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Application of Space Techonology in INDIA

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ARYABHATA

Born 476 AD at Kusumpura near Patliputra (Patna, Bihar). Important works: 'Aryabhatia' (499 A.D): summarized mathematics as known at the time. Most of it deals with astronomy and special trigonometry. He gave the solution of quadratic equation and general solution of indeterminate equations by application of continued fractions. Aryabhata gave an accurate approximation for pi(π) correct to the first four decimal places, recognised the important concept of 'zero' and the movement of the Earth around the Sun.

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1. Introduction

The last 35 years have seen a number of organised efforts in India to grow and apply Science and Technology to national development. Today the relevance and importance of Science & Technology to national economic & social well being is taken for granted. The debates and questioning is usually about the manner in which the activity is organised, what is imported, by whom and who benefits. The scientists, men of industry as well as the politicians all further their estate by using the cliche as a general principle. It is perhaps useful to recall that when Jawaharlal Nehru enunciated the proposition of 'making friends with Science & Technology' and using them for the regeneration of India, the country was still struggling to throw off the colonial yoke. Fully aware of the intrinsic cultural value of Science & Scientific activity Nehru was far ahead of his times in recognising the value of S & T and in its planned application for larger social ends.

1.1 When India became a free Republic there were few examples – other than the Soviet Union – for the deliberate planning of Science & Technology on a national scale. World War II had seen some remarkable examples of scientists making decisive contributions to the defence of the allies and the defeat of fascism. With the war over the organised focus apparently diffused and the extraordinary lessons of innovation in scientific, organisational matters in the face of extreme uncertainity seem to have been forgotten. The market forces again held sway and there developed a somewhat unholy relationship between Science and the Military Establishments.

1.2 The major issues in relation to science planning which confronted Nehru and his Government in the early years dealt, among other things, with questions of methodology and the criteria to be used for the selection and organisation of scientific institutions and programmes. One approach was to view the existing institutions left behind by the British as a base and to improve and strengthen them with an orientation towards tasks as percieved by the political leadership. Another approach was to selectively adapt the organisational aspects of institutions and activities abroad to India. The Department of Scientific and Industrial Research and the establishment of the CSIR chain of laboratories, the creation of new universities, the establishment of the IIT's and expansion of existing university departments of research, etc., are broadly results of this approach. Yet another approach sought to identify outstanding Indian Scientists, encourage and support them to initiate and grow advanced scientific research in the areas of their expertise and thus bring into being new scientific institutions.

2. The choice

To be sure these approaches and their variants, are not entirely mutually exclusive and several intermediate mixes and patterns can be observed in the Indian

S & T scene. However, on the whole – with a few notable exceptions – such support of Science & Technology was channelled into already identified & established scientific disciplines. The case of space technology (as also nuclear energy) is different. In 1962 when Vikram Sarabhai and Homi Bhabha suggested support to space science & technology for possible application to Indian problems, the Sputnik era was just 5 years old. At the time there were no established applications of space technology to problems on the Earth, although among the scientific community there did exist considerable activity and excitement about the uses of instrumented platforms orbiting above the Earth's atmosphere. Operational space systems were still in the future. Nehru's approval for the application of space technology in India was an act of extraordinary foresight and courage. In the absence of experience of operational systems, the newness and complexity of the technology, the high risks involved, the decision could only have been based on a vision of the future and abiding faith and confidence in the Indian scientists and people. The manner in which space technology was grown and established and is now beginning to be put to use in India is perhaps a rare and remarkable example of a scientific enterprise allowed to be concieved and run by scientists with the active support of the Government.

2.1 Scientific enterprises inherently tend to be "high risk" ventures in the sense that there is no apriori guarantee of attaining specific success. Scientific research if diligently and honestly carried out with the searingly critical appraisal of peers almost always results in new knowledge – often modifying and upsetting earlier theories and understandings. Even negative results make positive contributions. The case with new technology can be quite different. Technology, embodying scientific & engineering principles is directed towards human needs, felt, percieved or defined in some manner. It is thus closer to practical matters and more directly intertwined with human economic and social affairs. A given technology can be effective only in a particular social context. However efficient in the purely technical sense its success or failure is largely conditioned by the human environment. The results of introduction of a new technology in a particular socio-economic context or environment may turn out to be a 'disaster' or a 'boon'. Many of the problems of the third world in S & T applications are related to this issue and often are compounded by internal socio-political weaknesses and the distortions generated by foreign governments and international organisations which influence aid programmes with the selectivity mechanisms based on parameters derived from applications in the advanced countries. The desire to adopt the 'forced march' approach, relying on the selection and adoption of technology developed elsewhere and not organically grown within the country of application, adds to the risks of producing a mis-match. In this background, the selection of space technology for India carried inherent risks and it was obviously important to be perceptive about the manner of its growth and application in the country. Finally it must be noted that it is not technology that guarantees social objectives – it is people who must decide.

2.2 A selected technology, especially an advanced one, must have special features potentially of special application in relation to Indian problems. The most remarkable feature of space platforms is their global reach. Near earth orbiting satellites go around the globe in the course of about 90 minutes. By selection of orbital parameters and onboard control any area of the earth can be covered repetitively. Radio signals from satellites in geostationary orbit (about 36,000 km above the earth) have a reach to about a third of the globe. Sun-synchronous satellites in polar orbits about 500 to 1000 km above the earth can survey the entire surface of the globe in a matter of days.

2.3 India is a subcontinent with an area of over 3 million sq. km. with a population of over 700 million people. The major problem of India's transformation into a modern democratic country is essentially the development and utilization of resources – both human as well as physical. India is rich in both.

The human resources:

These are the men, women & children – including the present as well as the future generations. The socio-cultural patterns by which the varied communities of India live and work are linked with history and constitute the warp and woof of national life.

The physical resources:

These include the renewable and non-renewable natural resources – what nature has endowed INDIA with, as well as the wealth created through human intervention. Geological and mineral resources, water and weather (the monsoons), agriculture, forests and soils are typical examples.

2.4 It is interesting and non-trivial to note that virtually all resources – human as well as physical – to varying degrees are associated with human social activity and derive any value in the final analysis from this relationship.

Education and its handmaiden communication – language, the spoken and written word – are critical elements for human civilization and are essential components of national development. Thus the potential capabilities of space technology in the Indian context can be examined with regard to the contribution that it can make to enhance

(a) education and communications, and
(b) management of the natural resources

In such an organised effort the central focus must remain on India.

Figure 1 shows a view of the world as seen from Space with INDIA at the centre. The first tenet in the application of space technology then can be stated: The effort must continually and sinlge mindedly focus on INDIA & Indian problems.

Figure 2 shows the distribution of the major written languages in the form of scripts and the literacy in 1961 with an all India average of about 25 % and many regions below 10 %. The mean figure is now about 40 % as ascertained in the 1981 census. With over a hundred dialects spoken across the land literacy alone can only be a partial measure of education in the Indian context. The oral tradition among the people of India is both rich and varied and while modern education with an essential component of Science does require more than the three R's, no development strategy can ignore the fact that the cultural level of the average Indian especially in the rural areas, is quite high – especially in their sense of values, veneration for learning and the varied and rich art forms. Recognition of such parameters is central to the planning of a technology based system to enhance communication and education throughout the country.

Figures 3 & 4 show the range and complexity of natural resources. If technology is to subserve social goals rather than end up by alienation of people from their own culture or strait jacket them into caricatures the problem of distribution, employment and assimilation must receive serious attention simultaneously with the purely technical questions. The problem is neither simple in structure nor are applied solutions easy to borrow from elsewhere. Space technology cannot by itself generate values and meet social objectives, but if handled firmly and imaginatively it might subserve them. The distance that Indian T.V has yet to travel before becoming a positive force for education is a valid example.

2.5 With their synoptic reach Communication Satellites and Earth Observation Systems have received world wide attention – especially in the USSR & USA and more recently in Europe, Japan, China, India as well as most other countries. Developments during the last two decades have seen extensive use of space systems – many of them in the advanced countries being very closely linked with strategic defence. The Indian pattern and use is unique in being wholly directed towards peaceful goals and differs in specific details from elsewhere.

3. The Approach

The general approach and methodology followed in using space technology in India bears rough similarity to the planning and conduct of scientific research. After the initial hypothesis and assessments of the early 1960's based on inference and projections from the early experiments in Space, a broad direction and a rough time table was presented to the Government of India. The programme was outlined in a 10 year profile in 1970 and conceptualized the main steps in translating the use of space systems for enhancement of communications (Telecom, TV & Radio) and resource management.

3.1 Since the creation of the Department of Space and the Space Commission in 1972 an overall set of policy guidelines have shaped the space activity. Some aspects of these policies were derived from the Atomic Energy Commission [1] under whose aegis the space activities were conducted until 1972. Other were implicit in the G.O.I Scientific Policy Resolution of 1958 and were made explicit and specific for space from time to time.

The main elements of this policy were:

1. Application of space techonology in India must be firmly directed towards assisting the solution of large scale identified problems, exploiting the unique capabilities of orbiting satellites where they hold out distinct advantages over other alternatives.
2. The introduction and application of space technology must while introducing a new dimension, essentially support and enhance the capabilities of other national systems, catalysing the modernization process through injection of new technology, systemic analyses and definition approaches and forging linkages between agencies affected by the programme.
3. While remaining fully cognisant of developments elsewhere and encouraging international co-operation in space the essential components of space technology must be mastered and grown within India as speedily as practicable. Technology transfer to and the utilization of Indian industry is an important element in the task.

   It was recognised that the overall time-table of events would be largely governed by inherent time scales rather than financial resources.

Rather than a sequential description of the developments it is interesting and informative to see what has happened in the last 20 years or so.

4. Application of communication satellites

Figure 5 summarizes about 15 years of the experimental phase of Satellite Communications.

The experimental phase 1967-83 began with the establishment of an Experimental Satellite Communications Earth Station (ESCES) in 1967 at Ahmedabad with UNDP assistance and ended with the closure of the APPLE mission in September 1983. The period spans the planning and execution of three major experiments SITE [2], STEP [3] & APPLE [4]. The first used the NASA-ATS-6 satellite from 35 °E longitude location and covered clusters of 400 villages in six states of India with direct satellite-to-receiver TV sets and lasted for one year 1975-76. Detailed and systematic research for the TV software and its evaluation preceded SITE. The second experiment used the Franco-German Symphonie satellite from 45°E and did for domestic telecom what SITE did with TV. All system design, software, development pretesting and research, ground hardware (including earth stations, receivers and TV sets etc) were designed and built within India. The main cooperating agencies were the Ministries of Information and Broadcasting and Communications, and with them the Departments of Education, Health and Family Planning, and Agriculture as well as a number of public and private industries. The evaluation criteria and methodology both for the software (TV programmes) social gains and the hardware were laid down before hand with the essential controls [5], [6], [7], [8], [9], [10], [11]. Assessments of results were available soon after each experiment. SITE & STEP were followed by the development of an Indian Geostationary Experimental Communication Satellite, APPLE which was launched by the European launcher Ariane from Kourou in 1981. The mission was entirely controlled from India. APPLE, in addition to providing valuable experience in developing a state-of-the-art 3-axis stabilized spacecraft, continued further the SITE & STEP application experiments. Figure 5 shows the Experimental Phase and the APPLE mission, and Figure 6 Community TV & examples of Earth Station Technology resulting from SITE & STEP. The three major space experiments paved the way for the INSAT-1 system, the first Indian operational space system carrying four major national services viz.

- □ Telecommunications
- □ T.V & Radio
- □ Meteorological Service
- □ Data Relay & Disaster Warning Service.

Table 1 depicts a summarized chronology of events leading to operationalizing the INSAT-1 system – spanning nearly twenty years. Some interesting points to note are:

- The decision to proceed with INSAT-1 could not await the full results from SITE, STEP and APPLE. The needs, the practicability, etc., were assessed by Government as the experiments proceeded and decisions taken.
- Even after investment decisions are clear it takes 5-6 years to plan, establish and stabilize a space service.
- Once established a space service must go on round-the-clock. Replenishment strategy and advance planning assume critical significance.
- Space systems carry intrinsic risks and contingencies must be carefully planned for, balancing the extra cost against possible failures.

The INSAT-1 system concept evolved through various phases eventually into a multimission spacecraft with an integrated ground segment.

5. The INSAT System [12].

The first generation INSAT-1 system consists of two identical multiservice

3-axis stabilized spacecraft located at 74 °E and 94 °E and a country wide ground segment covering the Telecommunications, TV and Radio, Meteorological imaging and the data collection and disaster warning services. The system represents a transition from the preparatory experimental phase in the Indian space programme to round-the-clock nation wide operational space services. The conceptualisation and execution of the INSAT-1 system has occurred side-by-side with other ISRO R & D activities – intimately interacting with them, continuing to provide an overall focus for the satellite communications programme and inturn gaining from the results of the experiments and the continuing R & D. Figure 7 shows the INSAT-1 system and the spacecraft which was built by Ford Aerospace (USA) to Indian specifications. Figure 8 shows the Master Control Facility (MCF) at Hassan which controls the space segment and the P & T Network Operations Control Centre (NOCC), Delhi where all operations linking the spacecraft with the P & T switching plant are controlled. The first INSAT-1 satellite (INSAT-1 A) was launched in April 1982 but had to be deactivated in September 1982 due to on-board fuel depletion following a loss of Earth lock event caused by moon interference into the earth sensor and other anomalies. Loss of the INSAT-1 A was fully covered by insurance. For an interim period some of the INSAT-1 services were partially continued through transponders leased from INTELSAT and the Soviet STATIONAR satellites. The system was re-established in October 1983 through the launch of INSAT-1B in August 1983 and has now completed 21 months of full operation. Figures 9, 10, 11 and 12 show the service ground segments and some components for the major nation wide services. The integration of multiple services into a single spacecraft with matching ground segments has resulted in significant economies. The current state of utilisation of the INSAT-1 system is summarized below:

Status of INSAT-1 System Utilization (July 1985)

TELECOM	T.V.	RADIO	MET.
• 2093 Circuits in use (out of 3956 total)	• 164 TV Transmitters (70 % coverage of India)	• 86 out of 91 Radio Stations networked.	• 10 images/day
			• Wind Vectors
• 1840 more on 1 C (3rd Q. 1986)	• 885 Community Sets		• Sea-surface Temperature
• 34 Earth Stns. + 90 more in next 2 years.	• ETV. covers 1953 schools and 62 colleges.		• Cloud Cover • WMO Service
			• 76 out of 100 DCP's deployed
			• Disaster Warning Service begins Dec.'85.

5.1 New Services

As experience in utilization of the INSAT-1 services grows many new demands for satellite services are emerging. These include:

- □ Expansion of T.V. channels
- □ Business communication/dedicated networks
- □ Customer terminals
- □ Satellite based rural telegraphy system
- □ Satellite based data network.

Some of these are being implemented, others would be first run on an experimental basis before operationalization and some would need to be phased for introduction when increased capacity and flexibility become available in the INSAT space segment.

5.2 INSAT-II

Since nation wide services need to be sustained continuously and enhanced to meet future needs, the planning for the INSAT-II system began soon after INSAT-1 launch. After detailed projections, assessments of the services required in the 1990's when the service life (7 years) of the INSAT-1 spacecraft would approach the end-of-life phase, Government have approved the development of the INSAT-II system. This would embody experience from the INSAT-1 system and the space segment would be based on higher capacity spacecraft designed and built in India. These satellites, which would weigh about 1900 kg in GTO and be 23 metres tip-to-tip, have been sized so as to be eventually launched by the Indian Geostationary Satellite Launcher, currently under definition with the PSLV as the core vehicle but replacing the upper stages by a cryogenic stage. Figure 13 is a system diagram of the INSAT-II system. The space segment would consist of two spacecraft collocated at the primary 74 °E orbit location and one at 94 °E. Each spacecraft would carry 18 C band transponders for the telecom service; 2 S-band transponders for T.V. plus the Met VHRR instrument and data relay transponder. The two collocated satellites would thus provide more than double the capacity of the INSAT-1 satellite and be seen as a single station by the telecom ground segment. The third satellite would be an active spare providing reserve capacity in case of emergencies as well as backing up growth of services.

The INSAT-II spacecraft are currently under development at the ISRO Satellite Centre, Bangalore. First launch of the INSAT-II test spacecraft is scheduled for 1990.

6. Remote Sensing of Natural Resources

Parallel to the evolution of satellite communications ISRO began experimenting with the techniques of modern remote sensing about 15 years ago. This phase included studies based on data acquired through sensors on aircraft and later the NASA Landsat satellites. The experimental phase included the design and construction of space and airborne sensor systems as well as experimental spacecraft for remote sensing. Bhaskara I & II [13] with two-band TV cameras and a passive Microwave Radiometer, and Rohini with a solid-state 'Smart' sensor were part of this effort. The design and operation of these experimental systems in cooperation with identified users provided invaluable experience in evaluation and acquisition of the new technology. The use of computer based digital image processing systems and interpretation of multispectral data, etc., is the key to the exploitation of remote sensing technology.

6.1 Satellite remote sensing is based on the principle that the electro-magnetic radiation reflected from an object contains an "image" of the object. The reflected radiation is thus a 'signature' from which information about the object can be derived. In the practical applications to the study of natural resources on the earth, a variety of complex interactions that occur during the passage of the radiation through the atmosphere have to be understood and accounted for. The nature of the substance or object illuminated by the radiation (vegetation, soil, water, rocks, etc), its absorption, scattering and reflection properties obviously enter into the "recognition" of the signature. A very large part of remote sensing applications depend on the Solar illumination or 'insolation' of the earth – this largely covers the visible and IR windows in the electromagnetic spectrum. However 'active' remote sensing using micro-waves (radars) with ability to penetrate clouds and to some extent soils is increasingly coming into use. The 'Sensors' and the processing and interpretation of the data received are key elements of the technology.

The large scale involvement of over a dozen major user organisations over nearly a decade has resulted not only in the design of the space systems to be responsive to the users practical needs but also developed good capabilities among them ensuring wide utilization of the data. In particular the Department of Agriculture and the Geological Survey of India of the Government of India have played a major role in shaping the satellite remote sensing programme.

6.2 The period 1970 to 1983 saw the organisation and execution of many Joint Experimental Projects (JEP's) between the Department of Space and potential user agencies as well as individual scientists in the country. Parallel to this, efforts were made to identify all the central and state agencies who were already concerned in the survey, identification, utilization and monitoring of natural resources. The priorities and focus for these efforts were derived through a series of structured presentations and discussions with the Planning Commission and the major agencies. Logically the highest priority was accorded to Agricultural resources including major crops, soils, forests and water. Minerals, marine and coastal resources, environmental problems, etc., were also included. These studies and exploratory activities culminated in a National Seminar on Natural Resource

Management at Hyderabad in 1983 [14], [15]. Some 400 scientists and resource managers presented papers embodying the results of the experience so far and projecting how remote sensing technology could be inducted at the operational and semi-operational levels. Areas of research were also highlighted. Following the Hyderabad Seminar the Planning Commission directed the constitution of nine task forces to prepare the ground for implementation during the 7th Plan with the Indian Remote Sensing Satellite to be launched in 1986 as the key integrating element. Thus the stage is set now for the emergence of a resource managing system which would cover the entire country. This would in a phased manner, integrate all major existing and on-going activities of Central and State Government agencies and provide a new dimension through the regular availability and use of satellite and related aerial imagery and data with fast data processing and interpretation facilities and trained manpower.

6.3 The National Natural Resources Management System (NNRMS)

With the increasing tempo of development, the greater utilization and conservation and efficient use of natural resources have been regarded by the Planning Commission as a high priority area since the early '70s. The component of the Indian Space Programme relating to this is the Remote Sensing programme including the development of Indian remote sensing satellites – the IRS series. Within ISRO/DOS all efforts have been directed to master the technology and achieve at the earliest a satellite based operational system. It must be recognised that although the US Landsat satellites have been operating since over a decade, as yet there is no fully operational system for natural resources anywhere in the world. The Weather satellites of the USA and USSR, and recently of Europe, Japan and India, are the only operational civilian satellite-based remote sensing systems. With the launch of the French satellite SPOT late in 1985 and the Indian IRS-1 in 1986 the first semi-operational systems for natural resources management would appear on the scene. The Indian programme calls for a family of IRS satellites beginning with IRS-1A in 1986 to be launched at approximately 2-year intervals with successive improvements in resolution and capability, and eventually include active microwave sensors with all-weather and soil-penetration capabilities. Except the first satellite IRS-1 A which would be launched from the Soviet Union, the IRS series would be launched from India by the PSLV launcher. India would also retain the capability of receiving data from the Landsat and SPOT satellites to supplement the IRS System.

6.4 The experimental phase of remote sensing activity which would come to a close with the arrival of IRS, is shown in Figure 14 for the period of 1970-83. Table II summarises the main areas studied. Approximately a third of the country has been covered through the detailed experiments. A composite of India from

Bhaskara-II images is also shown. Some of these have already provided valuable data and information which have been used by major agencies. Figures 15 through 23 are a few examples of satellite remote sensing activity in India. They cover a very wide range of applications. Some notes on the imagery follow:

Figure 15 Shows the satellite data receiving terminals at NRSA, Hyderabad as well as the Avro aircraft fitted with multispectral scanners. Data from the Landsat, SPOT, IRS and the NOAA meteorological satellites can be received.

