low Cost Terminals in these areas.

The INSAT system is also being used to set up networks involving a large number of small terminals throughout the country for a variety of applications ranging from administrative, business, computer communications, information exchange, to captive networks involving ONGC, NTPC, NICNET, etc ....[5]

The Press Trust of India disseminates news and fax messages to newspapers around the country in different languages through the INSAT system. And, over the last few years, 'The Hindu' newspaper has been using the INSAT network for facsimile transmission of its fully composed pages from Madras to New Delhi. And, a new service for emergency communications for post-disaster relief operations has also been commissioned.[6]

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4 GOI, DOS, Annual Report 1991-92, p.20.

5 Rao, n.3, p.12.

6 ibid,

Under the National Informatics Centre Network (NICNET), over 450 micro terminals are under operation. This network, one of the 23 Captive INSAT networks, provides data communication links between the State Capitals, the District Headquarters and the Central Government Departments.

The Remote Area Business and Message Network (RABMN), similar to the NICNET, is under implementation. It is being designed to provide data communication between industries and construction projects located in rural and remote areas and their headquarters in distant cities. A total demand of 1,024 micro stations has been registered for this network, out of which 101 have been supplied.[7]

Another similar network under implementation is the Information Library Network (INFLIBNET) of the University Grants Commission which aims at inter-connecting the libraries of different universities and Research and Development institutions in the country.

Another area in which INSAT has had an impact is television and radio broadcasting. India's television network

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7 GOI, DOS, n.4, p.20.

now includes over 520 transmitters which cover over 75 per cent of the population.[8] And, INSAT has also led to the installation of over 100,000 direct reception television sets which provide coverage to very remote corners of the country.[9]

The two S-Band transponders aboard the INSAT provide national programmes and regional television services. They also support "a 6 channel radio networking service, DWS standard time and frequency signal dissemination and a direct satellite retransmission facility for processed INSAT meteorological images."[10] The C-band transponders provide regional television networking services.

The INSAT network helps in covering important events within the country using transportable television uplinking stations.

The INSAT system also provides facilities for broad-casting education programmes. About 100 hours of programmes per month are being transmitted to about 4,000 schools and colleges.[11] In addition, programmes are also telecast to help adults become literate. Also, INSAT is being used for teacher training and for reorientation programmes.

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8 Rao, n.3, p.14.

9 GOI,DOS, n.4, p.22.

10 ibid, p.21.

11 ibid,

INSAT's radio networking service includes the provision of reliable 6 channel national or regional feeds for re-transmission by stations of All India Radio, single channel uplink from Bombay, Calcutta and Madras, etc ...

WEATHER FORECASTING

Early efforts at meteorological applications were made with sounding rockets. A number of such rockets, both Indian and those belonging to other countries, were flown regularly. At present, Soviet M-100 rockets and Rohini sounding rockets are launched for this purpose.

The launch of BHASKARA-1 gave India the opportunity to study the atmospheric processes from a space platform. The satellite was equipped with three microwave radiometers which transmitted data on the atmosphere and the seas surrounding the Indian subcontinent. For example, the satellite was used for studying the feasibility of estimating rainfall over the seas around India.

BHASKARA-2 was an improved version of BHASKARA-1. It was also used on an experimental basis. For example, it was used in December 1981 to estimate the dimensions of a cyclone over the Bay of Bengal.[12]

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12 Rajan, n.1, p.113.

Weather forecasting on a regular basis became possible only after the operationalization of the INSAT system. INSAT is equipped with a Very High Resolution Radiometer (VHRR) which provides half-hourly observations of weather systems over the Indian territory and the adjoining land and sea areas. Data products generated using VHRR imageries relate to upper winds, sea surface temperature and precipitation index. INSAT imageries are regularly used on Doordarshan's news coverage and by newspapers for reporting on weather.

VHRR data is now available in real time at 22 secondary Data Utilization Centres (SDUCs) in various parts of the country. It is also possible to transmit these data to any location in the country through the direct satellite re-transmission service provided by INSAT.

One hundred Data Collection Platforms (DCPs) have been installed for the purpose of collecting meteorological information in remote areas. Data collected by the DCPs is relayed by the INSAT Data Relay Transponder to the Meteorological Data Utilization Centre (MDUC) at New Delhi. In addition to these DCPs, the Central Water Commission has deployed 14 DCPs in the Yamuna Catchment area for the purposes of forecasting floods.[13]

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13 GOI, DOS, n.4, p.21.

And, as part of the INSAT meteorological network, one hundred Disaster Warning System (DWS) receivers have been installed in select cyclone-prone coastal areas of Andhra Pradesh and Tamil Nadu with uplinking facility from Madras.[14]

REMOTE SENSING

India's remote sensing activities began in the late 1960s with aerial surveys over coconut plantations in Kerala and sugarcane plantations in Mandya for evaluating crop yields and pest diseases.[15]

The establishment in 1979 of a LANDSAT receiving station at NRSA, Hyderabad gave an opportunity for gaining valuable experience in the interpretation and analysis of satellite data.[16]

In order to gain much-needed experience in satellite remote sensing, India embarked upon the Bhaskara project under which two Bhaskara satellites were launched (1979 and 1981). The satellites carried a dual television camera system operating in the visible and the near infrared spectra, with a spatial resolution of about 1 km. Imageries

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14 ibid,

15 Rao, n.3, p.5.

16 ibid,

from these satellites were used for studying forest, hydrological and land resources.