Figure 16 Shows examples of crop identification and classification.

Figure 17 Depicts identification of potential mineral bearing zones in the Orissa-Bihar border and a soil classification map of south Tamil Nadu – some 23 soil types have been identified.

Figure 18 Shows the snow cover in the Sutlej region of Himachal Pradesh feeding the Bhakra system. Such imagery is now used for regular forecasts and regulation of the Bhakra reservoir. The figure 18 also shows a set of IR & visible band Bhaskara imageries of the mouth of the river Ganga. The boundaries of the land in one and the sediment zones in the other are clearly seen.

Figure 19 Shows a photograph of the Krishna delta with the Krishna and Pennar rivers and the land use classification map derived from it.

Figure 20 Shows detection of Wheat Rust disease and the Ganga Jamuna confluence near Allahabad.

Figure 21 Shows two large scale applications for the entire country – a vegetation map and a forest change analysis showing that over the period of about 7 years about 3 % of area (90,000 sq. km.) has disappeared. Such maps will be regular features of the IRS monitoring system from 1986 onwards.

Figure 22 Shows two other uses: Changes in the city of Ahmedabad and its environs over a period of about 7 years and an application of remote sensing for archaeology. Based on satellite imagery the old course of the legendary river Saraswati has been reconstructed.

Figure 23 Shows the IRS-1A spacecraft [16] and the data collection system. The sensors on IRS-1 A are based on charge coupled devices and operate in four spectral bands: 0.45-0.52 micron, 0.52-0.59 micron, 0.62-0.68 micron and 0.77-0.86 micron. The spatial resolution will be about 35 m and 70 m for two cameras. The repetition cycle for covering the country is 22 days.

Currently the active constituents of NNRMS are engaged in defining the specific tasks to be undertaken for utilization of the IRS after its launch in mid-1986. Essentially the planning of facilities, dedicated manpower and tasks are being targetted for the 7th Plan. A major support activity – the 5 Regional Service Centres and the IRS Utilization Programmes of DOS are already at an advanced stage of establishment. Each major component is in the form of interlocking projects with specific targets, infrastructure, budgets and allocated manpower.

Figure 24 is a diagrammatic representation of NNRMS.

As it evolves, NNRMS – which includes many of the well established technologies as well as the newer components of satellite based earth observation systems – is bound to undergo changes and modifications. It has the potential of making substantial contributions to the national economy.

7. Space Technology

This brief overview of the application aspects of space technology in India would not be complete without a mention of the development of Indian satellites and launch vehicles. Operational nationwide space based services need to be sustained indefinitely – being periodically modified and enhanced to meet future needs. One approach could have been to base the defined national needs through import of the important technical constituents, integrate these into an Indian operational system with periodic replacement from abroad of the life expired system elements. The Indian Airlines system is an example of this approach. The Indian Space Application Services are based on a different approach – that of growing the technology within the country from concept to the operational stage. Thus the establishment of satellite and launch vehicle technology [17], [18], [19] is an intrinsic part of the application programme, eventually leading to the design and development of all the critical elements of space-based services within the country. In this approach successive phases would lead to Indian built application satellites being launched from national launch ranges and being backed by an Indian space industry. Important milestones in this approach broadly set out in the 1970-80 Space Profile [1] and made more concrete in the 1980-90 Profile [20] would be reached with the development of the INSAT-II satellites and the PSLV and GSLV launchers. After the IRS and INSAT satellites built in India are in orbit, satellite technology would have stabilized to meet the national needs. However, the Indian goal of self-reliance in launch vehicle technology and the attainment of launch capability for geo-stationary satellites would take somewhat longer. Starting with small sounding rockets over a twenty year period ISRO has engineered and established all essential facilities and capabilities to design satellite launch vehicles. However, as the scale of the launch capability has increased – the propellents and propulsion systems, inertial guidance and onboard navigation electronics, special materials and the testing and launch range equipment have made demands on Indian fabrication technology which has not kept pace with the design capability. Much has been accomplished with Indian industry but more needs to be done before a self-sustaining point is reached. The Department of Space's 7th Plan makes significant provisions for industry in this regard.

7.1 Figures 25 to 33 provide a fleeting glimpse of Indian satellite and launch vehicle technology and the planned missions over the decade 1985-'95. When the first INSAT-II spacecraft is placed into geo-stationary orbit by the GSLV from SHAR the Indian space efforts would have attained all the technical goals set some thirty years earlier.

8. Conclusion

The lecture has attempted to provide a glimpse of the application of space technology in India. The choice of technology, the risks involved, the necessity to sustain an Indian view point throughout for the larger socio-economic purposes, the experiments and the emerging operational space services, all are part of the story. The period covers over 20 years – four major national elections and many ups and downs. It is a tribute to the sustained enthusiasm, dedication and hard work of men and women of ISRO/DOS and other co-operating agencies – but above all to the people of India who not withstanding their trials and tribulations have seen fit to provide the political and emotional support to this programme.

> One has however to contend with change. Over the 25 years a new generation has grown up in India. Those who made the selection of space technology and provided the inspiration, initial momentum and enlightened political support have passed into history. How will the new generation of scientists, political leadership and the people at large see the social goals and the role that should be assigned to space technology?

As the experimental phase transitions into space operations and the lives of millions of Indians can be influenced and affected, people are bound to ask, 'is this for our good'? The tools have been built, how will they be used? Will T.V., now that it can reach the millions, help them? Centrally beamed programmes reach every nook and corner but they are one way – what is the feed back? Don't the teachers want to listen to the students? Can we not devise a two-way system? Will the resource managers decisions, armed with good and timely information help the farmer, the urban elite or the stock exchanges? A million questions! These cannot be answered by space technology. Only people who care can.

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– S Dhawan

Table I

EVENTS CHRONOLOGY

Domestic Satellite Communications in India

1962	– INCOSPAR set up by the Department of Atomic Energy
1963-67	– INCOSPAR Studies Satellite TV Potential for India
1967	– Experimental Sat. Com Station set up at Ahmedabad
	– Organisation of Krishi Darshan – 80 villages around Delhi
	– Interagency Study Team on Satellite TV for India
1968	– UNESCO Mission recommends Educational TV via Satellite for India
	– NASCOM group for communications satellite for India.
1969	– DAE-NASA Study on Use of ATS-F by India
	– Decision on SITE
1969-71	– Studies on National Satellite System
1972	– Space Applications Seminar, Ahmedabad
1973	– Planning Commission Task Group on Plan for INSAT-1
1975-76	– SITE – 2,400 DRS community TV sets in cluster of 400 villages in Six States.
1975	– Govt. decision to proceed with INSAT-1
1977	– INSAT-1 System definition report.
	– INSAT-1 Spacecraft. Telecom & Met. investment approvals
1977-79	– STEP
1978	– INSAT-1 Spacecraft contract award
1981	– TV & Radio utilization investment approval
1981-83	– APPLE
1982	– INSAT-1A Launch
	– INSAT-1A Failure/Deactivation
1983	– INSAT-1B Launch
	– INSAT-1C authorization and contract award
1984	– INSAT-1 System dedication to nation by Prime Minister
	– INSAT-II System definition
1985	– INSAT-II investment approval and project start

Table II
Selected Examples of Satellite Remote Sensing in India

Overall Appraisal of Natural Resources	Indravati Basin 40,000 km^2	Orissa, MP Maharashtra	Under Developed-Complex terrain Multilevel maps
	Tripura 10,500 km^2	State NE. Council	* Update on entire state: 1:250,000 Maps Heavy population pressure Jhum Cultivation – 13% Reduction of Forest
	Idukki district 5000 km^2	Kerala	* Effect of Major projects on Forests & Landuse
Geological Mapping & Mineral Exploration	Cumbun Valley, Watrap Area Palayam Kottai Area Mahendragiri Area	Tamil nadu	* Evaluation of Hydro Geological potential zones * Significant reduction of Time and costs.
	Saurashtra Peninnsula (14 sites)	Gujarat	* Hydro-Morphological Analysis identified sites for Drilling with positive results
	Singbhum Belt	Bihar-Orissa	* Application of Digital Processing & Enhancement Techniques to Mineral targetting
Ecological Change	Ukai Command Area 3600 km^2	Gujarat	* Land Degradation (Water Logging & Salinity due to changes in cropping pattern) * Spectral Band Optimization for IRS
	Tirap District	Arunachal Pradesh	* Effect of Shifting Cultivation on Forest degradation
	Kudremukh Mining Project 400 km^2	Karnataka	Detail Monitoring of Vegetation cover-grasslands & River Pollution 1976-1978-1981
Coastal Studies	Shoreline Change 560 km-1700 km	Kerala	1972-1982 Effects of Neo. Tectonic movements on Erosion
	Gulf of Cambay	Gujarat	* Coastal Morphology * Suspended Sediment Transport * Erosion due to constructions
	Off Cochin	Kerala	Marine Resources Assessment
Urban Change	Ahmedabad	Gujarat	Pattern of City Growth: 1975-82 Change in Tree/Vegetation Cover
	Delhi	New Delhi	Urbanization Pattern 1959-80
Flood Assessment	Sahibi River Aug.1977	Haryana, Delhi	Inundation Area Map
Research	Health of Crops	Wheat (Triticum Aesthum Linn)	Assessment of Crop Growth & Health by Remote Sensing
		Chickpea (Cicer Arietnum)	Detection of Waterstress in Crops Detection of Rust Disease
		Mustard (Brasica Campestri)	Establish Relationship between Plant variables and spectral signatures, crop Yield forecasts
		Rice (Oryza Satival)	Correlation of Canopy Temperature & leaf area index

Ref: International Journal of Remote Sensing Vol 6 No's 3 & 4 March, April 1985.
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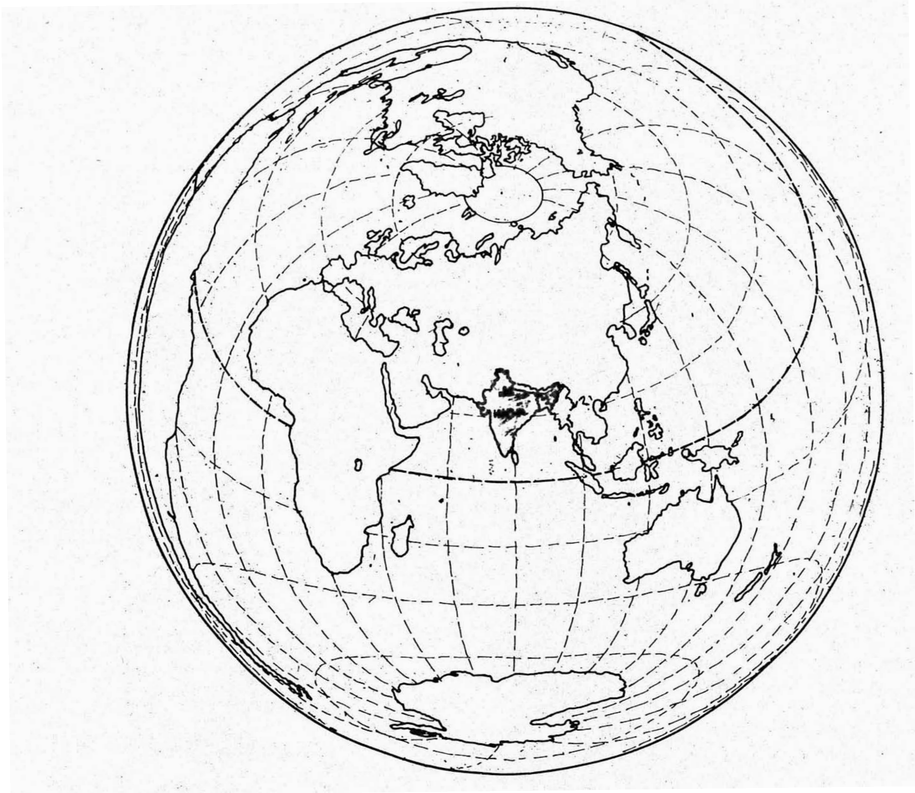
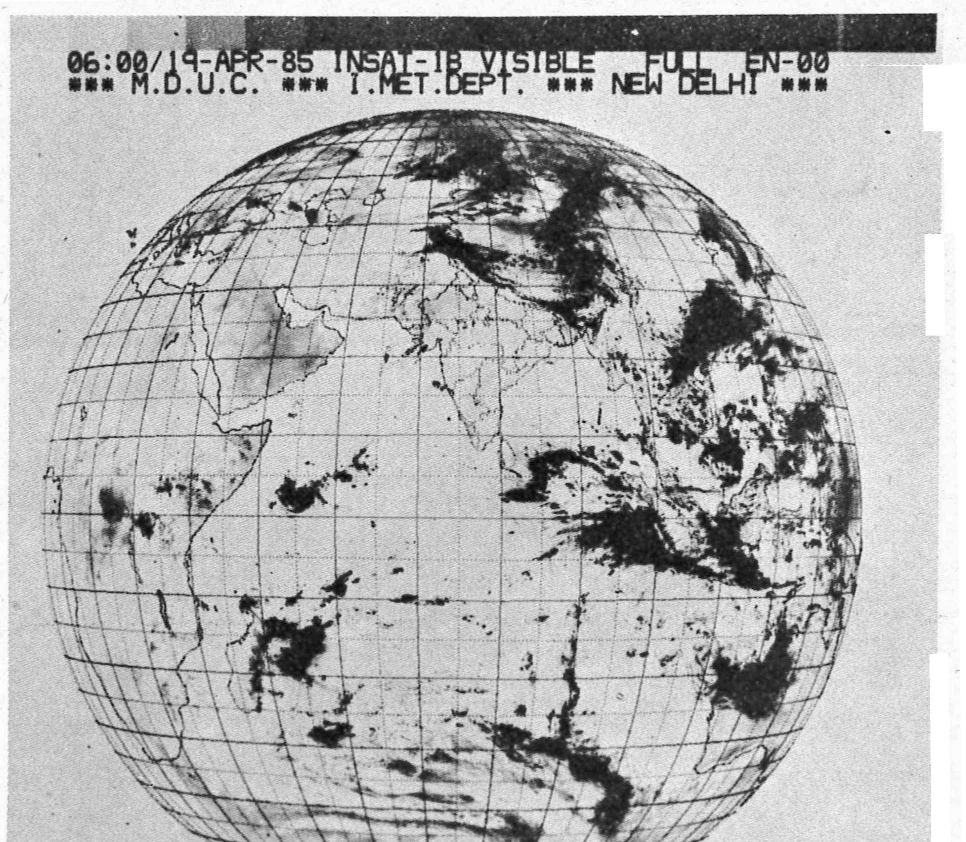


WORLD CENTERED ON INDIA



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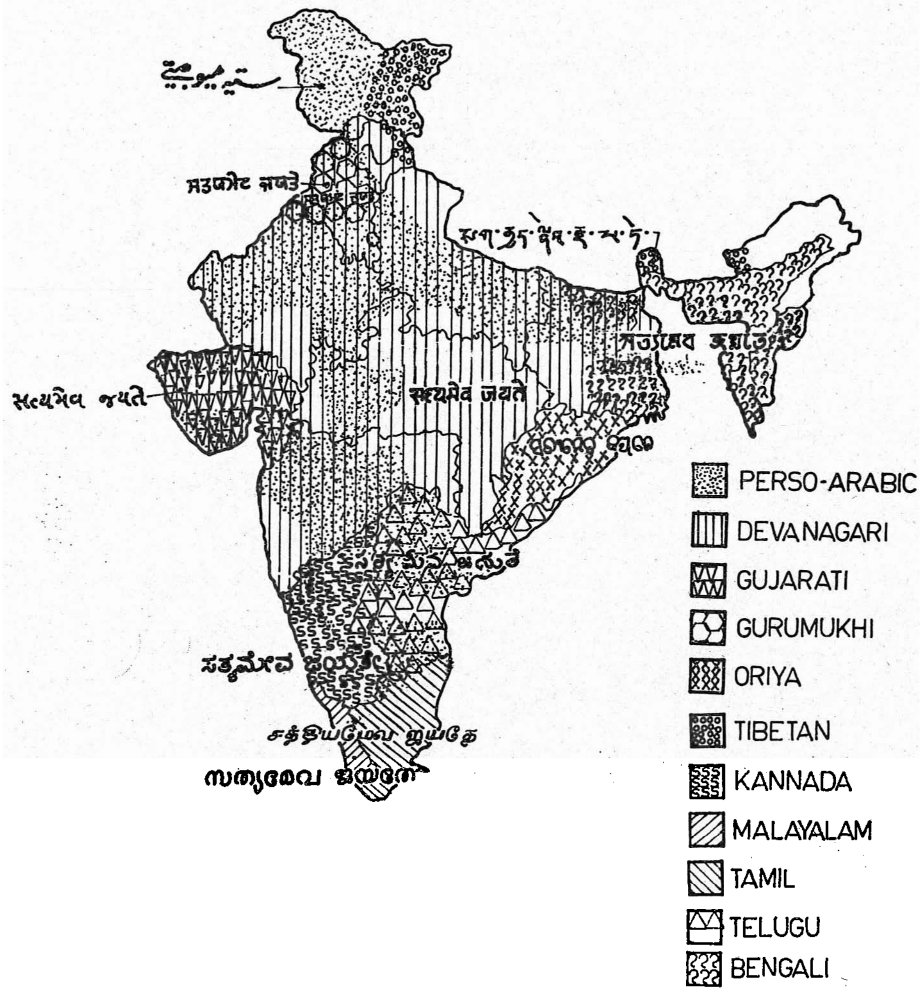
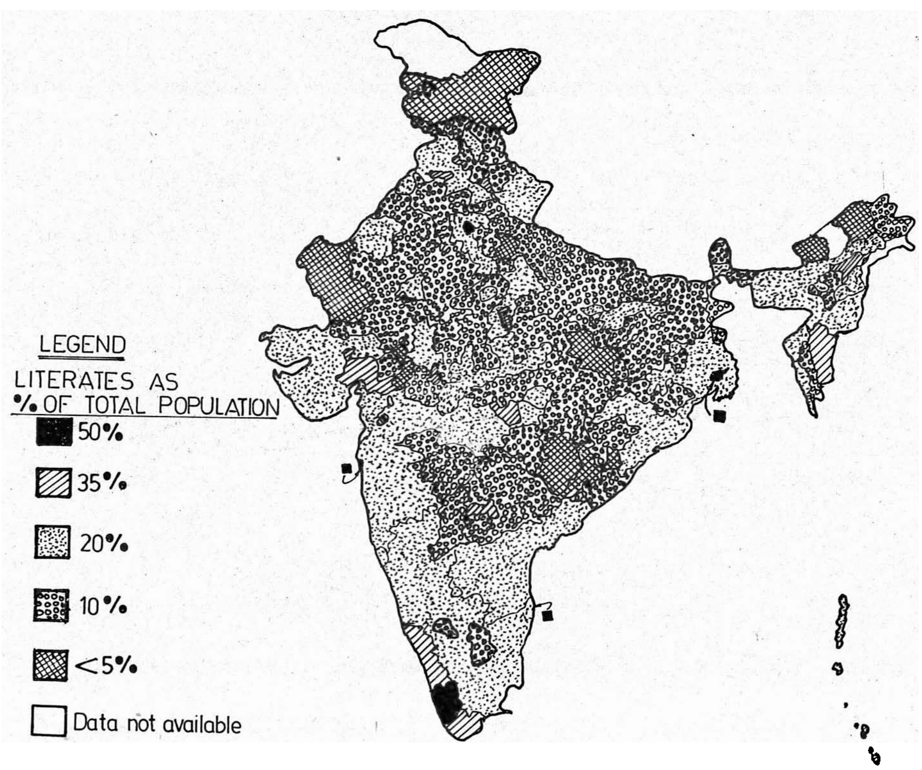
AREAS OF USE OF MAJOR SCRIPTS



LITERACY - 1961



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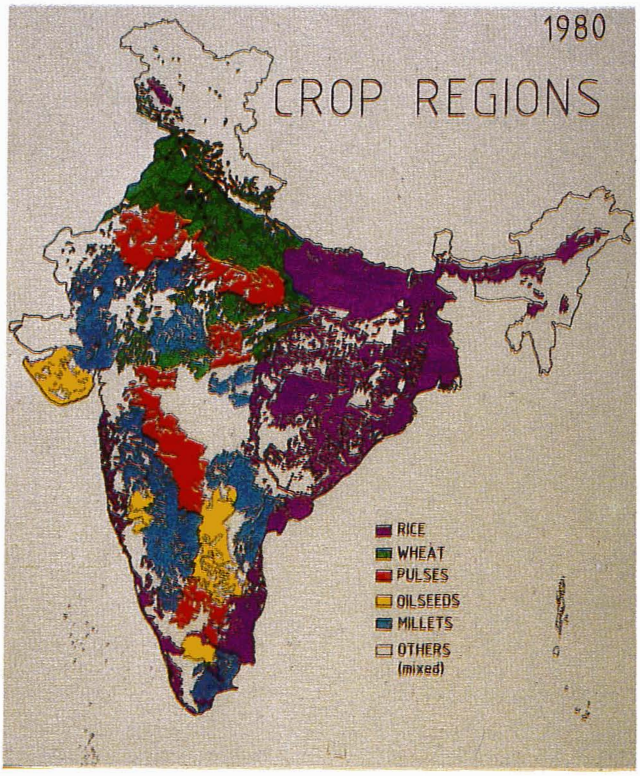

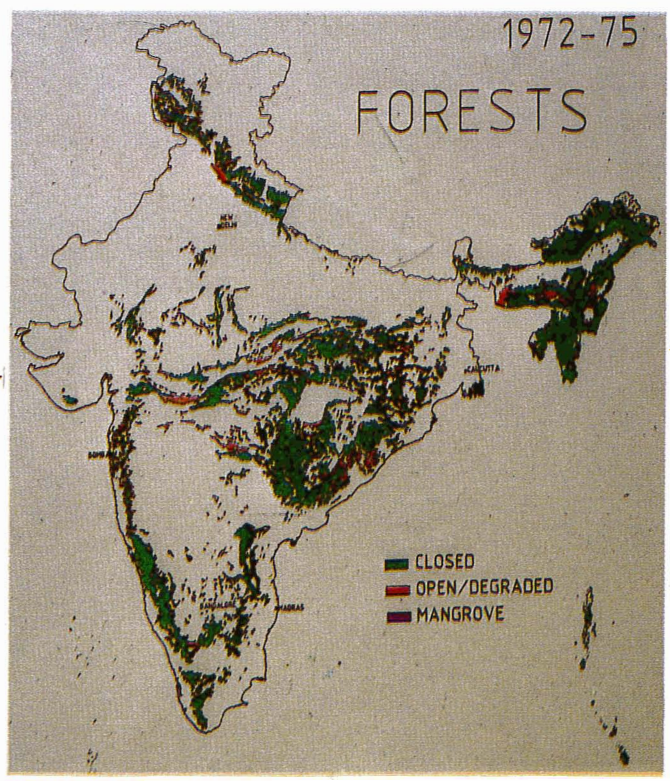

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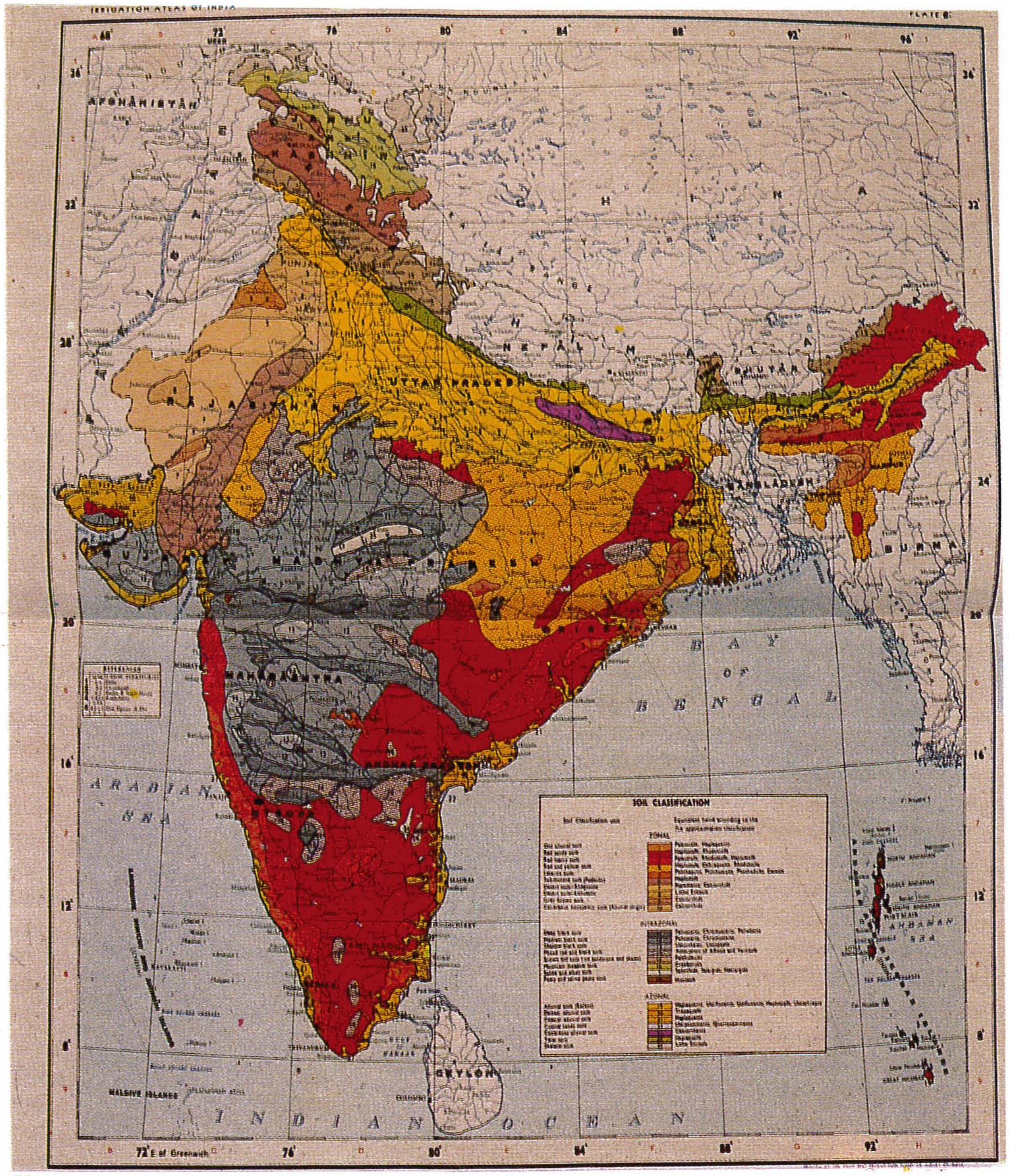

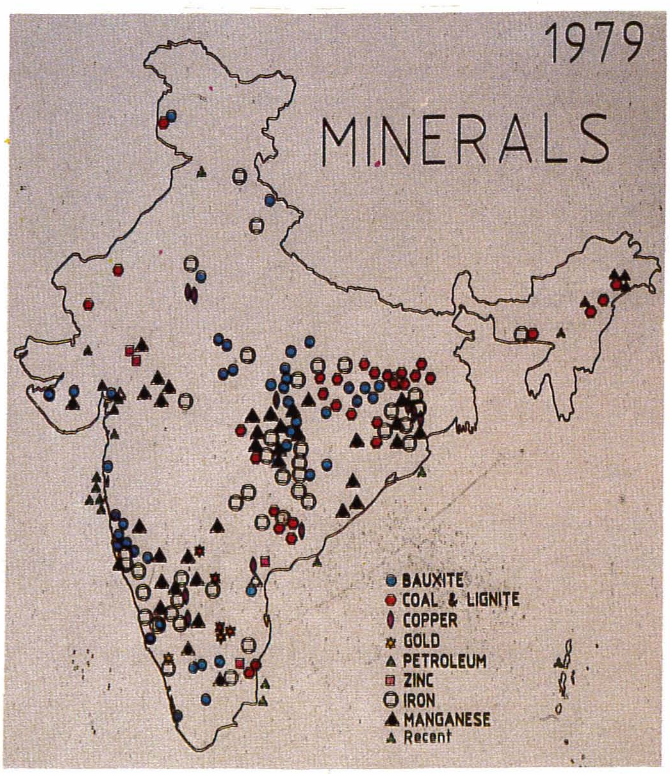

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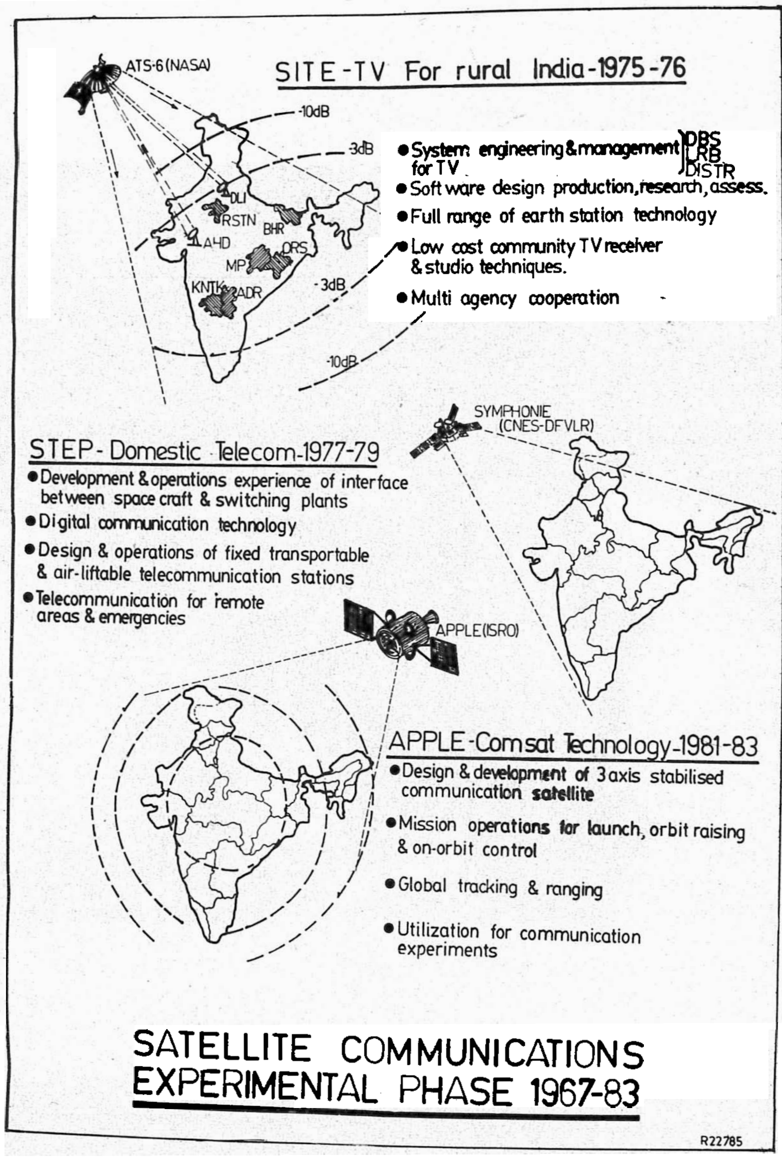

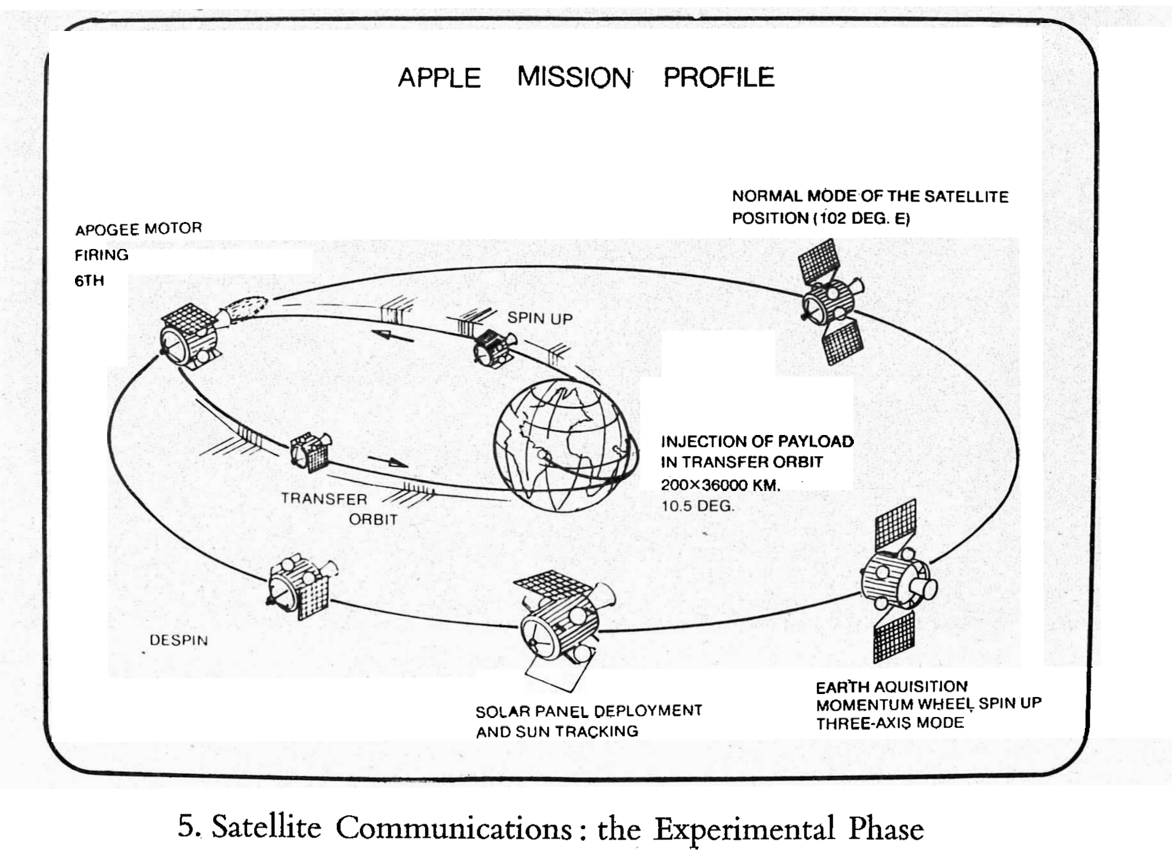

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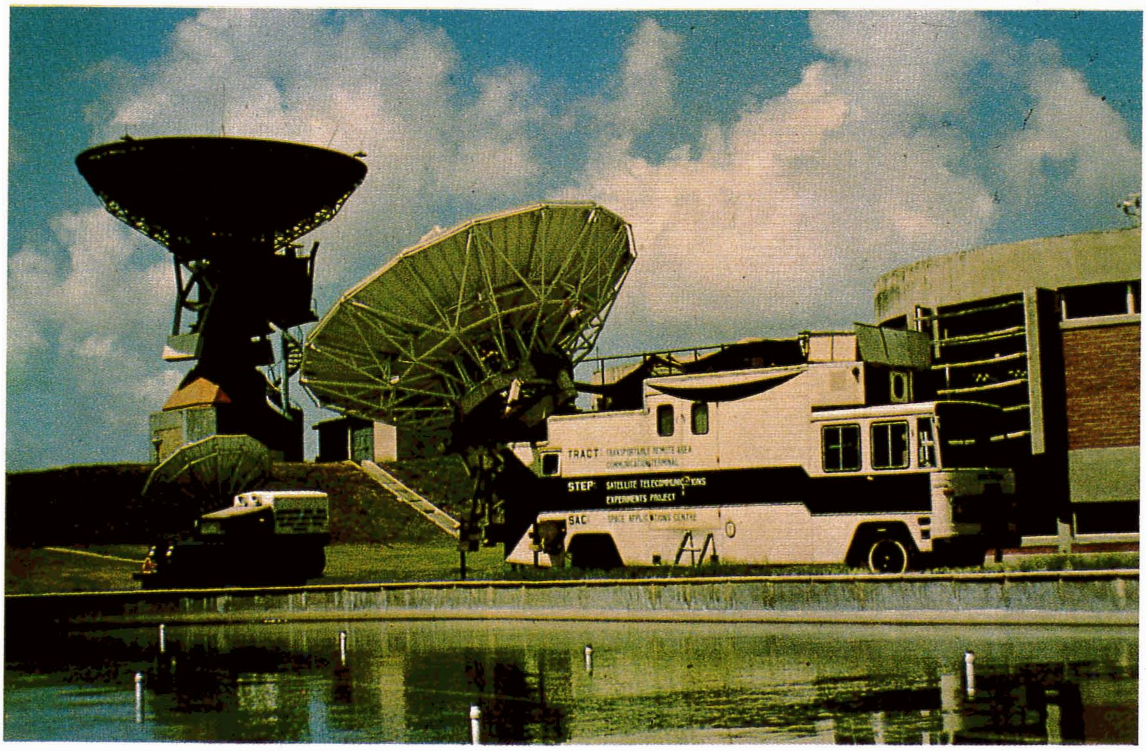

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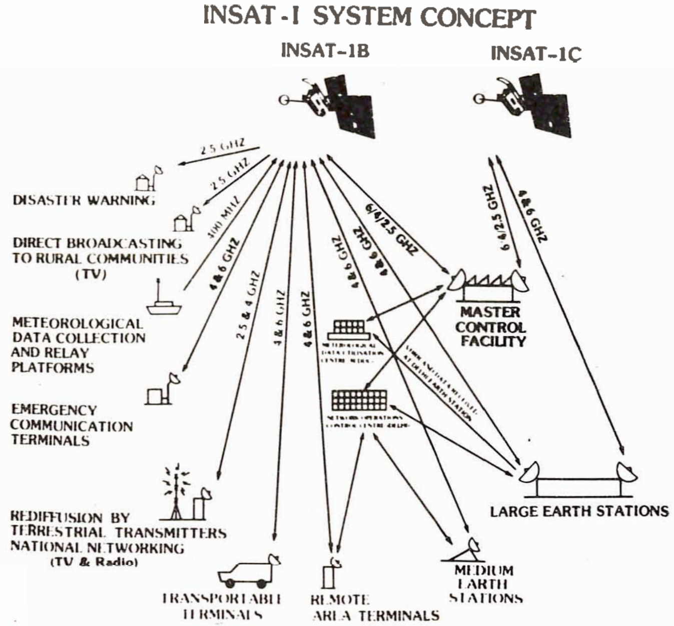

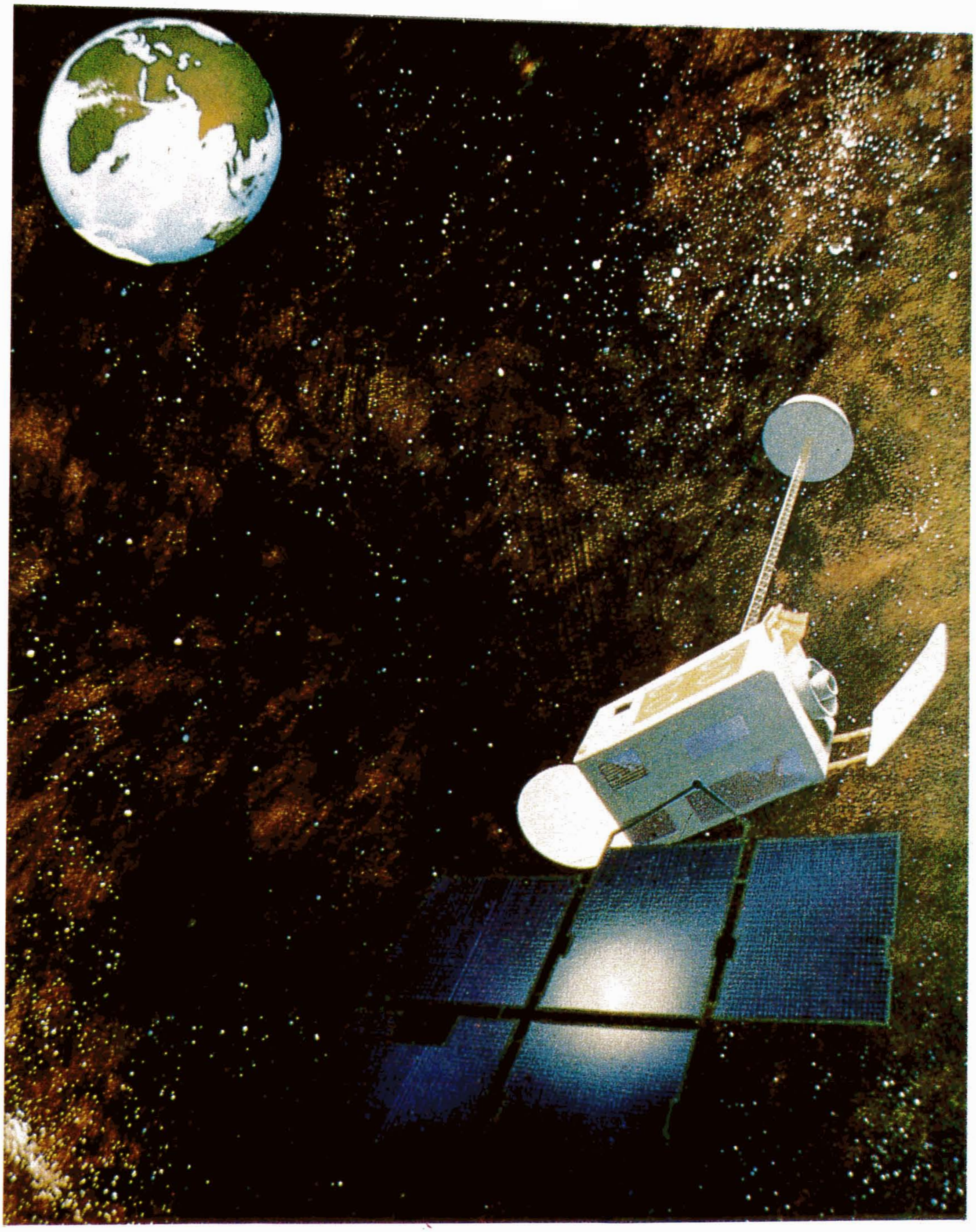

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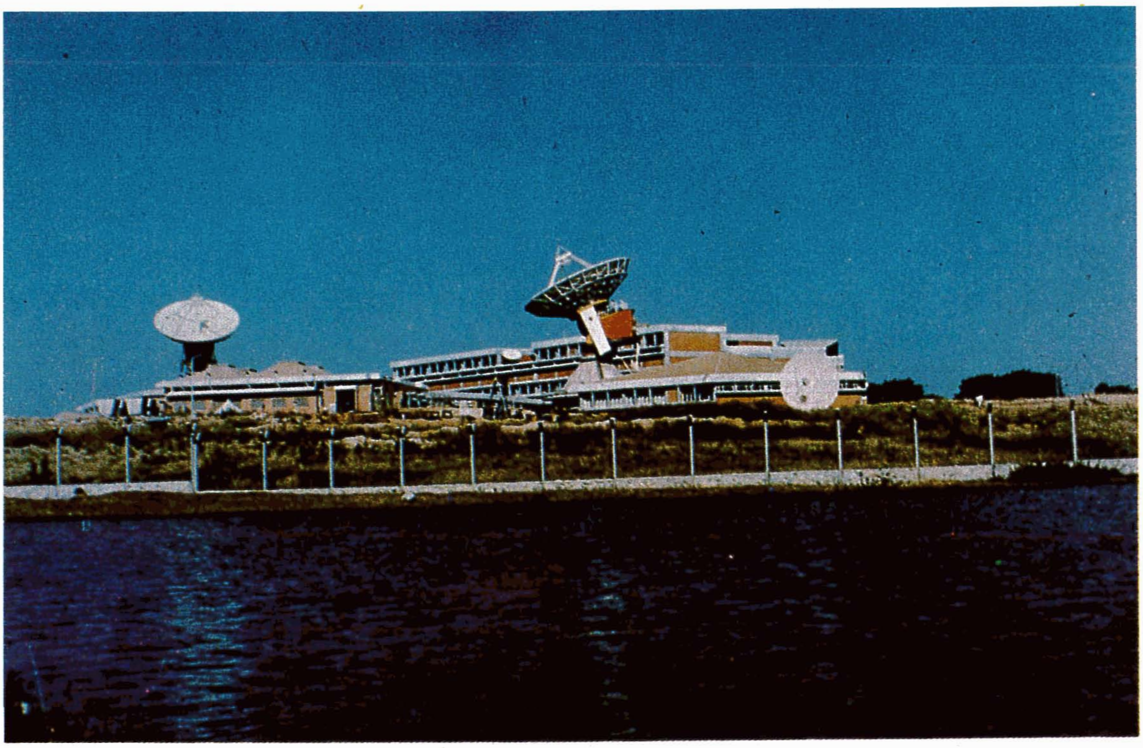