For example, using images from Bhaskara-1, the demarcation of the interface of water and land in the Gulf of Cambay was carried out over the Saurashtra coastal region. And, imageries from Bhaskara-2 were used for making land use maps for West Bengal and Bihar regions.[17]

Based on the experience gained from the Bhaskara project, India has succeeded in operationalizing remote sensing services through the India Remote Sensing Satellites. Remote sensing applications in India, under the umbrella of the NNRMS, "now cover diverse fields such as agriculture crop acreage and yield estimation, drought warning and assessment, flood control and damage assessment, land use/land cover mapping for agro-climatic planning, wasteland management, water resources management, mineral prospecting, forest resources survey and management, etc ..., there touching almost all facets of national development."[18]

Agriculture, the major economic activity in India, has been given much importance in remote sensing applications. The Department of Space has, in collaboration with the

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17 Rajan, n.1, pp.111-12.

18 Rao, n.3, p.6.

Department of Agriculture and Cooperation, launched a project on Remote Sensing Application Mission for agriculture applications. It has six sub-projects which are being implemented in collaboration with State and Central Government user agencies.

Beginning with 1986-87, crop acreage estimation has been done for every season. For example, rice crop acreage was estimated for the <u>Kharif</u> season of 1986-87 in Orissa, and wheat acreage for 1986-87 and 1987-88 in Haryana, Punjab, and parts of western Uttar Pradesh.[19]

Under the National Agricultural Drought Assessment Monitoring System (NADAMS), drought bulletins based on satellite observations are being issued on a fortnightly basis for 12 states.[20] This provides near realtime information to district authorities and agricultural resource planners for dealing with the drought situation.

The DOS is carrying out a nationwide project on land use/land cover mapping for the Planning Commission. This would help in preparing operational plans for the management and utilization of land for agriculture, forestry, etc..., in 15 agroclimatic Zones of India. Already, information on

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19 GOI, DOS, <u>Annual Report</u> 1988-89, p.25.

20 Rao, n.3, p.7.

373 districts has been provided to the Planning Commission.[21]

Satellite remote sensing also plays an important role in the survey and monitoring of forests in the country. The Forest Survey of India has started biennial forest mapping for the entire country using satellite remote sensing data.

Remote sensing also helps in the identification of water bodies suitable for inland fisheries and also for the identification of ocean areas rich in fish. All India Radio broadcasts information based on remote sensing data on the location of fish schools in order to enable fishermen to have a better catch.[22]

Satellite remote sensing also provides important inputs in managing water resources. For example, under the National Technology Mission on Drinking Water, a countrywide hydrogeomorphological mapping has been prepared using space imagery which indicates ground water prospect areas.[23]

Remote sensing data are also useful for mapping seasonal snow cover and estimating the snow-melt run off during

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21 GOI, DOS, n.4, p.28.

22 Rao, n.3, p.10.

23 U.R. Rao, Remote Sensing for Sustainable Development (Bangalore, 1991), p.14.

summer months. At present, remote sensing data for this purpose is applied in the Sutlej and Beas river basins. The estimates are given "three to four months in advance of the actual run off period to an accuracy of better than 3 per cent, which are now regularly used for optimising the use of water for power and irrigation."[24]

Remote sensing data is also used for the"identification and prioritization of erosion-prone areas in various watersheds as well as to provide inputs for undertaking desiltation plants."[25] As part of the Subansiri watershed study, investigation are being carried out on the migration of channels in the Brahmaputra basin.

Remote sensing data are also used for obtaining real time information on flood-affected areas regarding damage to infrastructure, crop losses, etc .. For example, flood maps were prepared for the Ganga and Brahmaputra basins in near real time during the 1991 floods and sent to the user departments.[26]

Using Remote sensing imageries, a glacier atlas has been prepared and a data base created. This has contributed towards the planning and operation of mini and micro hydro-electric stations.

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24 Rao, n.3, p.8.

25 ibid,

26 GOI, DOS, n.4, p.31.

Remote sensing imageries are also useful for planning and development of new urban areas. Land use and urban sprawl maps, using satellite data, provide vital inputs for the optimal location of industries, housing, infrastructural facilities, etc ... For example, satellite data was utilized in conducting a survey for aligning the proposed ring road for Bangalore Development Authority.[27]

The DOS, in cooperation with the National Wasteland Development Board, has carried out wasteland mapping of 146 critically affected districts with the help of space imageries to identify 13 wasteland categories at village level. This work has been taken up for a further 80 districts. Information thus collected "is being used to generate comprehensive solutions towards reclamation of wastelands."[28]

To utilise remote sensing for mineral prospecting, the DOS has taken up a project, in collaboration with the Geological Survey of India, named Vasundhara, which covers an area of 400,000 sq.km of South India.

SECONDARY BENEFITS

The benefits discussed above are the primary benefits which accrue directly from applications of space technology. There are also secondary benefits which accrue indirectly from the space programme.

A space programme requires contributions from diverse scientific disciplines ranging from chemistry to mathematics

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27 Rao, n.3, p.9.

28 ibid, p.8.

to electronics. So, a space programme acts as a technological pace-setter initiating constant improvement in other fields of science and technology. This raises the level of technological capabilities within the country and their applications in other fields of science or industry.

ISRO has transferred about 180 technologies to Indian industry, some of which have been put to applications in other fields. For example, the computerised analytical techniques developed for rocket systems have been applied by the Bharat Heavy Electricals Limited, Hyderabad for solving problems of turbine vibration, and by the Kerala State Electricity Board in designing arch dams.[29]

According to Rao, "the multiplier impact of this diffusion of tasks, skills, techniques and technologies" is evident in the emergence of a space-related sector of Indian industry which cuts across all sectors. He further adds that the experience of the West (USA and Europe) " is that the benefit from such a multiplier effect is almost three times the direct benefits. With the 'spin-offs' from space technology now being woven into our national fabric, there is no reason why similar benefits cannot be realised in our own national context."[30]

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29 P. Nanda Kumar, "Space Research in India," Indian and Foreign Review vol.15, no.2, 1 Nov. 1977 , p.19.