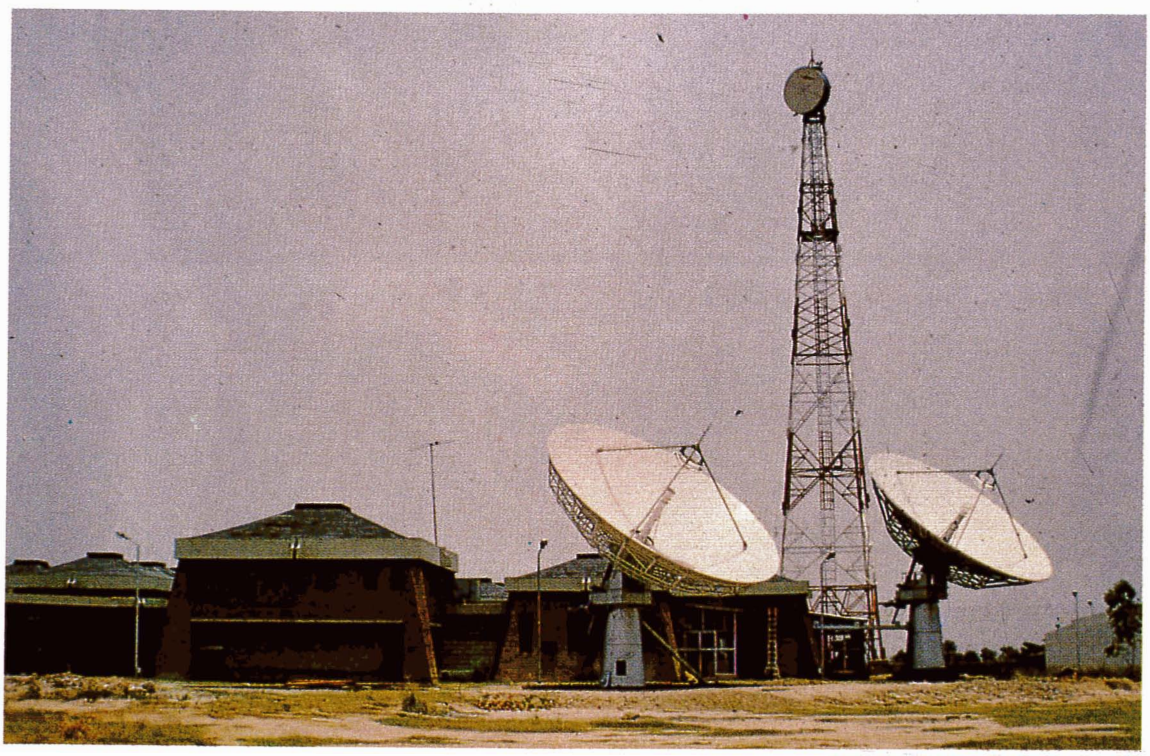

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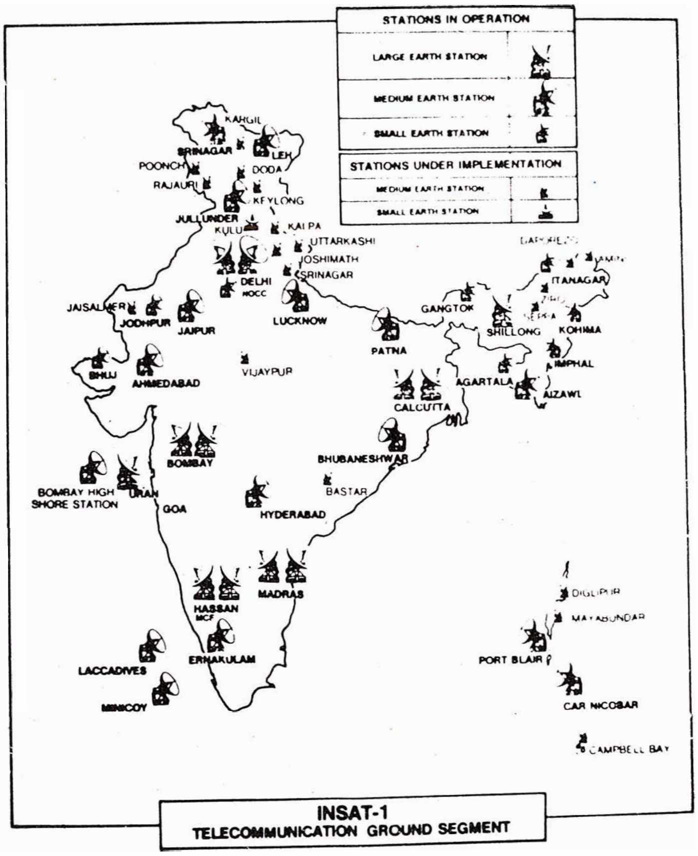

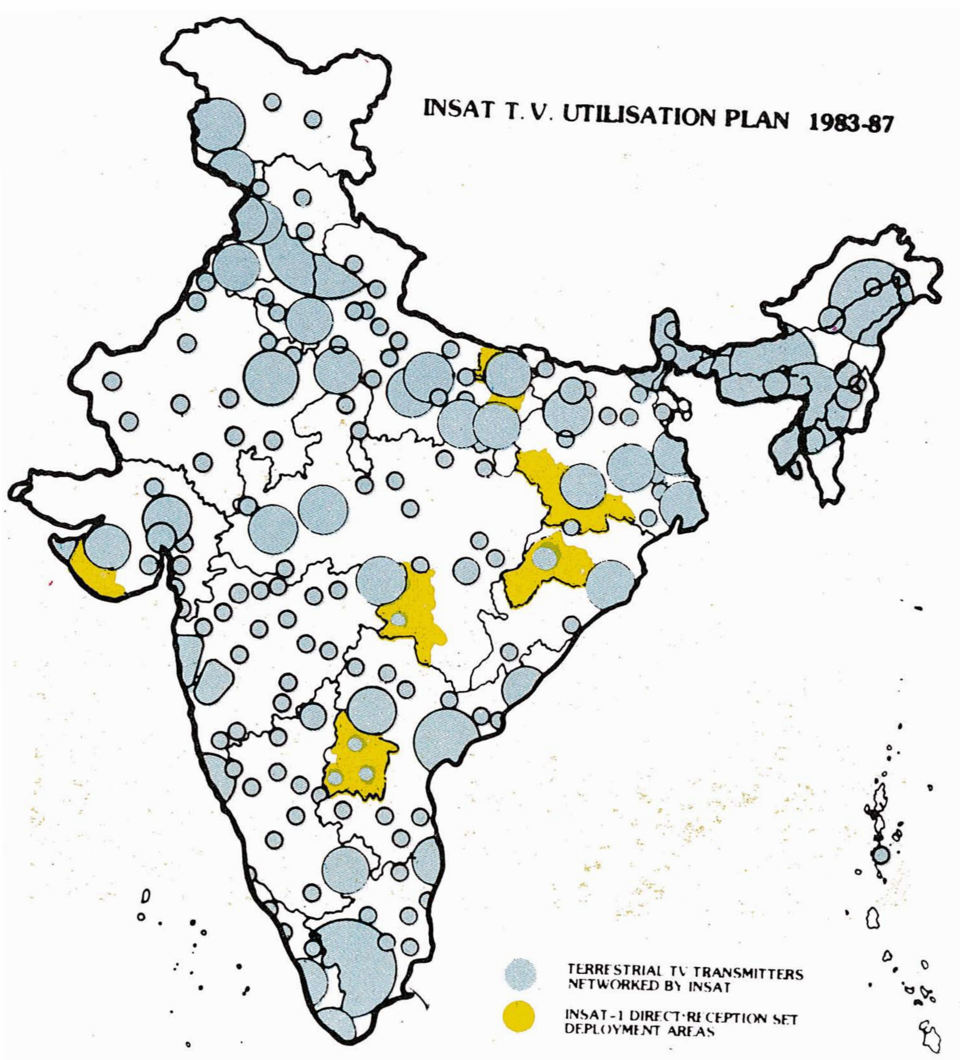

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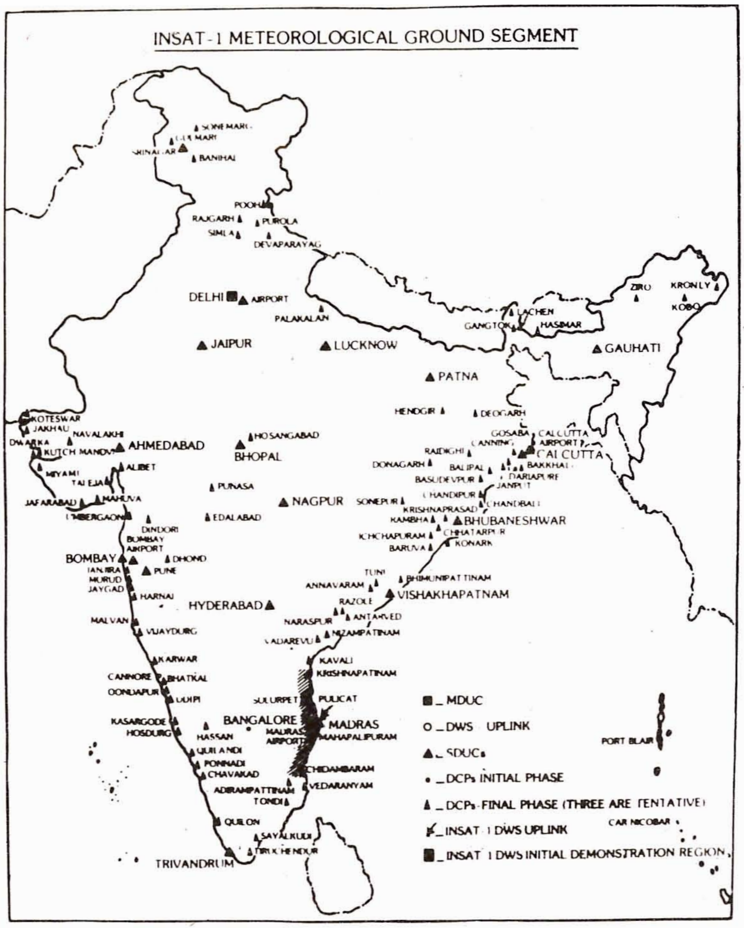

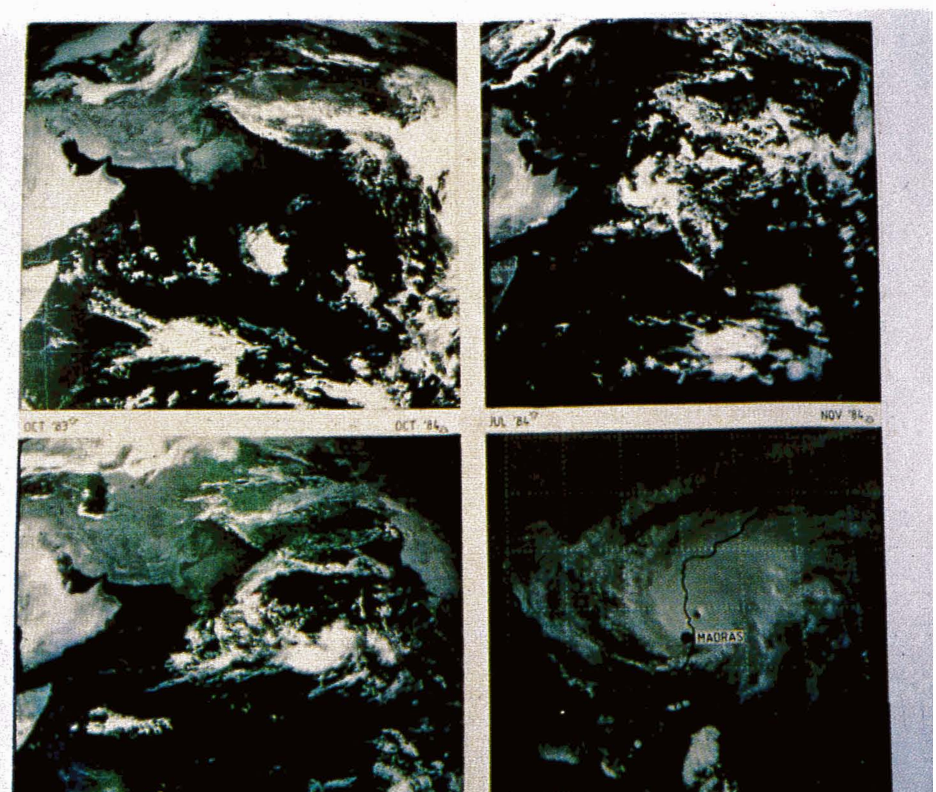

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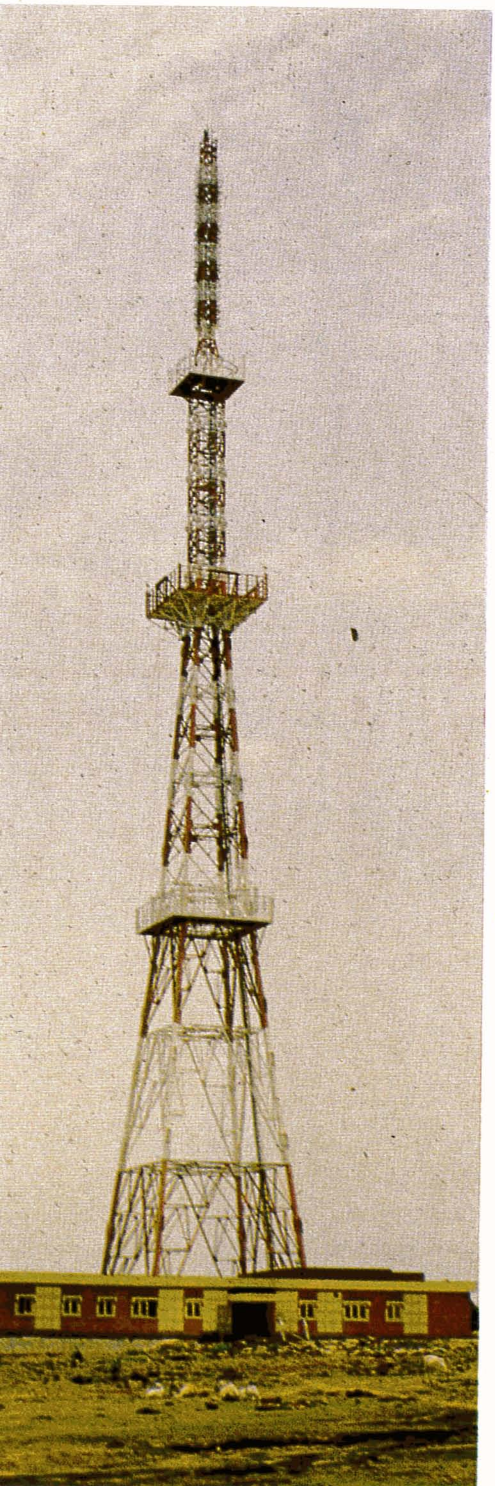

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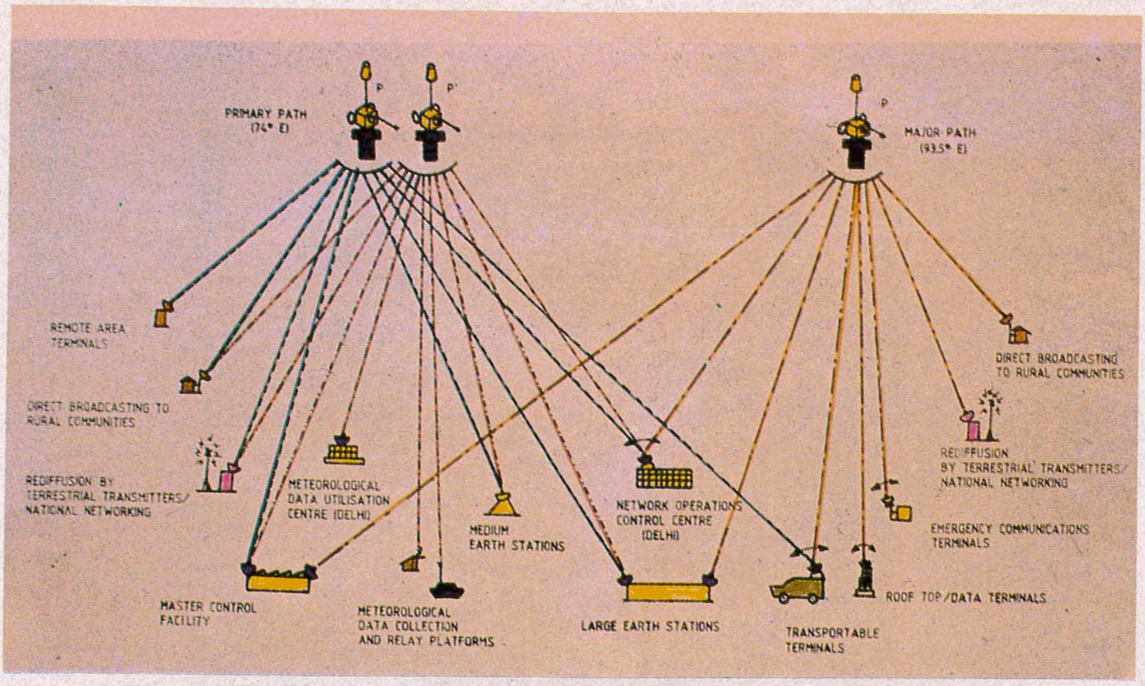

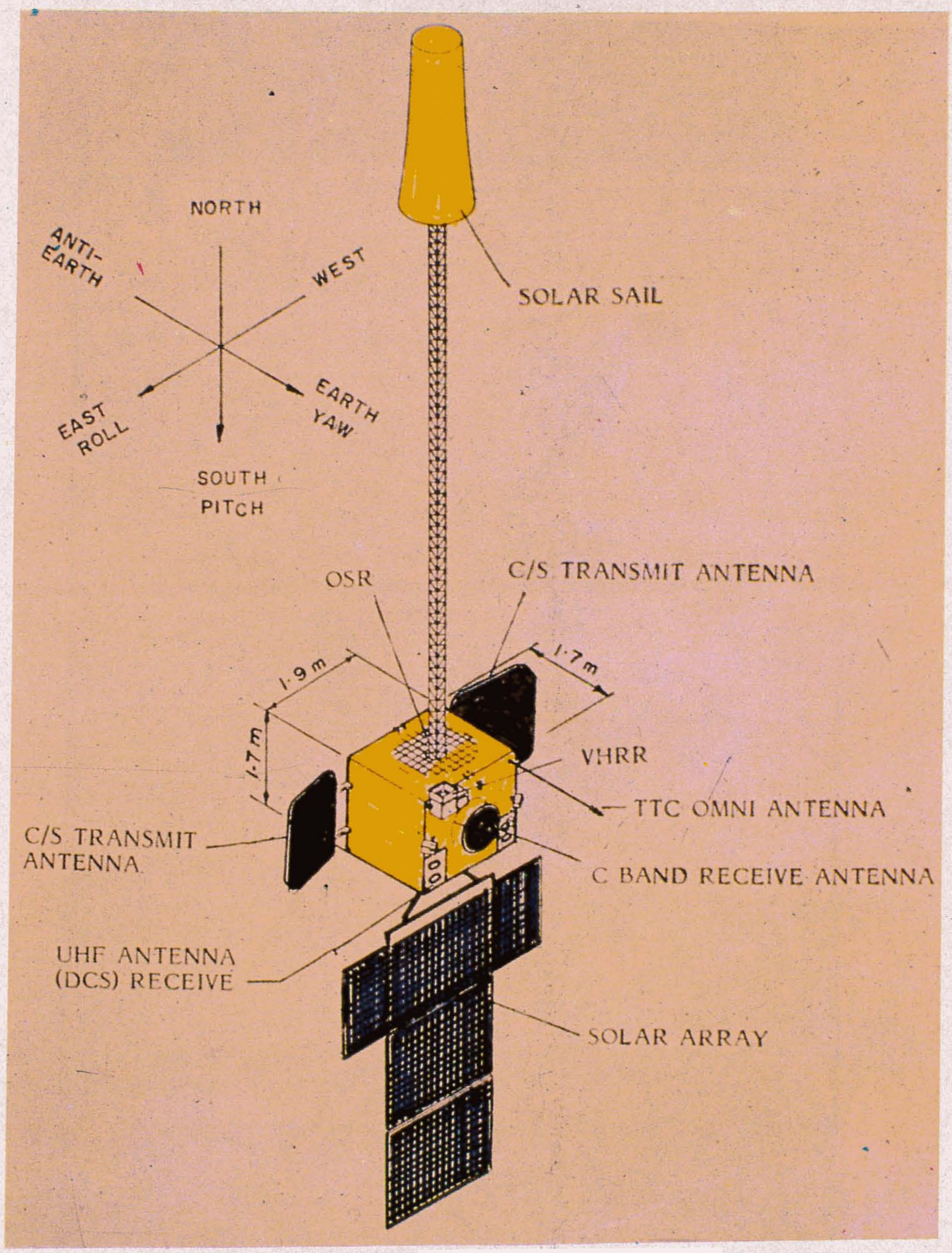

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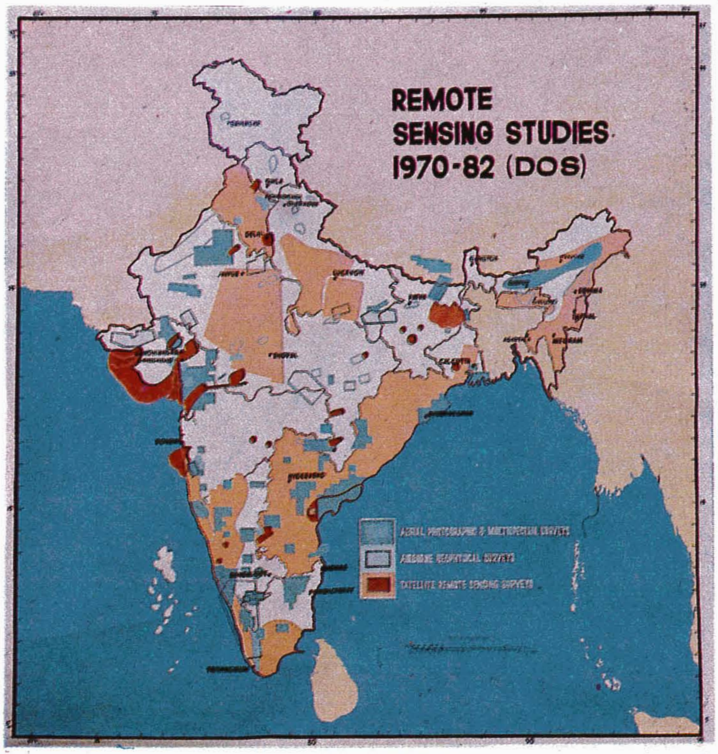

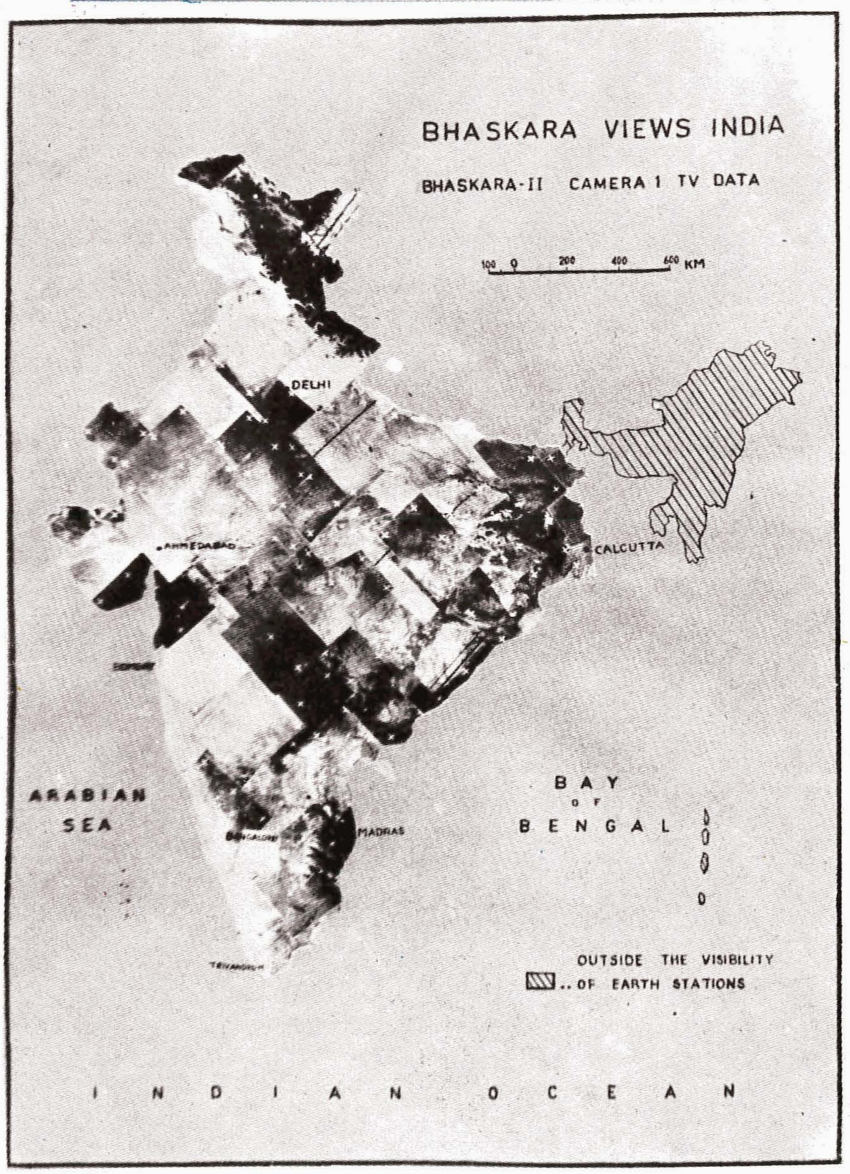

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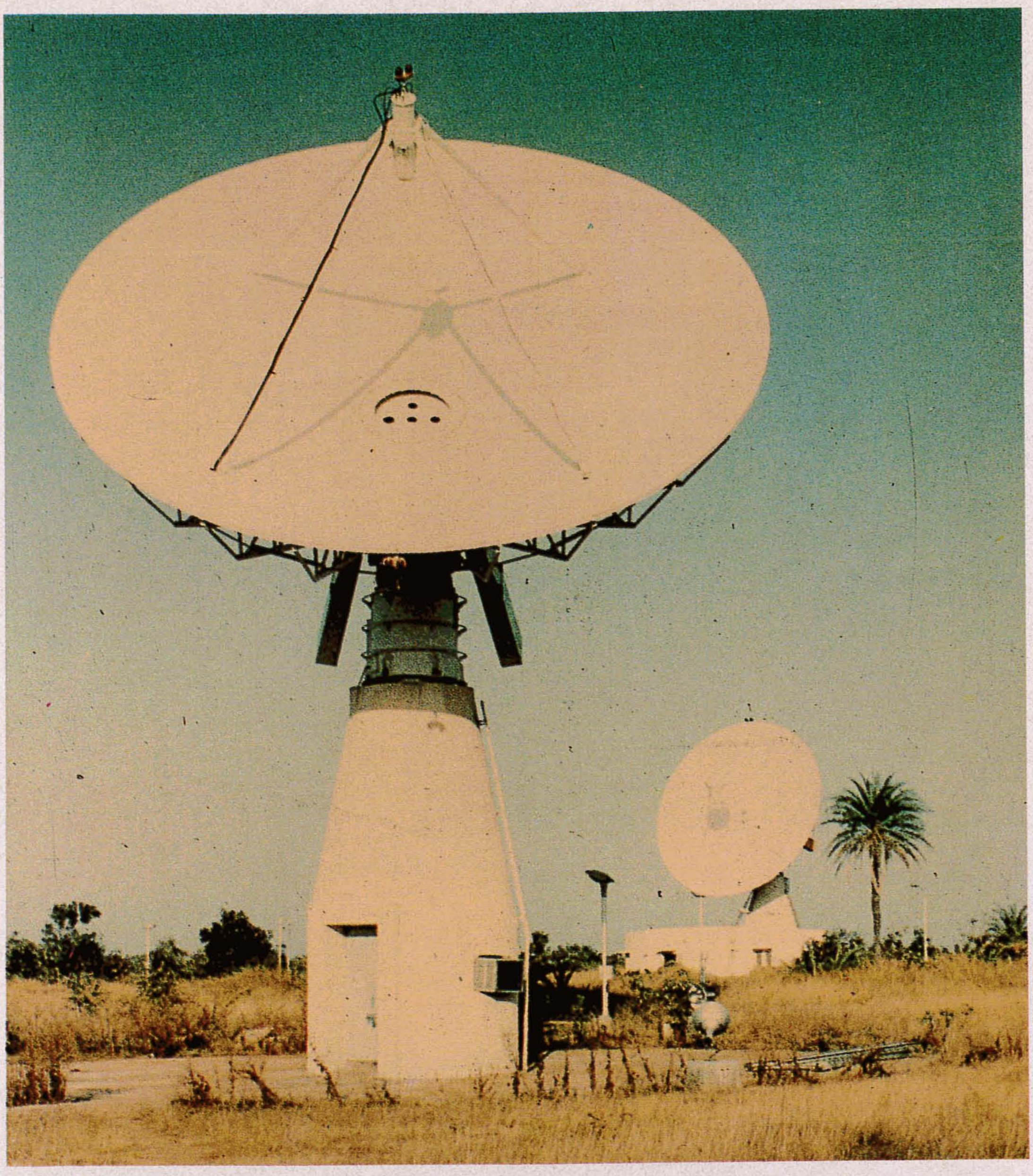

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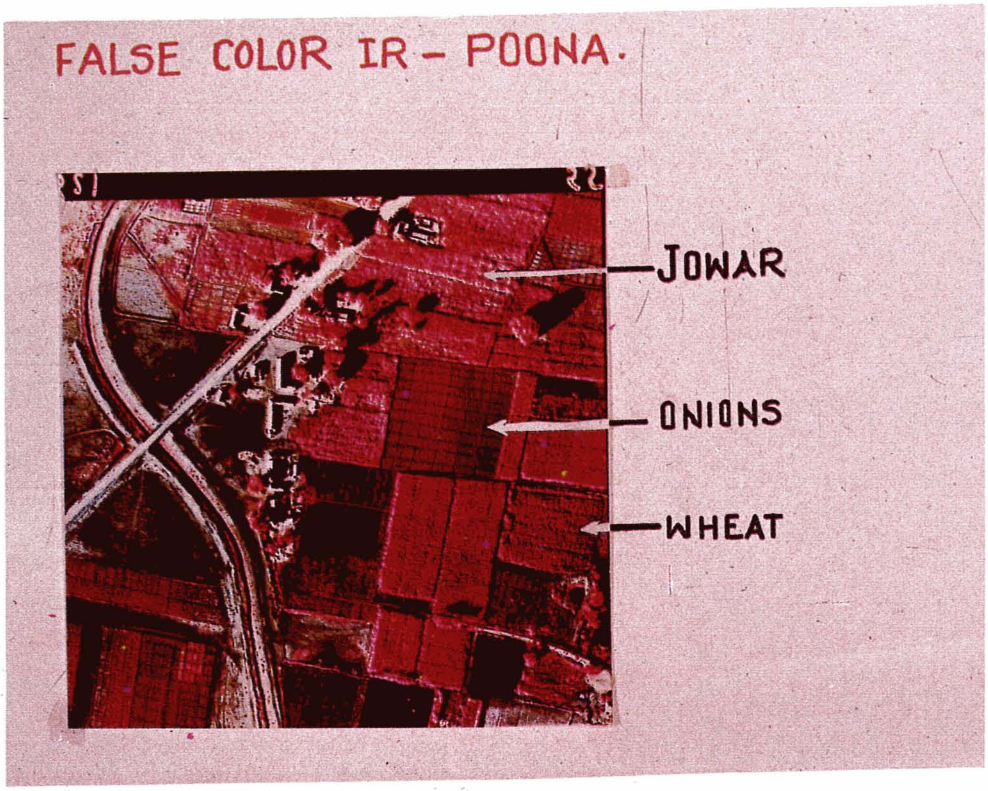

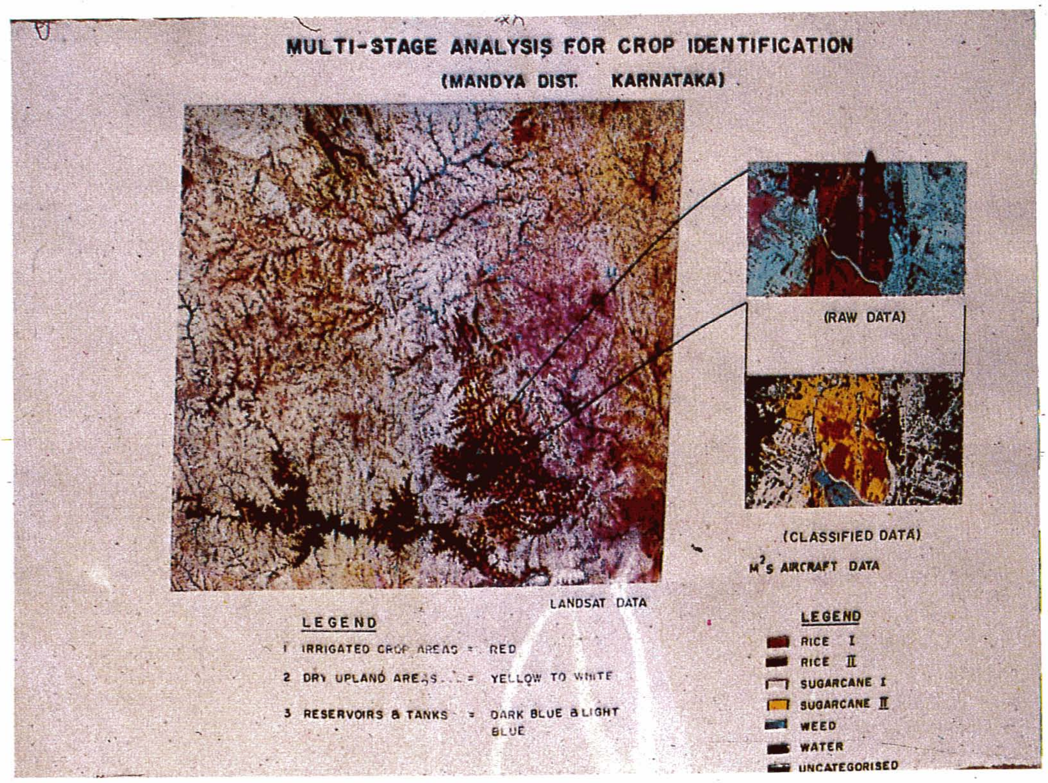

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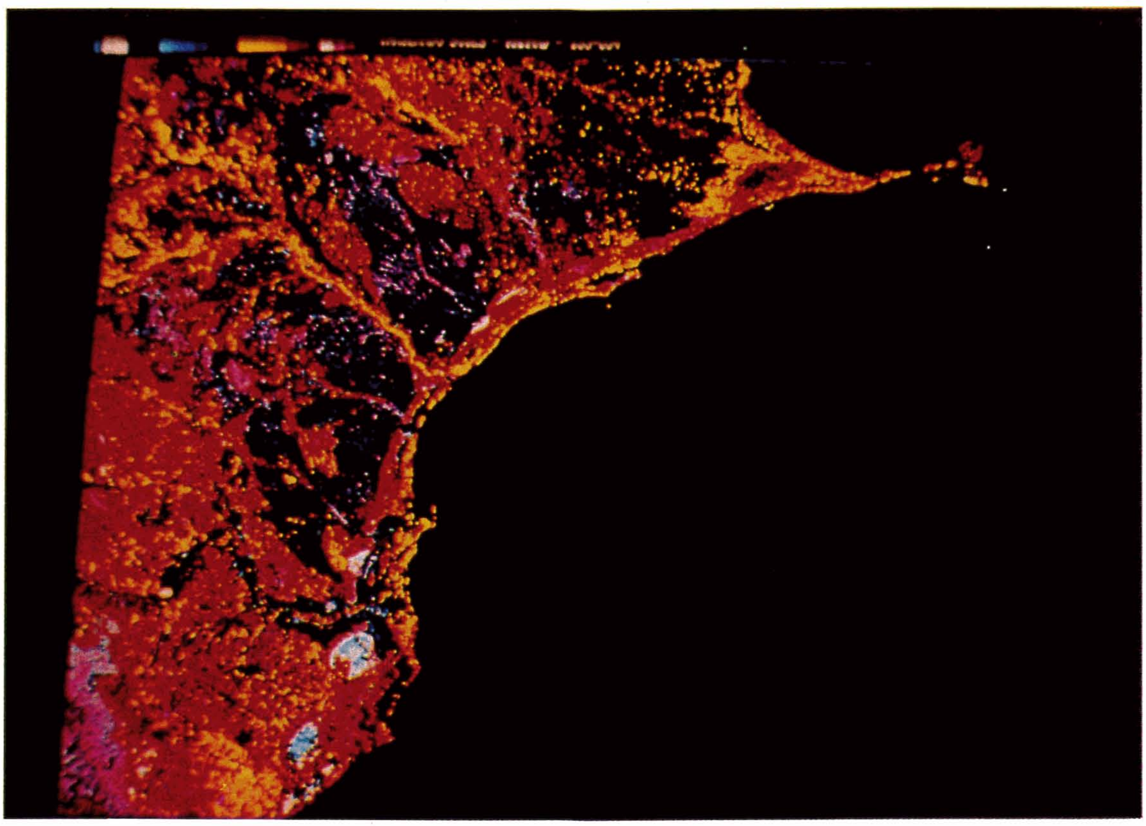

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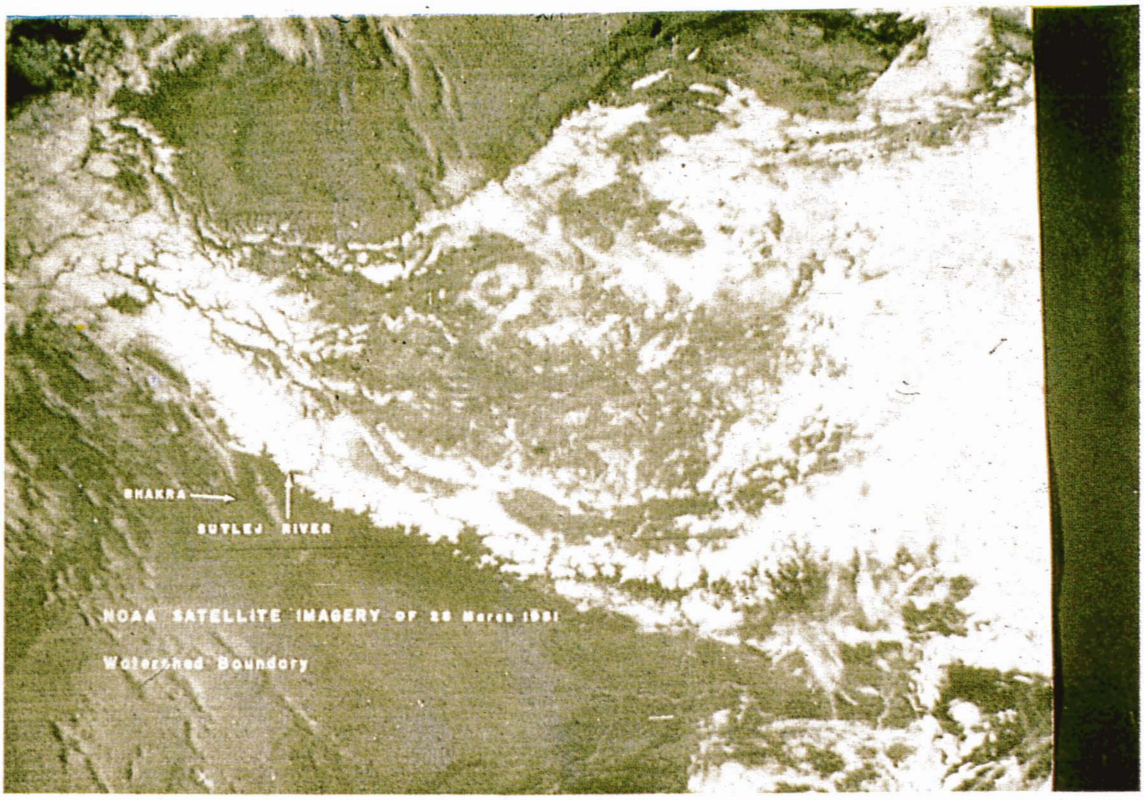