30 Rao, n.3, p.19.

MILITARY APPLICATIONS

Space technology also has a number of aplications in the military sphere. While remote sensing satallites (with resolutions of 10 m or less) can be effectively used for spying over the territory of adversaries, communications satellies provide improved command, control, communications and Intelligence (C^3I) facilities and, most important, launch vehicles can be used as missiles for delivering weapon payloads deep into the territory of the adversaries.

There are no reports so far of India using its satellites for military purposes. But, she has utilised her experience in launching satellites in designing and developing missiles which are to be used by the Indian armed forces.

India's efforts in the field of military rocketary dates back to the 'Devil' programme of the 1970s which attempted the reverse-engineering of Soviet Surface-to-Air missiles into Surface-to-Surface missiles.[31] The only worthwhile success of this programme was the development of a three-tonne liquid fuel engine which later came to be used in both the 'Prithvi' and 'Agni' missiles of the Integrated Guided Missiles Development Programme (IGMDP).[32]

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31 VAYU (New Delhi), no. 3, (1989), p.6.

32 Sango Panwar, "India's Missiles : A New Dimension in South Asia", VAYU, no.6, (1989), p.23.

The IGMDP, initiated in July 1983, followed India's sucess in placing a Rohini satellite on-board the indigenous SLV-3 launch vehicle. The missile programme has benefited from the experience gained in the space programme. Infact, the IGMDP was placed under the charge of A.P.J. Abdul Kalam who earlier led the developmental effort of the SLV-3 launch vehicle . On 7 July 1992 he was appointed as the Scientific Advisor to the Defence Minister and will now also head the Defence Research and Development Organization. The mandate of the IGMDP included the development of four missile systems - 'Trishul', 'Prithvi', 'Akash', and 'Nag'. - and the testing of an Intermediate Range Ballistic Missile (IRBM) 'technology demonstrator', 'Agni'.

Trishul, a quick-reaction Surface-to-Air missile, was the first to be tested in September 1985. It has a maximum range of 9 km and is to be used by the Army and the Air Force. A naval version is also under development for the purpose of countering sea-skimming missiles. This version was succeffully tested during 1991-92[33]. A number of developmental tests of this missile system have been carried out so far, and it is expected to be deployed during this year.

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33 FRONTLINE (Madras), vol 9, no. 11 (5 June, 1992), p.6.

Maraging steel is being used for the rocket motor chamber of the 'Trishul'[34] This was initially developed as part of the space programme for use in the PSLV motor by ISRO along with the Welding Research Institute, BHEL, MIDHA-NI, Rourkela Steel Plant, etc.[35]

'Prithvi' was the next to be successfully flight-tested on 25 February, 1988. It is a Surface-to-Surface battlefield support missile, with a maximum range of 250 km and a payload capacity of 500 to 1000 kg. It is to be used by the Indian Army for the purpose of destroying troop concentrations, crippling enemy air bases and striking at enemy headquarters.[36] So far, seven test flights of the missile have been conducted with one failure in February 1992.

The design of this missile is based on the satellite launch vehicle module.[37]

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34 VAYU, n. 31, p.7.

35 Sanat Biswas, "Space Programme in Driver's Seat of Economy." LINK, vol 28, no. 25 26 Jan. 1986 , p. 24.

36 Panwar, n. 32, p.24.

37 Rajendra Prabhu, "Space Programme: Defence aspects cannot be ignored," Hindustan Times (New Delhi), 18 May 1992.

'Nag', the third generation anti-tank missile was first flight-tested on 24 June, 1990. It has a maximum range of 4 km and is being equipped with a terminal guidance system. The second flight-test was carried out on 29 November, 1990. A total of 9 tests are to be carried out before user trials begin.

'Akash', the fourth missile under the IGMDP, was successfully flight tested in August 1990 from the Interim Test Range at Balasore. It is a transportable Surface-to-Air missile with a maximum range of 25 km and is to be used for providing defence to vital areas, points, and installations, etc... It is to undergo 9 flight trials over two years.

'Agni', the IRBM 'technology demostrator', was successfully flight-tested on 22 May, 1989 from the Interim Test Range at Balasore. The second test on 29 May 1992 was only a partial success for the missile "failed to carry out the final manoeuvres in the reentry stage."[38]

'Agni', is a Surface-to-Surface missile with a maximum range of 2,000 km and a payload capacity of one tonne. It is a two-stage missile, with the first stage using a solid

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38 THE HINDU (Madras), 30 May 1992.

propellant and the second stage using a liquid propellant. While the first stage motor is the same as that of the SLV-3's first stage,[39] the second stage is a modified version of the 'Prithvi' liquid engine. Even the missile's heat shield (in the reentry vehicle) and guidance system came from India's space programme.[40] The heat shield was made up of carbon composites which the West German space agency helped India in developing.[41] West Germany also helped in the development of guidance systems for its space programme. The closed-loop guidance system, used in the 'Agni' missile was first used in the Augmented Satellite Launch Vehicle.

Thus, the space programme has served a dual purpose. It has not onlu supported the socio-economic development of the country, but has also contributed towards the country's security needs.

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39 ibid.

40 Gary Milhollin, "India's Missiles: With a Little help from our friends", Bullettin of the Atomic Scientists, vol.45, no.9 (Nov 1989), p.31.

41 ibid, p.35.

CONCLUSION

Basic human needs are both physiological and social. While the former comprises food, shelter, health-care and clean environment, the latter takes the form of education, communication, transportation, etc.. Space technology can make significant contributions towards satisfying these basic needs. For example, in the case of agriculture, while meteorological satellites contribute towards planning the planting and harvesting seasons, remote sensing satellites gather information on crops and livestock, and communication satellites help in the dissemination of these and other information on farming techniques, etc...

Space technology can be adopted either on an ad hoc basis, when each national agency decides whether "space technology is cost-effective for meeting its requirements - or by establishing a space program to develop technology to meet national needs."[1]

India embarked upon the latter option by establishing a space programme whose goals were to develop the requisite technology - in ground network, satellites, and launch vehicles - for identified applications in the fields of

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1 Ralph Chipman, The World in Space : A Survey of Space Activities and Issues (Englewood Cliffs, New Jersey, 1982), p.493.

telecommunications, remote sensing and meteorological forecasting.

The Indian decision not only to utilize space technology but also to develop it can be said to have been motivated by the following considerations :

(a) that space technology can be productively applied to help improve the socio-economic conditions of the people ;

(b) that the development of space technology would play an important role in the development of industrial capabilities within the country;

(c) that space technology is more economical than other methods in certain areas ; and,

(d) that the space programme would contribute towards the overall development of the country.

Having embarked upon an integrated space programme, the Government of India initiated a number of policy measures which were designed to help achieve the goals set for the programme. These include :

(a) the decision to build up the infrastructural base for the development of technology and for providing the ground network;

(b) the decision to train and build-up a sufficient number of scientific, technical and administrative personnel to carry out the space programme;

(c) the decision to co-opt other national agencies and the Indian industry in the space programme ;

(d) the pursuit of cooperative relationships with the space agencies and space industries of other countries,etc.....

A number of projects were initiated under the space programme which were initially designed to gain experience in the development and utilization of space technology, and later to operationalize space-based services. The satellite development projects have been successful, though with some major failures. This has helped in the operationalization of INSAT and IRSS systems, which have been providing services in the areas of telecommunications, weather forecasting and remote sensing.

The major failures in the case of satellites have been INSAT-IA and INSAT-IC. The failure of these two satellites has been attributed to their peculiar design which became necessary because of the Indian insistence on the accomodation of the Very High Resolution Radiometer (VHRR) instrument in the INSAT series. Because of the inclusion of this instrument, the solar array (which powers the spacecraft) had to be given an asymmetrical shape so as to keep it out of the VHRR field of operations. This, in turn, necessitated the inclusion of a solar sail for balancing the whole satellite.[2] The two satellites were lost mainly because of the failure of their solar sails to open up. INSAT-IB was also plagued by a similar probelm, but ISRO and NASA scientists succeeded in deploying it after various manoeuvres.

A separation of the meteorological payload will not only solve this problem, but would also reduce the weight of INSAT-1 class of satellites to about 700 kg. And, this would enable them to be launched by a modified version of the PSLV[3].

The launch vehicle projects of the Indian space Programme have made less progress compared to the satellite projects. This could be attributed to the high priority being given to the development of satellites because of the compulsion to demonstrate the relevance of the space programme in national development.[4] While the first two flights of the Augmented Satellite Launch Vehicle (ASLV)

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2 S. Satyanarayanan, "Rocket Technology: with a little bit of help", Economic Times (New Delhi), 25 April 1992.

3 ibid.

4 Ashok Raj, "ASLV failure only temporary setback," PATRIOT (New Delhi), 17 April 1987.

were total failures, the Polar Satellite Launch Vehicle (PSLV) which was initially envisaged for launch in 1985-86 [5] has not yet been flown.

While the failure of the first ASLV test in 1986 was attributed to the non-ignition of its first stage motor, the Failure Analysis Committe (of ISRO) has traced the second failure to a design flaw in the launch vehicle. The flaw relates to the instability of the launch vehicle because of its length-to-diameter ratio and also the control systems which are designed to correct deviations in the launcher's trajectory. Deviations which normally result in launch vehicle trajectories were further aggravated in the case of the ASLV in which many of the critical events like booster separation and ignition of the core stage occur in the lower atmosphere where dynamic pressure and wind loads are high. This eventually led to the breaking up of the vehicle due to the vehicle experiencing maximum dynamic pressure.[6]

The Failure Analysis Committee recommended a number of design changes which were incorporated in the successful third developmental flight of the ASLV.

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5 GOI, DOS, Space Research and Development: Profile for the Decade 1980-1990, (Bangalore, 1981).

6 THE HINDU., (Madras), 1 August 1989.

India has achieved significant benefits from its space programme in the areas of telecommunications, remote sensing and meteorological forecasting. In the field of telecommunications, the benefits include improved domestic and international telephone connections, expansion of the television and radio networks, and other networks for the provision of a number of new services like PTI news service for rapid dissemination of news, data communications, etc....

Improved weather forecasting, based on satellite observations, has made significant contributions towards the management of water and other resources, in predicting natural disasters like cyclones, thus enabling precautionary measures for damage reduction, etc...

And, in the field of remote sensing, satellite data have been extremely useful in a number of fields ranging from agriculture to mineral resources survey to urban development, thus touching upon the major facets of national development.

In addition to these direct benefits, the space programme has also made valuable contributions towards the development of industrial and technological capabilities within the country. Also, the effects of the exploitation of the space environment can result in India entering the stage of, what Harry Stine refers to as, the "Third Industrial Revolution."[7] This should enable India to leap-frog some of the stages of development, as had been perceived by the Indian leadership.