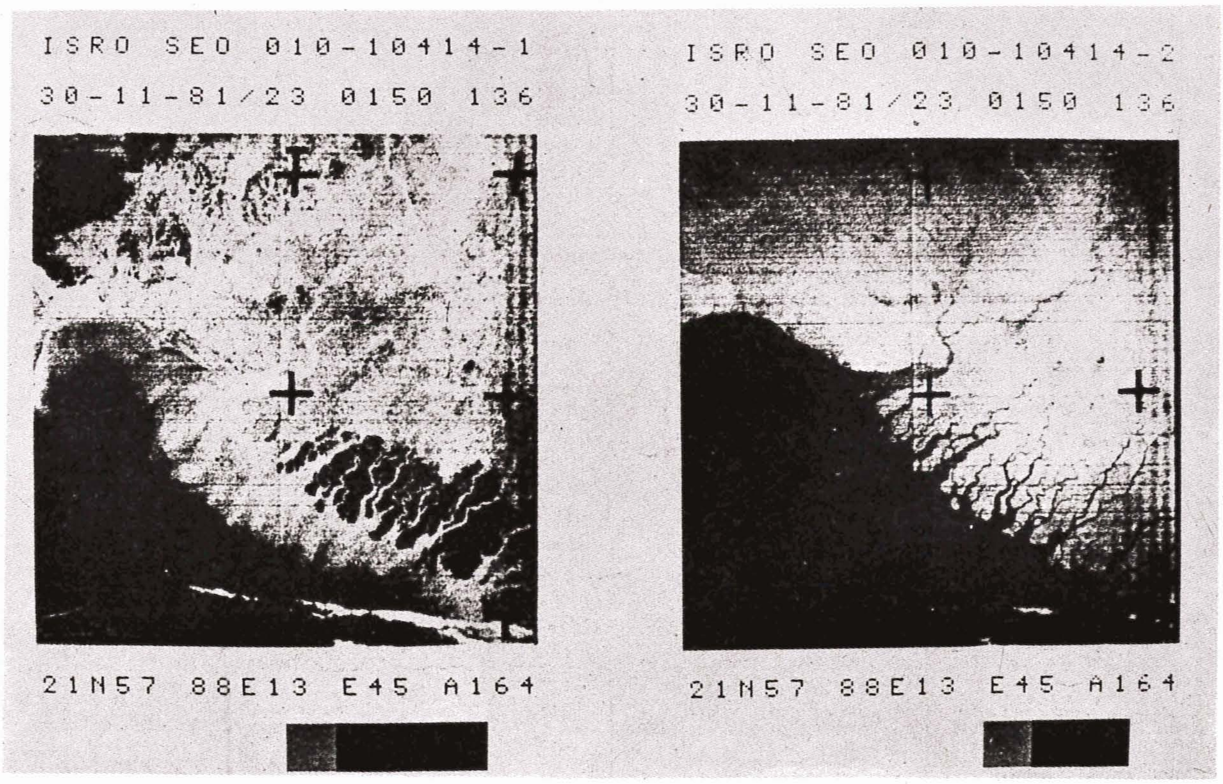

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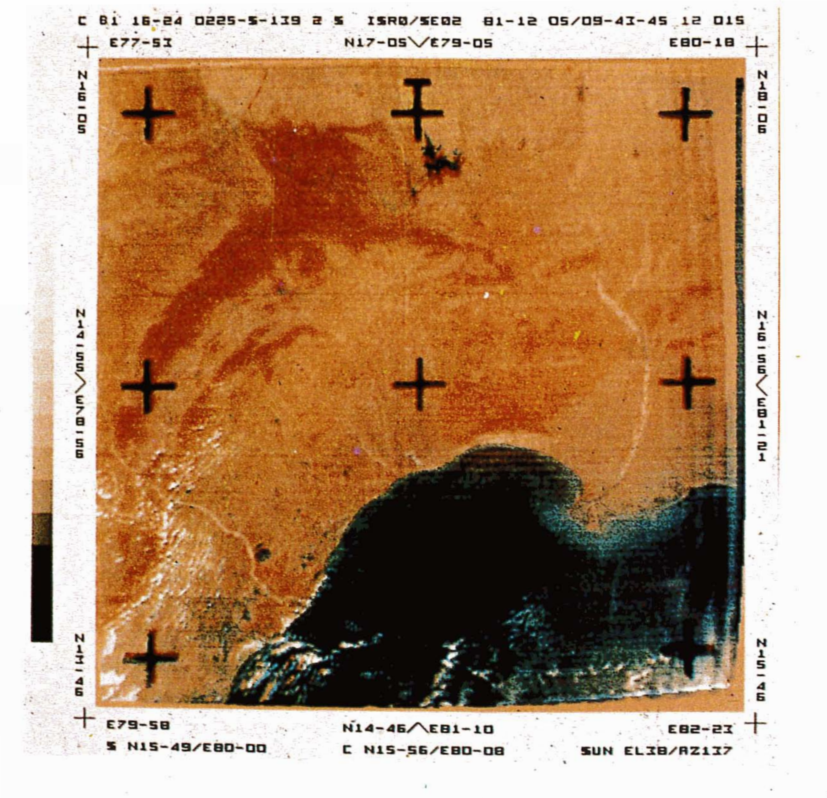

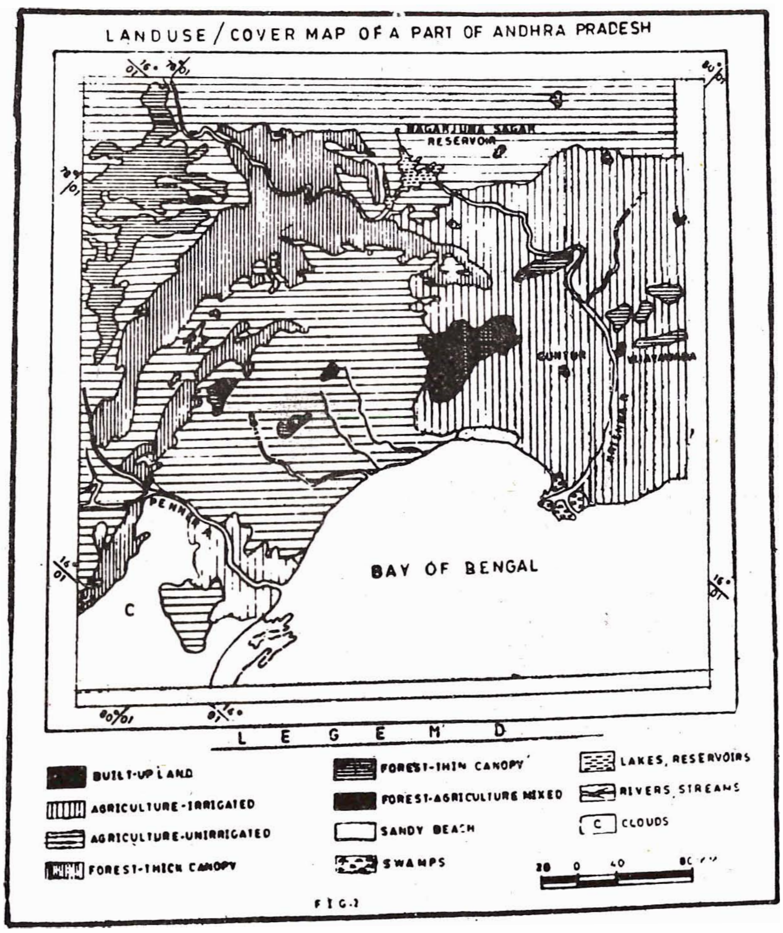

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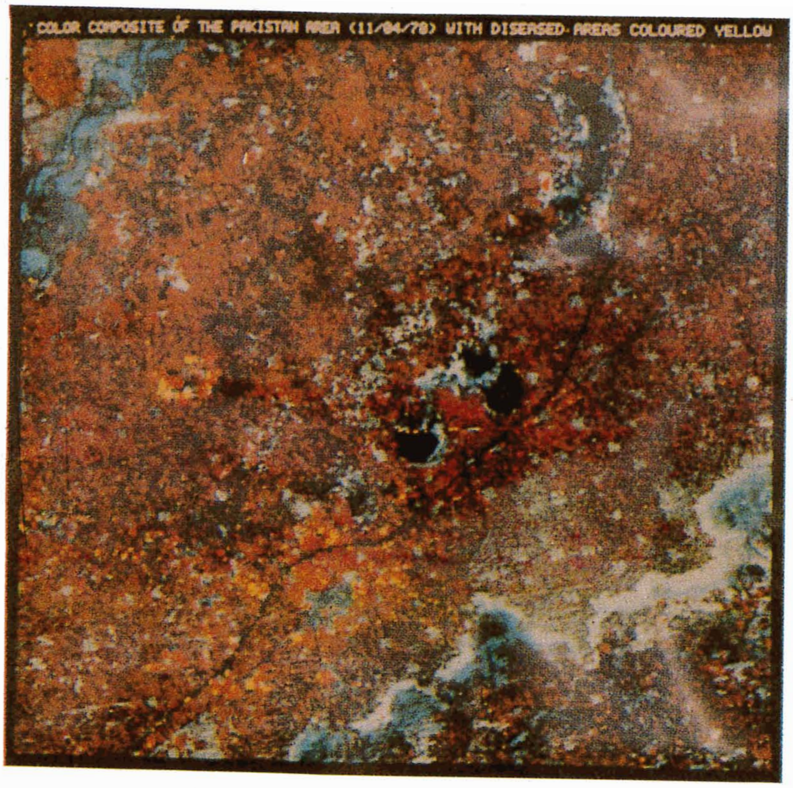

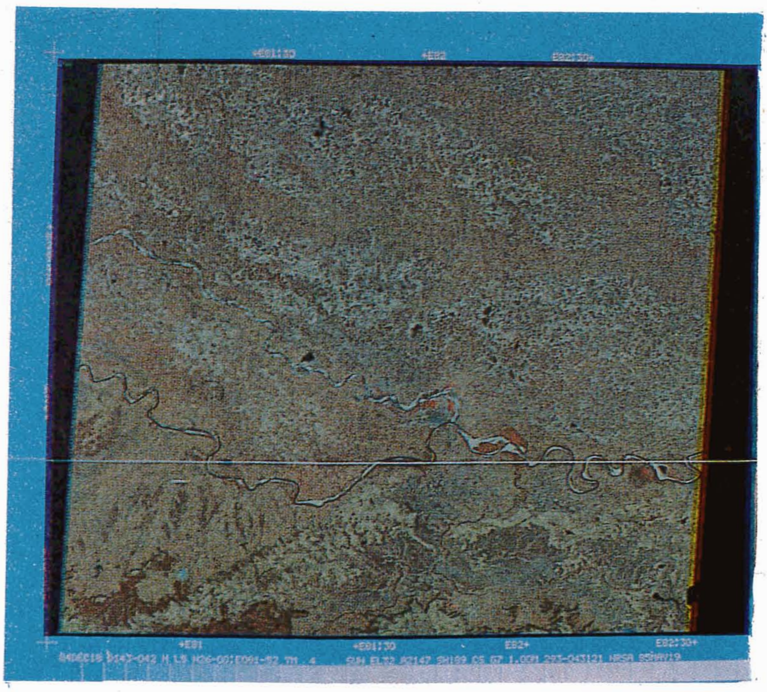

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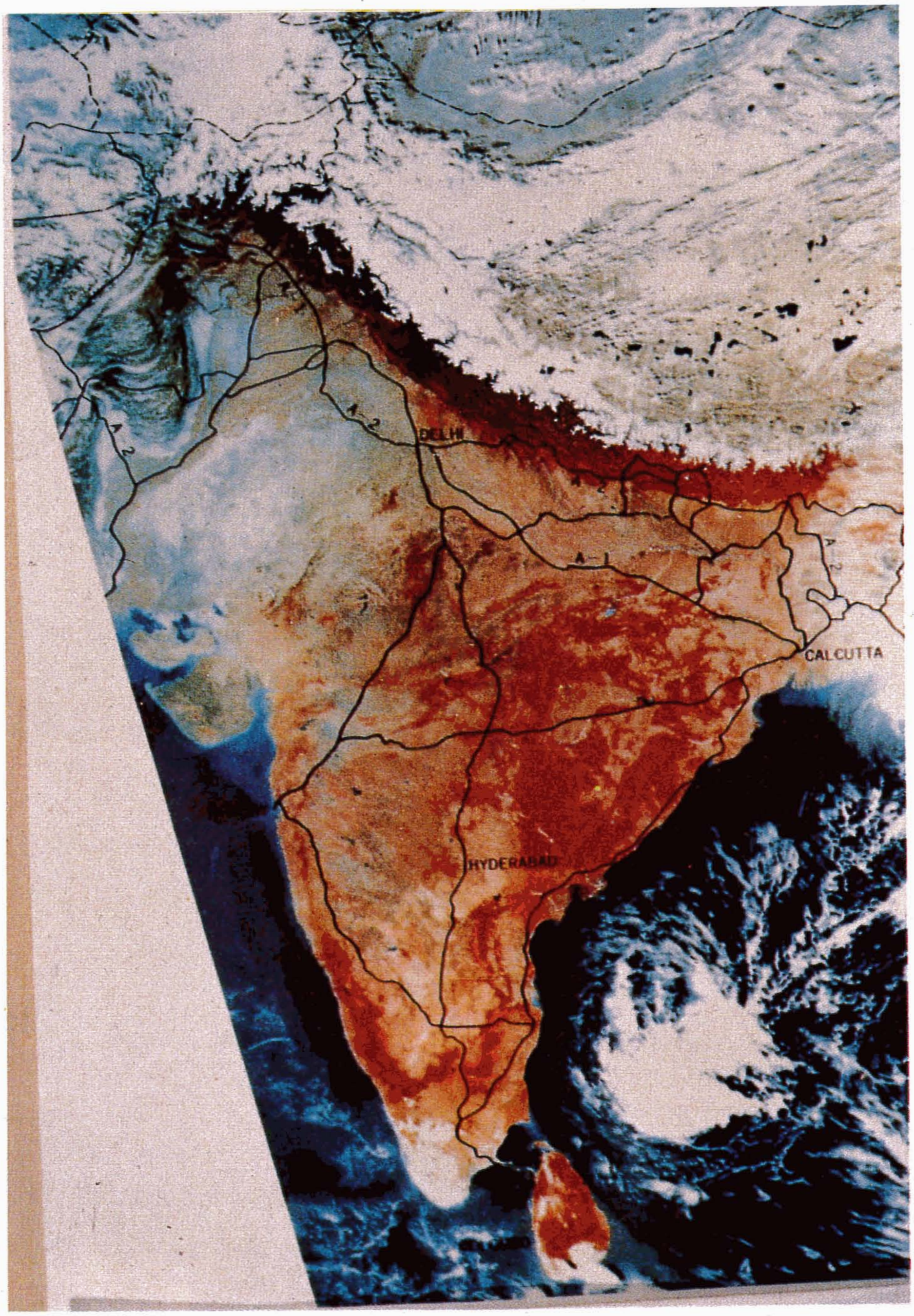

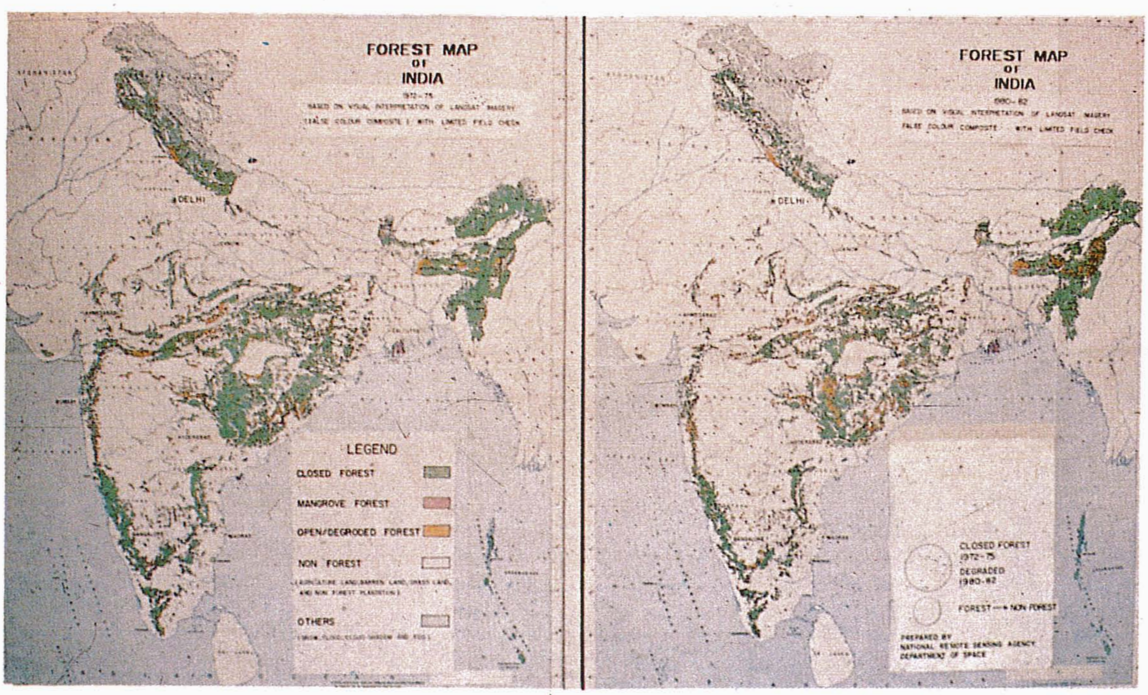

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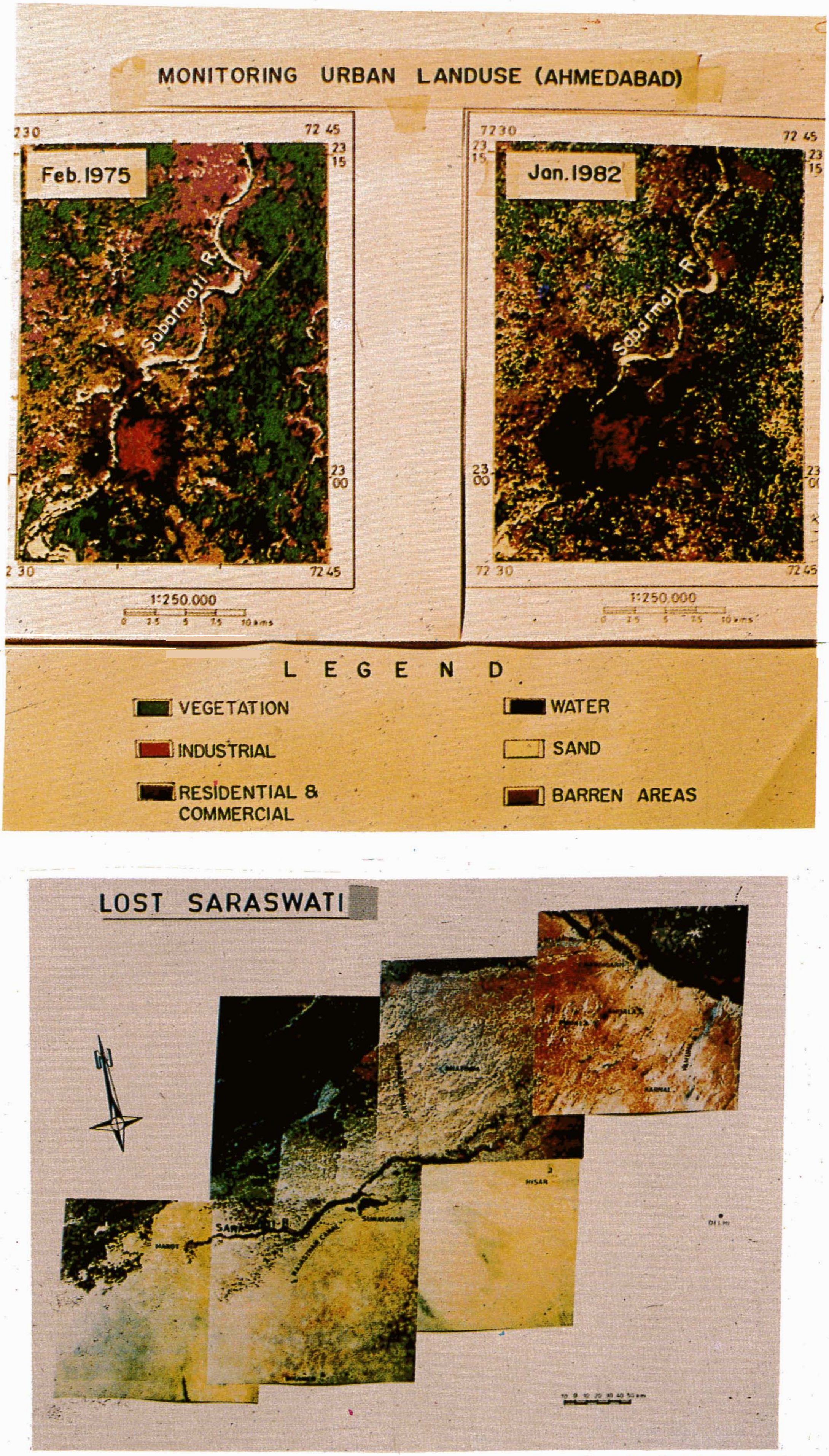