MTCR

Another area of application of space technology has been in the development of missiles. This has led to considerable apprehensions among Western countries, especially the United States. In a bid to curb the proliferation of ballistic missiles around the world, the United States along with its Group of Seven (G-7) partners announced a Missile Technology Control Regime (MTCR) in April, 1987. The aim was to curb international trade in missile technology. The items to be controlled were placed under two categories. Category I items included complete rocket and unmanned airvehicle systems which can deliver payloads of 500 kg or more over a range of 300 km or more along with their production facilities and subsystems. Category II consists of components.[8]

On the basis of the MTCR guidelines, the United States imposed a two-year ban on "American trade and technology

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7 Quoted in William Sims Bainbridge, The Spacecraft Revolution: A Sociological Study (New York, 1976), p.2.

8 Kathleen C. Bailey,"Can Missile Proliferation be Reversed ?" ORBIS (Philadelphia), vol.35,no.1 (Winter 1991), p.9.

transfers with and to the Indian Space Research Organisation"[9] on 11 May, 1992 following India's refusal to cancel its November 1990 contract with Russia's (formerly Soviet) space agency, Glavcosmos, for the acquisition and subsequent technology transfer of cryogenic rockets. The U.S. view is that cryogenic rockets would contribute to India's ballistic missile programme.

Constraints

The U.S. ban, according to analysts, is likely to hinder ISRO satellite and launch vehicle projects, especially the former. For, ISRO is dependent on the United States for a number of major electronic components apart from others. This is in addition to its dependence on foreign assitance for launching its satellites, for the design, fabrication and development of its satellites (till recently), for the acquisition of ground support systems and also for the training of its personnel.

This dependence on foreign assistance has been one of the major constraints faced by the Indian space programme. This has necessitated India taking into account the interests of other countries while pursuing its space policy.[10]

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9 Gautam Adhikari, "U.S. slaps 2 year ban on ISRO, Glavcosmos," TIMES OF INDIA (New Delhi), 12 May 1992.

10 Stephen F. Von Welck, "India's Space Policy: A Developing Country in the Space Club," Space Policy, vol. 3, no.4 (Nov 1987), p.331.

The recent U.S. insistence on the cancellation of India's deal with Russia is a case in point.

The level of Indian dependence on foreign sources has been very high even during the 'operationalization' phase of its space programme. So far, none of the Indian applications satellites have been launched by indigenous launchers. While two of the INSAT-1 series were launched by NASA, the other two were launched by ESA, and the two Indian Remote Sensing satellites were launched by the Soviet Union. The INSAT 2A was also launched recently by ESA.

In the case of satellite fabrication, all the four INSAT-1 satellites were fabricated by Ford Aerospace of the United States. The second generation INSAT spacecraft however, are being developed within the country.

ISRO has also been dependent on foreign sources for its ground support systems. For example, the Soviet Union supplied an AFU-75 camera and laser equipment for the ISRO Satellite Tracking and Ranging Station (STARS), Kavalur.

ISRO's dependence on foreign sources is acute in the case of electronic components like radiation-hardened integrated circuits, travelling wave tube amplifiers, etc... In fact, ISRO had been importing more than half of its requirements of electronic components from U.S. companies.[11] Other electronic components for which India is dependent on foreign sources are solar cells, charge-coupled devices, detectors for the VHRR (in the INSAT) and earth acquisition sensors.

Non-electronic components include reaction control systems (RCS) which includes high speed momentum wheels and reaction wheels, titanium alloy tanks and helium pressurant tanks, auxiliary thrusters for satellite orbit attitude corrections, beryllium reflectors, C-band antenna, etc...[12]

The Indian Space Programme which is dependent on the United States for most of these items is likely to suffer some setbacks due to the U.S. ban on ISRO.

Another constraint faced by the Indian Space Programme has been the lack of adequate industrial capabilities within the country. Indian industry does not possess an adequate technology base "to enable it to cooperate with the ISRO in the implementation of the programme."[13] At the most, ISRO

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11 N. Gopal Raj, "French firm Willing to supply ISRO parts," THE HINDU (Delhi), 8 July 1992.

12 R. Ramachandran, " U.S, sanctions to cripple satellite capabilities," ECONOMIC TIMES, 13 May 1992.

13 Welck, n. 10, p.331.

can procure components and materials from Indian industry and also get certain systems fabricated or produced to its stipulations. For, the industries in India "tend to supply only component units rather than the entire functional units."[14]

Another major constraint faced by the Indian space programme is in financial allocations which are limited to the absolute minimum required. The budget allocations made during the 1980-1990 decade work out to an annual average of about Rs 235 crores. This sum is very meagre compared to the NASA's annual budget of 15 billion U.S. dollars during the early 1980s.

To overcome these constraints, India will have to make sustained efforts towards developing space technology in a self-reliant manner. Even though the policy of self-reliance was the guiding principle of the Indian Space Programme, the reliance on foreign assitance for several key components has continued to persist even after two decades. Such dependence leads to limitations being placed on India's space policy, for the country will have to take into account

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14 N. Gopal Raj, "From Sounding rockets to satellites," <u>FRONTLINE</u>, vol.3, no.21 31 Oct. 1986 , p.82.

the considerations of the countries on which it is dependent. Technological self-reliance has especially become an imperative for India, as well as for all developing countries, following the setting up of technology export cartels by the developed countries (like the MTCR).

The Department of Space has been seeking, over the last few years, the Government's approval for the establishment of a corporate front in the public sector. The proposed company is to be "essentially a promotion and service agency providing a range of high-tech services and will not itself undertake manufacturing activities."[15] Two roles have been conceived for the company - one, to market Indian space capability abroad and exploit the international market for space products and services; and two, to build up industrial capabilities within the country.[16]

While the prospects for the former appear quite dim in the wake of the recent U.S. ban on ISRO, the proposed company can play an important role in promoting industrial development. This, it can do in two ways - one, it can undertake

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15 N. Gopal Raj, "Corporate Front for Dept. of Space, "THE HINDU (Delhi), 28 May 1992, p. 17.

16 ibid,

a multi-disciplinary approach involving a wide range of techno-managerial legal and contractual, marketing, financial and promotional services; and two it can coordinate ISRO's interactions with industrialists as well as with financial institutions, market research organizations and Research and Development institutions and groups.[17]

These and other measures should enable India to carry on with its applications-oriented space programme more effectively "which has the capability to transform the entire society touching practically every aspect of human endeavour - education, communication, environment, habitation, agricultural output, and industrial productivity."[18]

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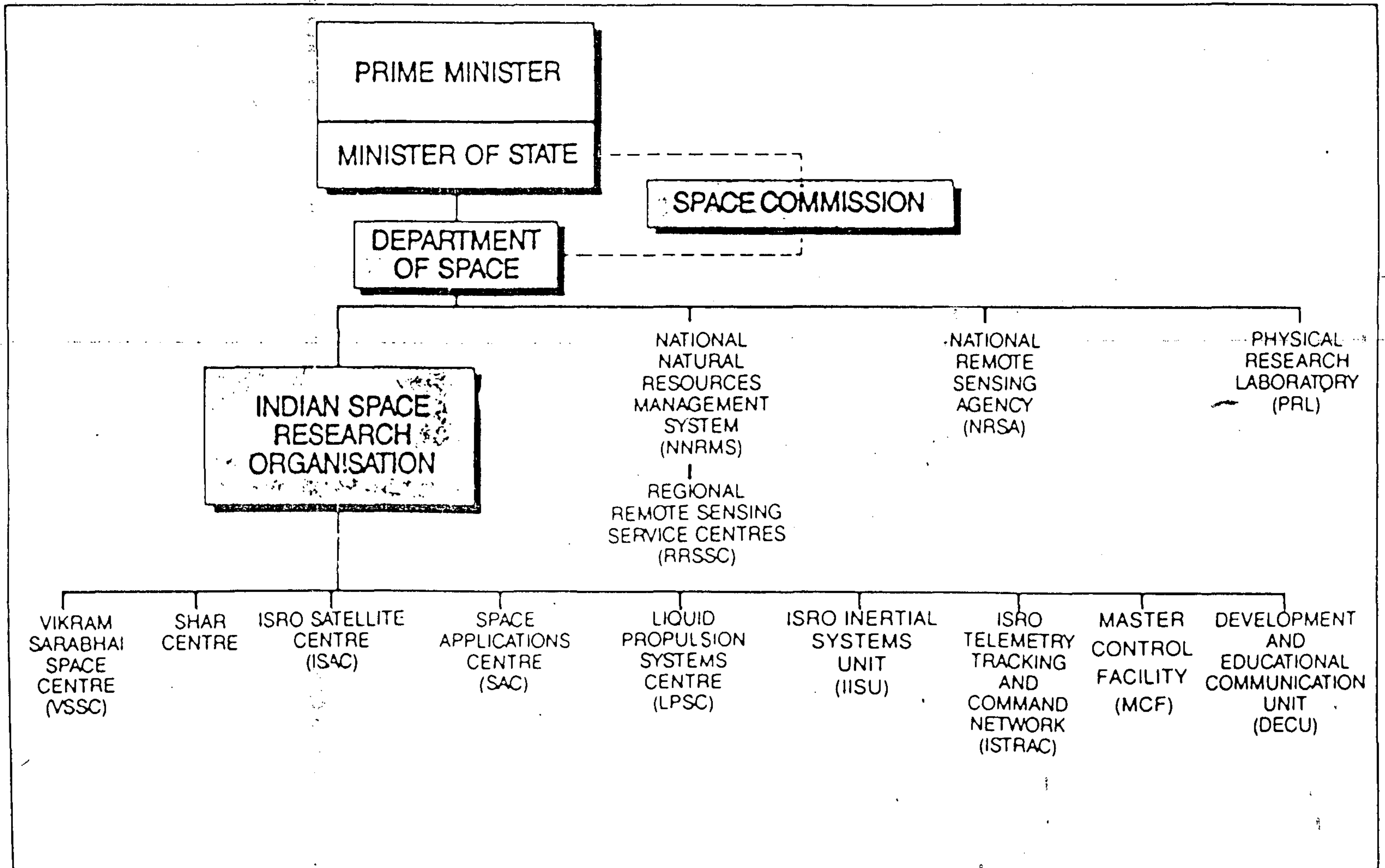
17 ibid,

18 U.R.Rao, The Next 40 Years In Space : A View Point of Developing Countires (Bangalore, 1989).

APPENDIX - 1



SOURCE: Government of India, Department of Space, Annual Report 1991-92, p.10.

APPENDIX - 2

GROWTH OF MANPOWER (1974-75 TO 1991-92)

YEAR	SCIENTIFIC AND TECHNICAL STAFF	ADMINISTRTIVE STAFF
1974-75	5137	2765
1975-76	5730	2864
1976-77	5715	3084
1977-78	6618	3269
1978-79	7050	3360
1979-80	6193	3422
1980-81	6200	3000
1981-82	7021	3622
1982-83	7852	3999
1983-84	7791	3964
1984-85	8835	4327
1985-86	9572	4523
1986-87	9988	4580
1987-88	10389	4848
1988-89	10405	5127
1989-90	10611	5189
1990-91	10255	5035
1991-92	10527	5395

SOURCE : Government of India, Department of Space, ANNUAL REPORTS 1976-77 TO 1991-92.