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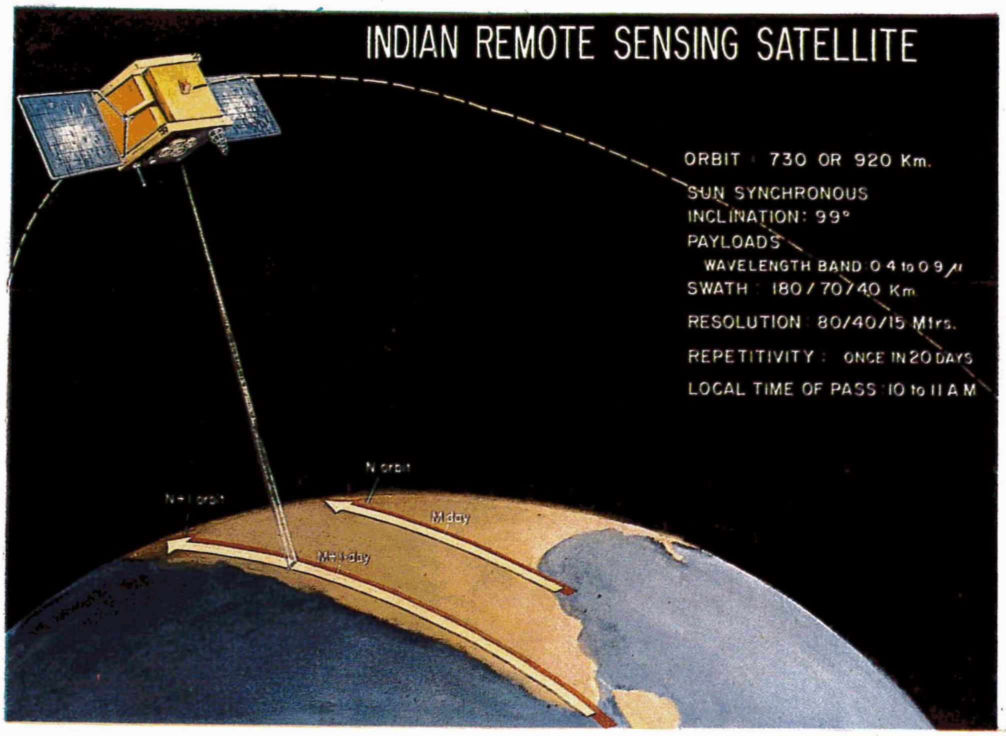

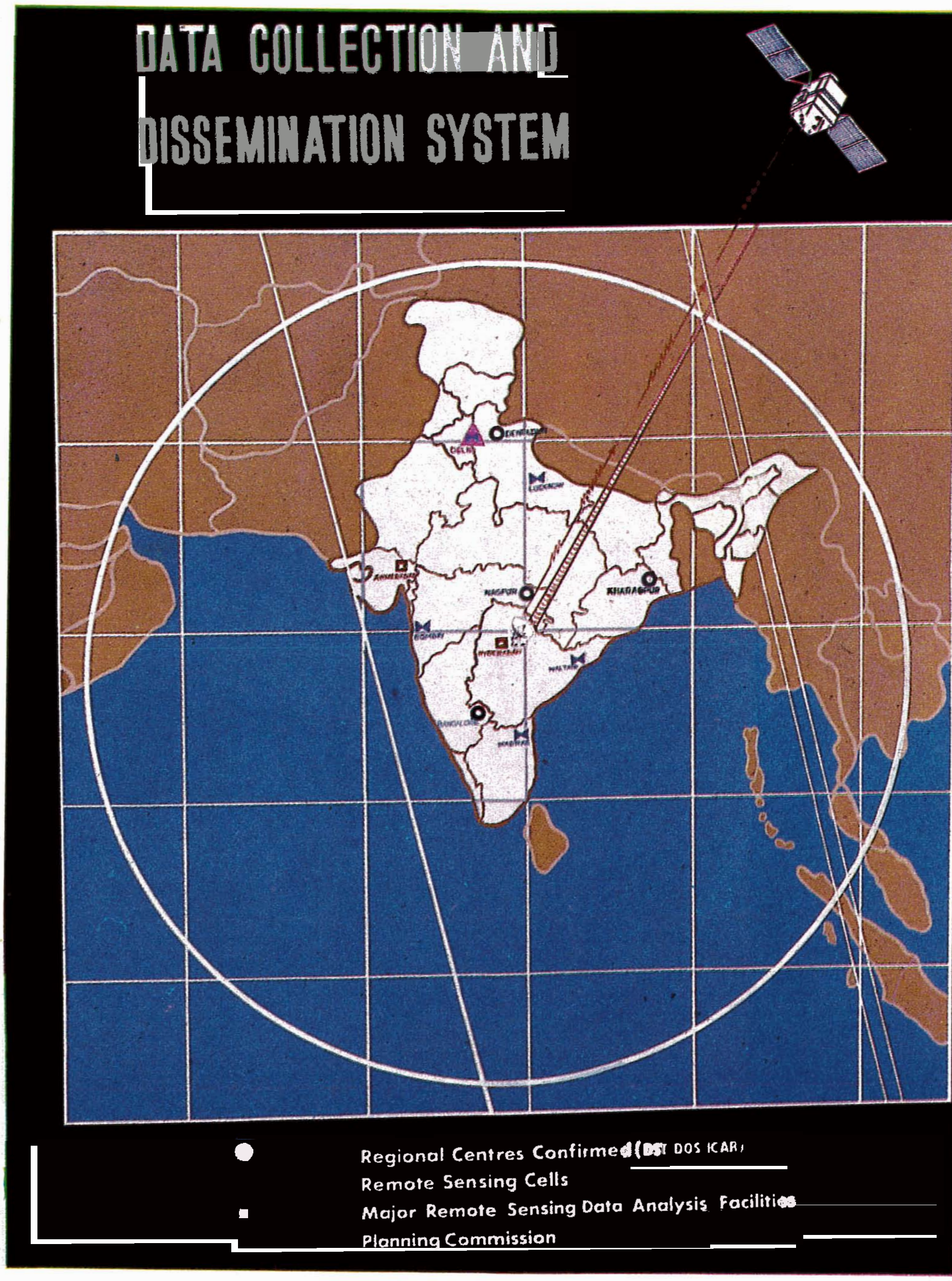

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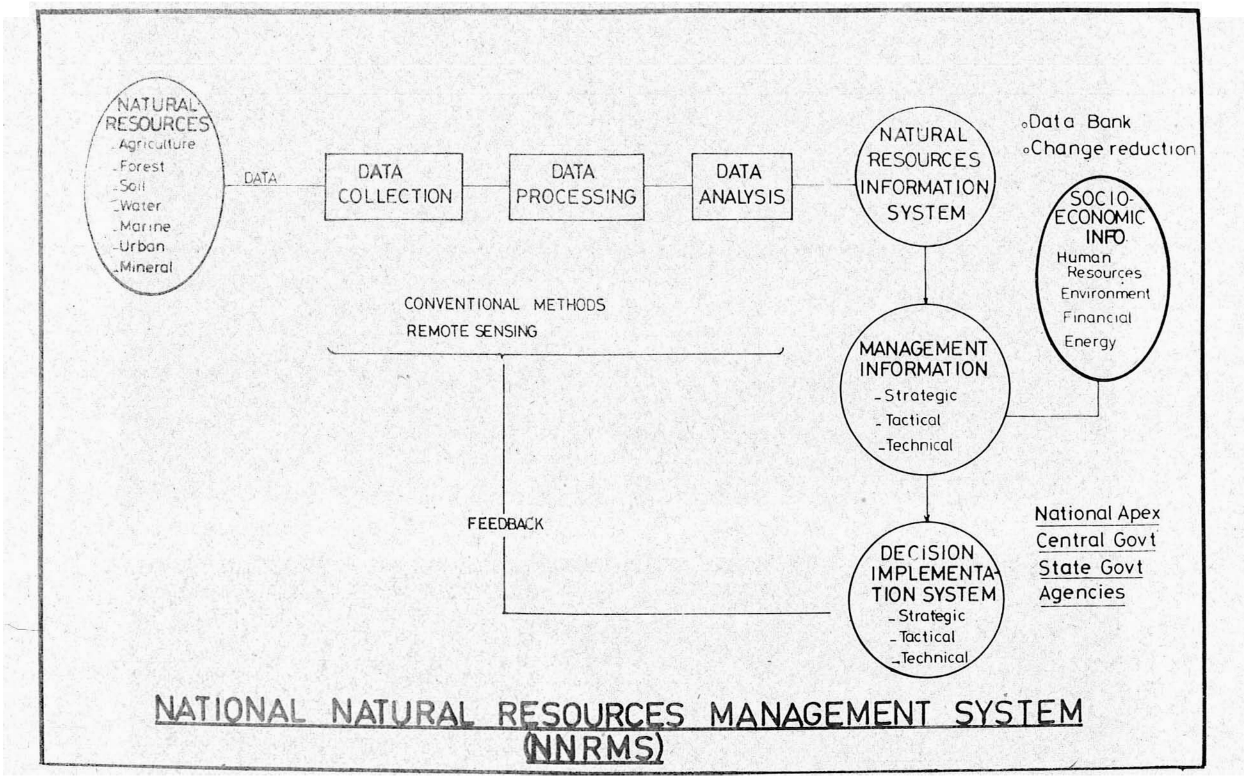

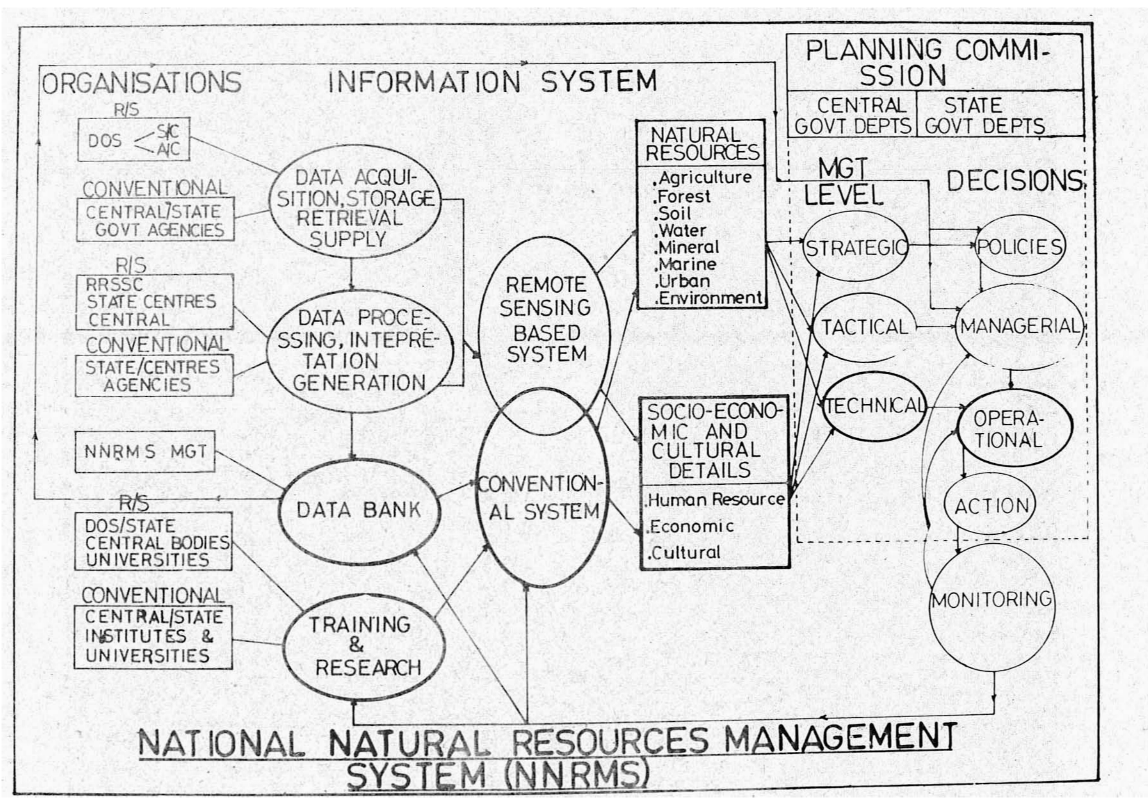

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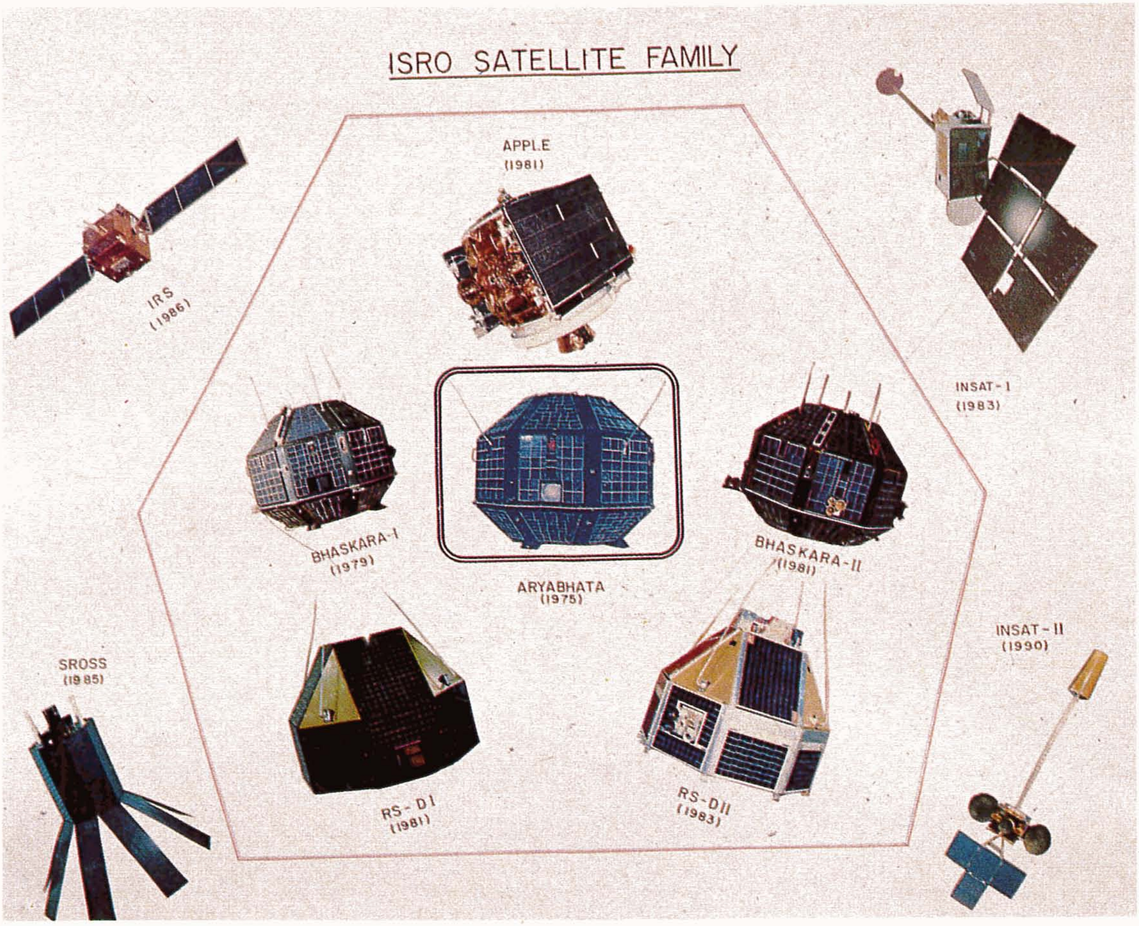

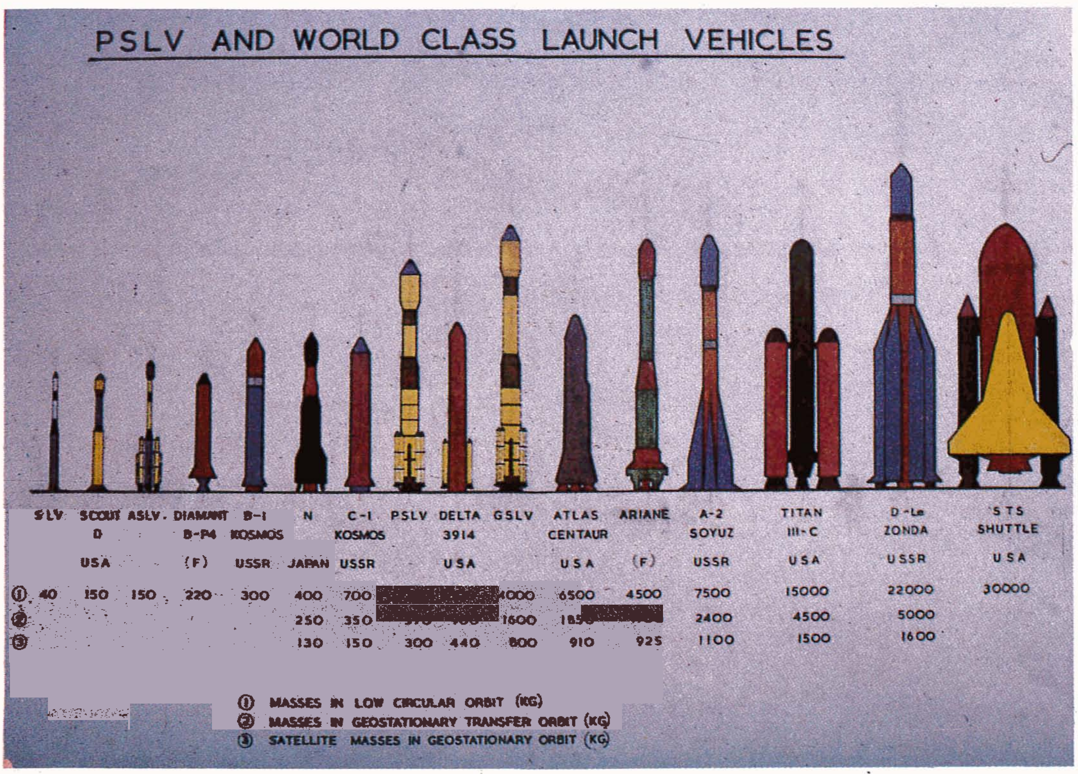

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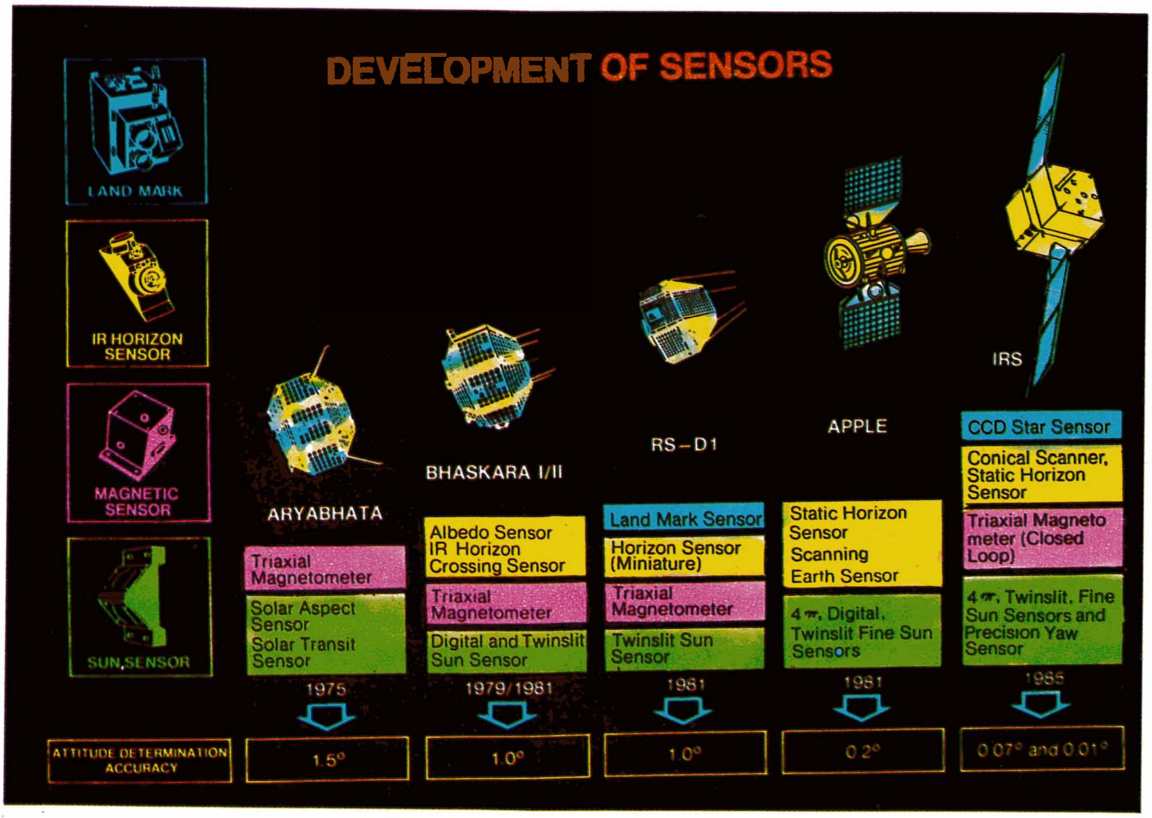