APPENDIX -

COST ESTIMATES OF THE SPACE RESEARCH PROGRAMME

Sl. No.	Item	Funds required		
		1970-80	1970-75	1975-80
		(Rupees in crores)		
1	Augmentation of facilities for R & D. at SSTC for building scientific and communication satellite and environment testing ..	5.00	5.00	—
2	Development of inertial & inflight guidance systems for rockets and onboard miniaturised computer	2.50	1.25	1.25
3	Development of High Performance Missile Tracking Radars and P.C.M. Communication Systems	3.75	2.00	1.75
4	Solid Propellant Plant and Testing Facility at SHAR	15.70	12.45	3.25
5.	Rocket Fabrication Facility for large sized rockets	2.00	2.00	—
6	Development of SLV-3 satellite launch vehicle	3.50	3.50	—
7.	Development of Scientific Satellite	3.00	1.00	2.00
8.	Expansion of Experimental Satellite Communication Earth Station including Satellite Instructional Television Experiment (SITE) ..	4.25	4.25	—
9.	Development of Communication Satellite	27.00	2.00	25.00
10.	Development of Satellite Launcher (SLV-SYN)	15.45	--	15.45
11	Operational requirements:			
	(i) Thumba Equatorial Rocket Launching Station	10.00	4.60	5.40
	(ii) Experimental Satellite Communication Earth Station	2.25	0.75	1.50
	(iii) Rocket Propellant Plant ..	5.00	2.00	3.00
	(iv) Space Science & Technology Centre	36.00	10.00	26.00
	(v) Rocket Fabrication Facility	9.00	3.00	6.00
	(vi) Sriharikota Range	20.00	8.00	12.00
	(vii) Indian Space Research Organisation	0.60	0.20	0.40
	Total	165.00	62.00	103.00

SOURCE : Government of India, Department of Atomic Energy, Atomic Energy and Space Research : A Profile for the Decade 1970-80, p.40.

APPENDIX - *

COST PROJECTIONS

Item	Estimated Expenditure in Rs. Crores (in 1979 prices) 1980-85	1985-90	Total 1980-90
FINANCIAL OUTLAYS			
1. Completion of on-going schemes and maintenance in infrastructure support including the operations of the Space Centres	163	218	381
2. IRS Project & post-launch operations	32@	1	33
3. SLV-Variants (Polar Launch Vehicle and Augmented SLV Projects) and post-launch-operations	41	10	51
4. Proto-INSAT Project & post-launch operations	21	27@	48
5. Tracking, ranging & other general facilities	18	2	20
6. Launch vehicle & Satellite related facilities	45	9	54
7. Follow-on projects of IRS, SLV-V & Proto-INSAT including advanced system studies	1	97	98
8. Facilities related to follow-on project	1	50	51
9. Miscellaneous support activities including support R & D and other projects	54	60	114
10. Technology transfer and utilisation	1	3	4
Total	377	477	854

* The costs of establishment and maintenance of Space Systems in the national operational sectors (for example INSAT in the Transport & Communication Sector) are not included in this profile, which addresses itself to the space research & development plan of the country for the decade.

@ Includes provision for external launch.

Note: The National Remote Sensing Agency (NRSA) has been placed under the Department of Space effective 4th December 1980. This profile does not include provisions for NRSA activities.

SOURCE : Government of India, Department of Space, Space Research and Development : Profile for the Decade 1980-90.

APPENDIX - 5

ANNUAL ALLOCATIONS TO THE SPACE PROGRAMME

(1969-70 TO 1991-92)

YEAR	ALLOCATIONS (IN CRORES OF RUPEES)
1969-70	3.66
1970-71	6.88
1971-72	11.74
1972-73	16.26
1973-74	18.71
1974-75	30.72
1975-76	37.18
1976-77	39.19
1977-78	37.36
1978-79	50.65
1979-80	56.41
1980-81	85.42
1981-82	108.90
1982-83	94.73
1983-84	163.10
1984-85	181.61
1985-86	235.05

1986-87	309.99
1987-88	346.96
1988-89	422.34
1989-90	398.56
1990-91	386.22
1991-92	482.80

SOURCE : For the years 1969-70 to 1973-74, Baldev Raj Nayar, India's Quest for Technological Independence : The Results of Policy (Lancers, New Delhi, 1983), vol.2, p.448.

For the rest, Government of India, Department of Space, Annual Reports 1976-77 to 1991-92.

APPENDIX - 6

AREA-WISE DISTRIBUTION OF FUNDS

(1974-75 TO 1979-80)

(RUPEES IN CRORES; PERCENTAGES IN BRACKETS)

YEAR	RESEARCH AND DEVELOPMENT	FACILITIES	PROJECTS	RANGES	DIRECTION AND ADMINIS-TRATION.
1974-75	11.83 [38.5]	5.99 [19.5]	8.29 [27]	3.69 [12]	0.92[3]
1975-76	11.53 [31]	10.78 [29]	9.3 [25]	4.46 [12]	1.12[3]
1976-77	15.28 [39]	7.05 [18]	11.37 [29]	3.92 [10]	1.57[4]
1977-78	14.57 [39]	8.59 [23]	8.59 [23]	3.74 [10]	1.87[5]
1978-79	21.27 [42]	6.58 [13]	12.66 [25]	8.61 [17]	1.52[3]
1979-80	24.82 [44]	8.46 [15]	10.72 [19]	10.72 [19]	1.69[3]

SOURCE : Government of India, Department of Space, ANNUAL REPORTS 1976-77 to 1980-81.

APPENDIX - 6

AREA-WISE DISTRIBUTION OF FUNDS

(RUPEES IN LAKHS; PERCENTAGES IN BRACKETS)

YEAR	ROCKET DEVELO-PMENT	SATELLITE DEVELOP-MENT	SPACE APPLI-CATION	SPACE SCIENCES	INSAT-1	DIRECTION AND ADMINIST-RATION.
1980-81	2733.44[32]	3502.22[41]	256.26[3]	1025.04[12]	213.55[2.5]	811.49[9.5]
1981-82	4415 [40.5]	1482 [13.6]	1045 [9.6]	335 [3.1]	3293 [30.2]	320 [2.9]
1982-83	4805 [50.7]	1383 [14.6]	1322 [14]	478 [5]	1155 [12.2]	330 [3.5]
1983-84	6177.87[37.9]	2265.63[13.9]	1185.16[7.3]	368.61[2.3]	5963.14[36.6]	349.29[2.2]
1984-85	9050.35[49.8]	2937.59[16.2]	1614.33[8.9]	414.78[2.3]	3711.44[20.4]	432.76[2.4]
1985-86	11237.31[47.8]	3607.76[15.3]	2256.69[9.6]	523.55[2.2]	4938.56[21.0]	904.63[3.8]
-1986-87	13190.71[42.6]	6188.53[19.7]	3083.53[9.9]	505.80[1.6]	7228.08[23.3]	872.54[2.8
1987-88	14700.93[42.4]	8809.27[25.4]	4059.92[11.7]	671.32[1.9]	5597.86[16.1]	856.75[2.5]
1988-89	16043.59[38]	13874.27[32.9]	4388.32[10.3]	767.16[1.8]	6224.29[14.7]	936.54[2.2]
1989-90	14740.70[31]	13892.24[34.9]	4507.35[11.3]	848.29[2.1]	4816.55[12.1]	1050.82[2.6]
1990-91	18128.59[47]	11800.30[30.6]	4444.96[11.5]	946.54[2.5]	2160.20[5.6]	1141.59[3.0]
1991-92	22242 [46.1]	14093 [29.2]	5085 [10.5]	1393 [2.9]	4082 [8.5]	1385 [2.9]

SOURCE : Government of India, Department of Space ANNUAL REPORTS 1981-82 to 1991-92.

APPENDIX - 7

COMPONENTS IMPORTED FOR SPACE PROGRAMME

SERIAL	ITEM	SOURCE OF SUPPLY
1.	Nickel-Cadmium Batteries	SAFT, France.
2.	Solar Cells	AEG, Telefunken, FRG
3.	lenses for LISS Camerass	MATRA, France
4.	High Density Digital Taperecorders	HONEYWELL, USA
5.	TWTA	CSF Thomson, France
6.	CCDS	FAIRCHILD, USA
7.	Computers	DEC, USA.
8.	Contour Nozzles	M/S VOLVO, Sweden.
9.	Vertical Mixer	M/S Day Mixing Company,USA
10.	Vertical Boring and Turning Mill	M/S Mitsui & Co., Japan.
11	MEV Linear Accelerator	M/S Radiation Dynamics, U.K.

SOURCE : Parliamentary News and Views Service Compendium of Policy Statements Made in the Parliament, Monsoon Session, 1986 (New Delhi, 1987), p.35.

APPENDIX –

THE INDIAN SATELLITE STORY

Satellite	Date	Launcher	Result
ARYABHATTA	March 19, 1975	USSR	Success
BHASKARA-I	June 7, 1979	USSR	Success
ROHINI	Aug 10, 1979	SLV-3	Failure
ROHINI	July 18, 1980	SLV-3	Success
APPLE	Jun 19, 1981	ARIANE	Success
BHASKARA-2	Nov 20, 1981	USSR	Success
ROHINI	May 31, 1981	SLV-3	Failure
ROHINI	April 17, 1983	SLV-3	Success
SROSS-1	March 24, 1987	ASLV	Failure
IRS-1A	March 19, 1988	USSR	Success
SROSS-2	July 13, 1988	ASLV	Failure
IRS-1B	Aug 29, 1991	USSR	Success
SROSS-3	May 19, 1992	ASLV	Success
INSAT-1A	Sept 4, 1982	USA	Failure
INSAT-1B	Aug 30, 1982	USA	Success
INSAT-1C	July 22, 1988	ARIANE	Failure
INSAT-1D	June 12, 1990	USA	Success
INSAT-2A	July 10, 1992	ARIANE	

SOURCE : *Times of India*, 11 July 1992, p. 1.

APPENDIX -

MAJOR INDIAN SPACE MISSIONS 1990 - 2000

					EIGHTH PLAN					
MISSIONS	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99	1999-2000
SROSS / ASLV		C D3/C1	3 C2			4 C4				
IRS		1B		1C			1D		2A/2B	
PSLV			D1	D2						
INSAT/ DBS	INSAT - 1D		INSAT - 2A	INSAT - 2B	INSAT - 2C	INSAT - 2D	INSAT - 2E	DBS - 1		INSAT - 3A DBS - 2
GSLV										
EXPTL./TECH. PAYLOADS			IRS - 1E	IRS - P2		GRAMSAT	GRAMSAT			

SOURCE : Government of India, Department of Space, Annual Report 1991-92, p.6.

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