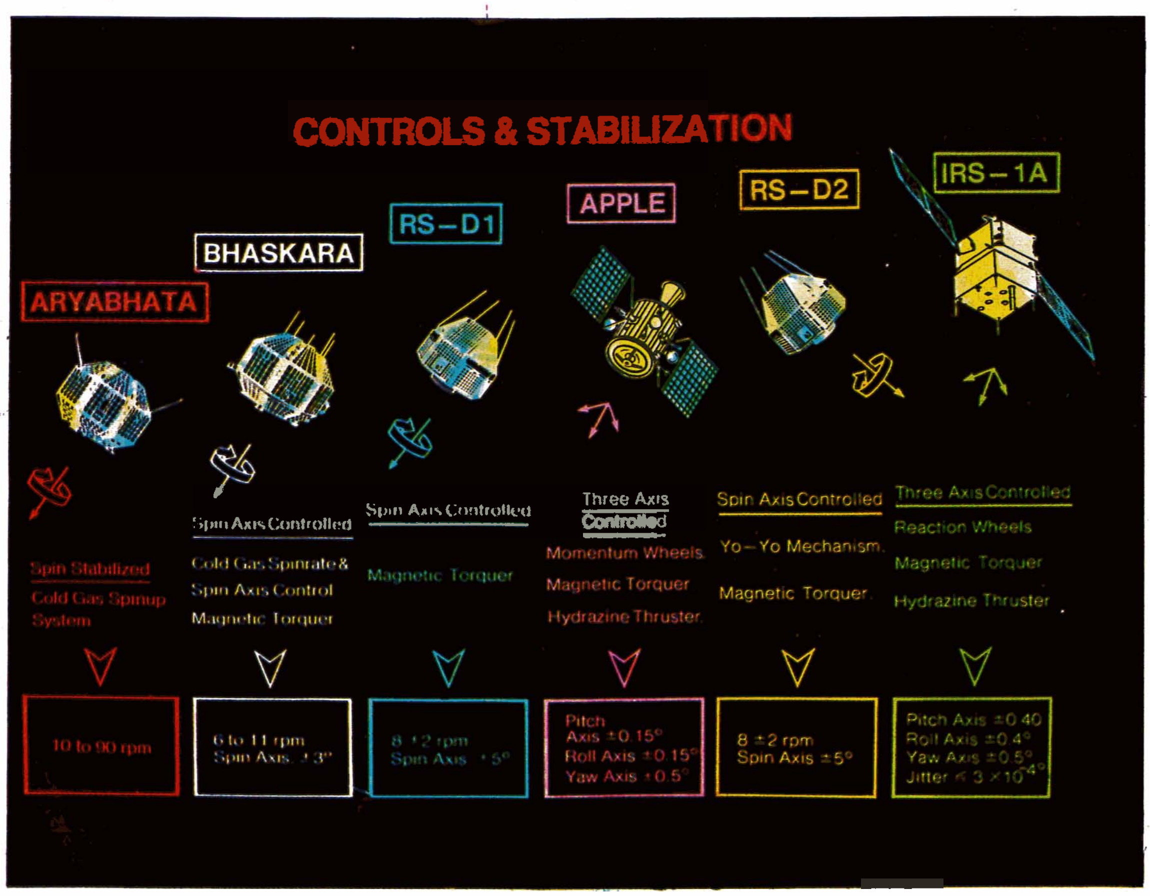

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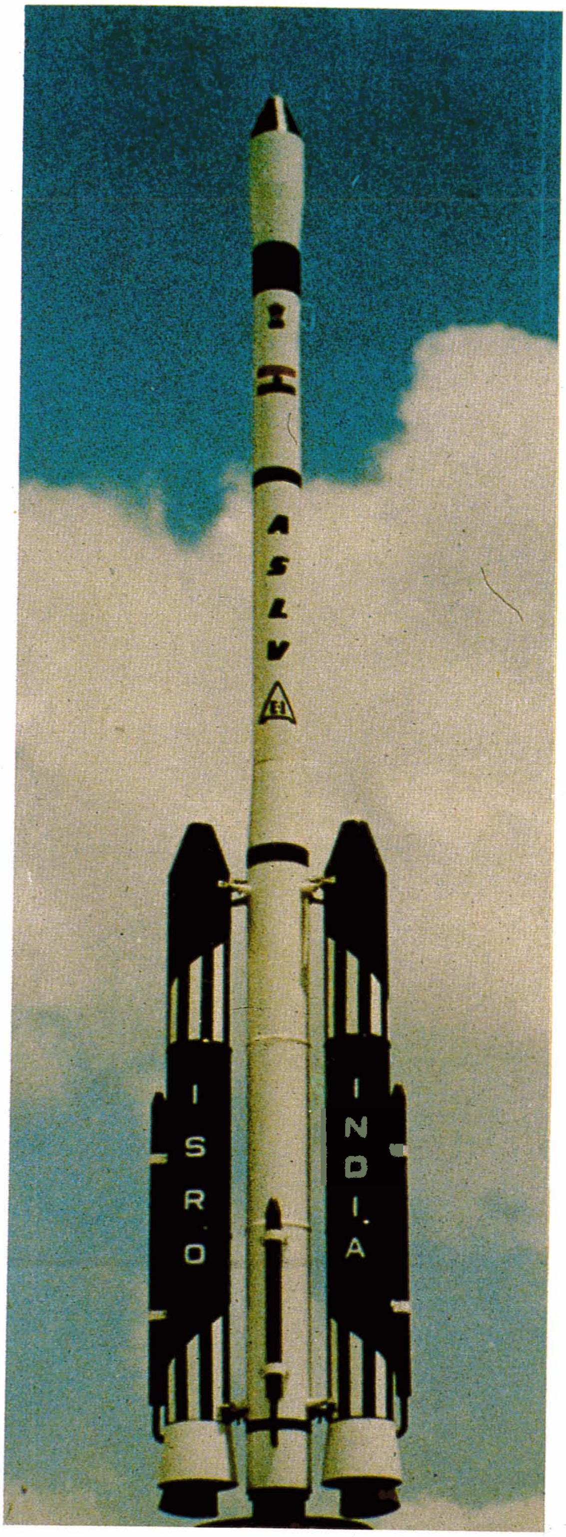

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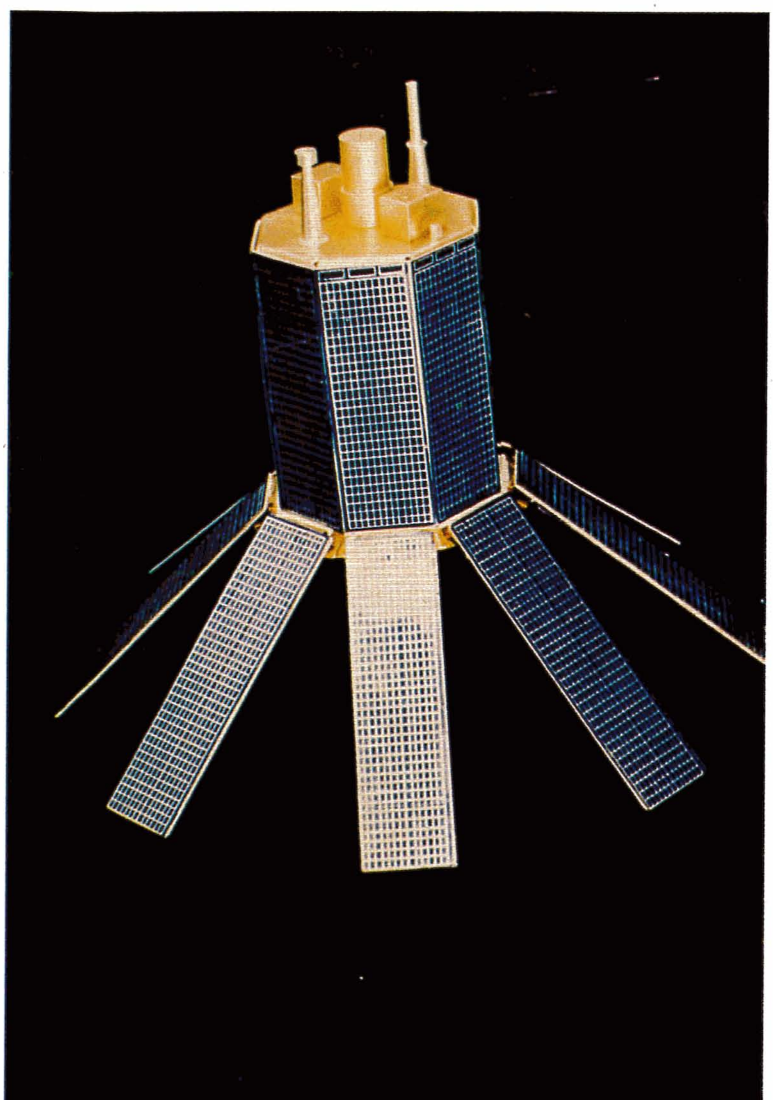

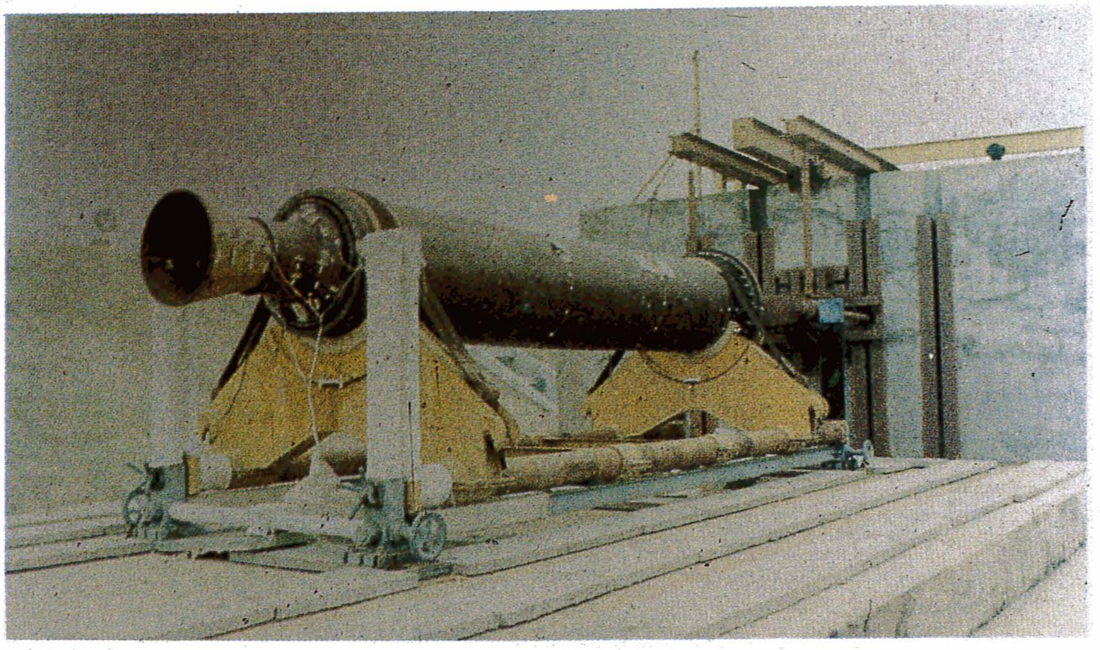

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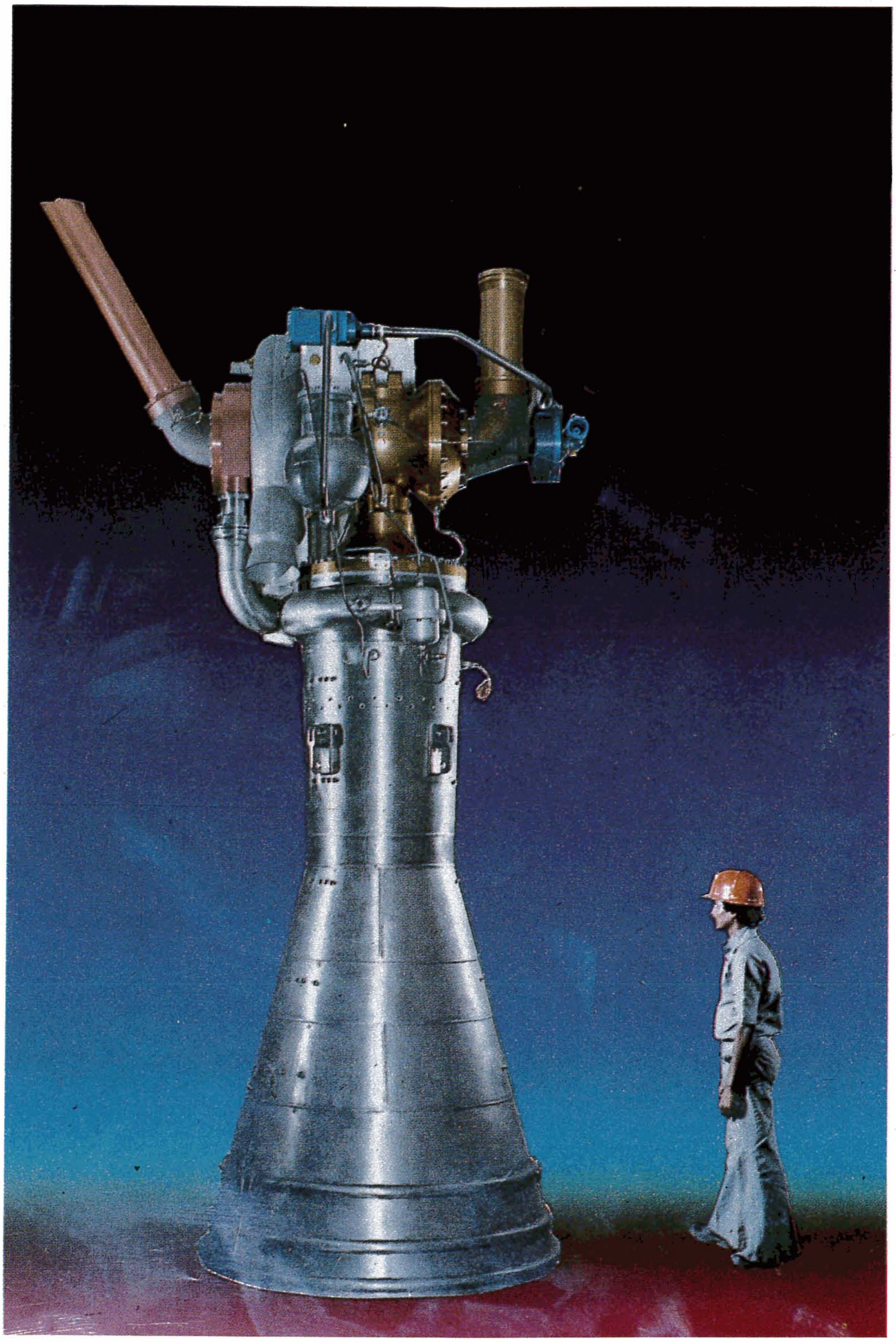

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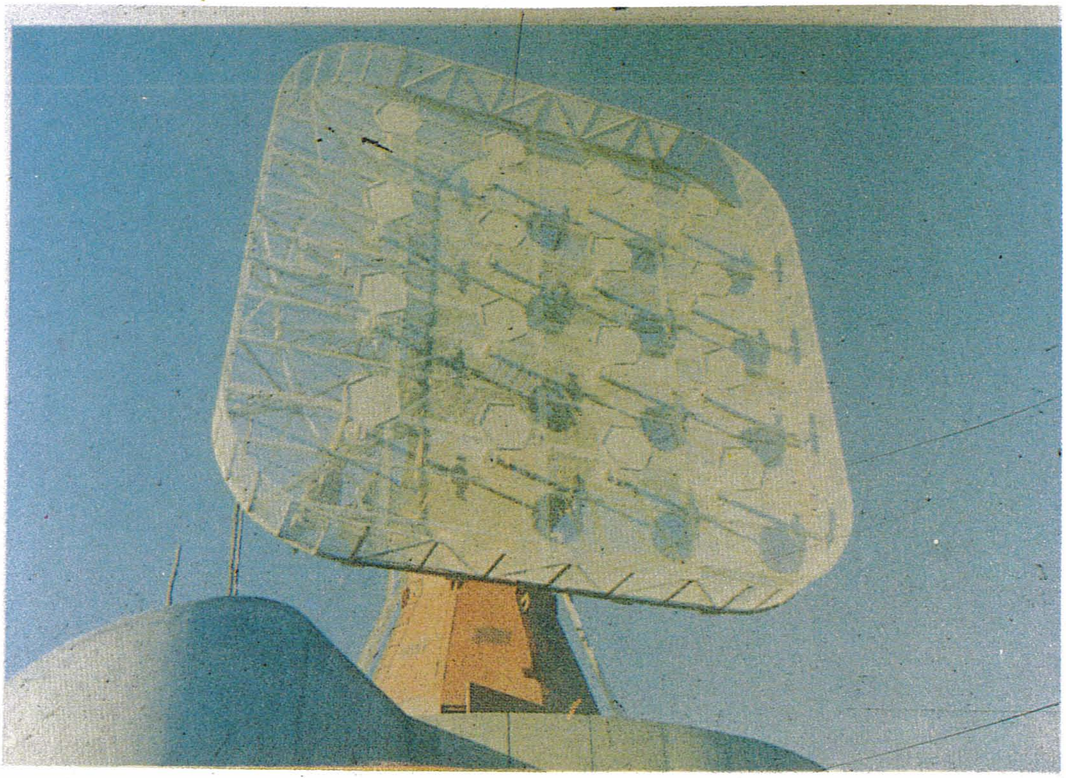

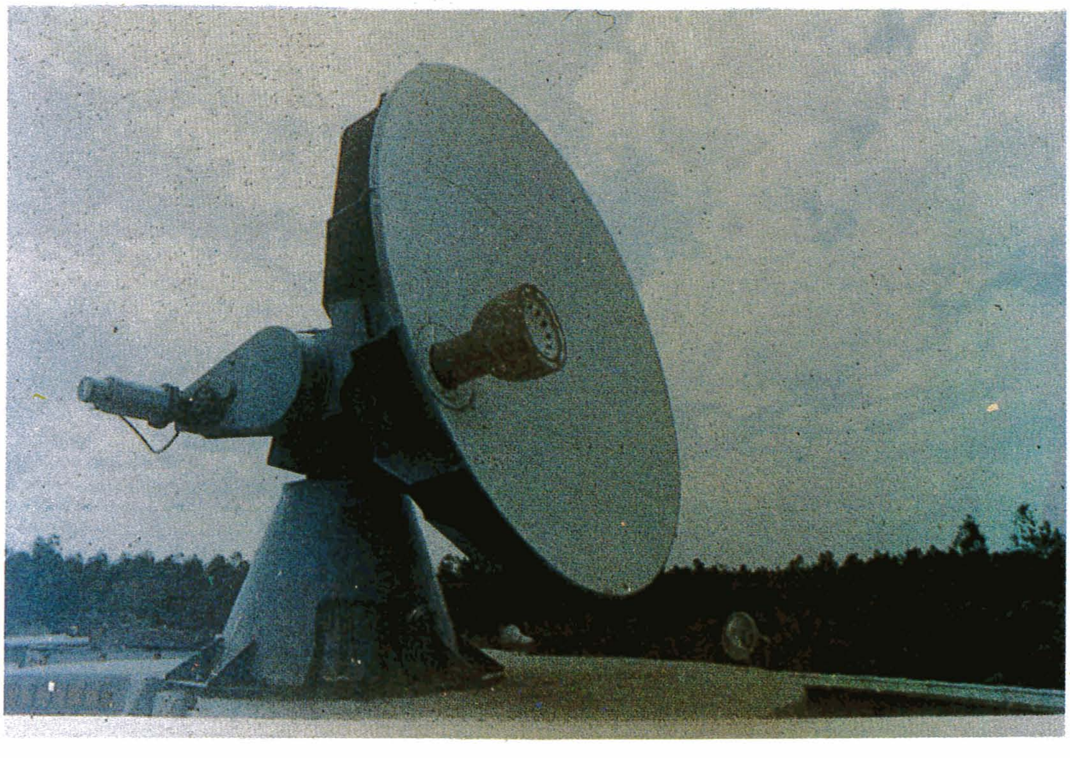

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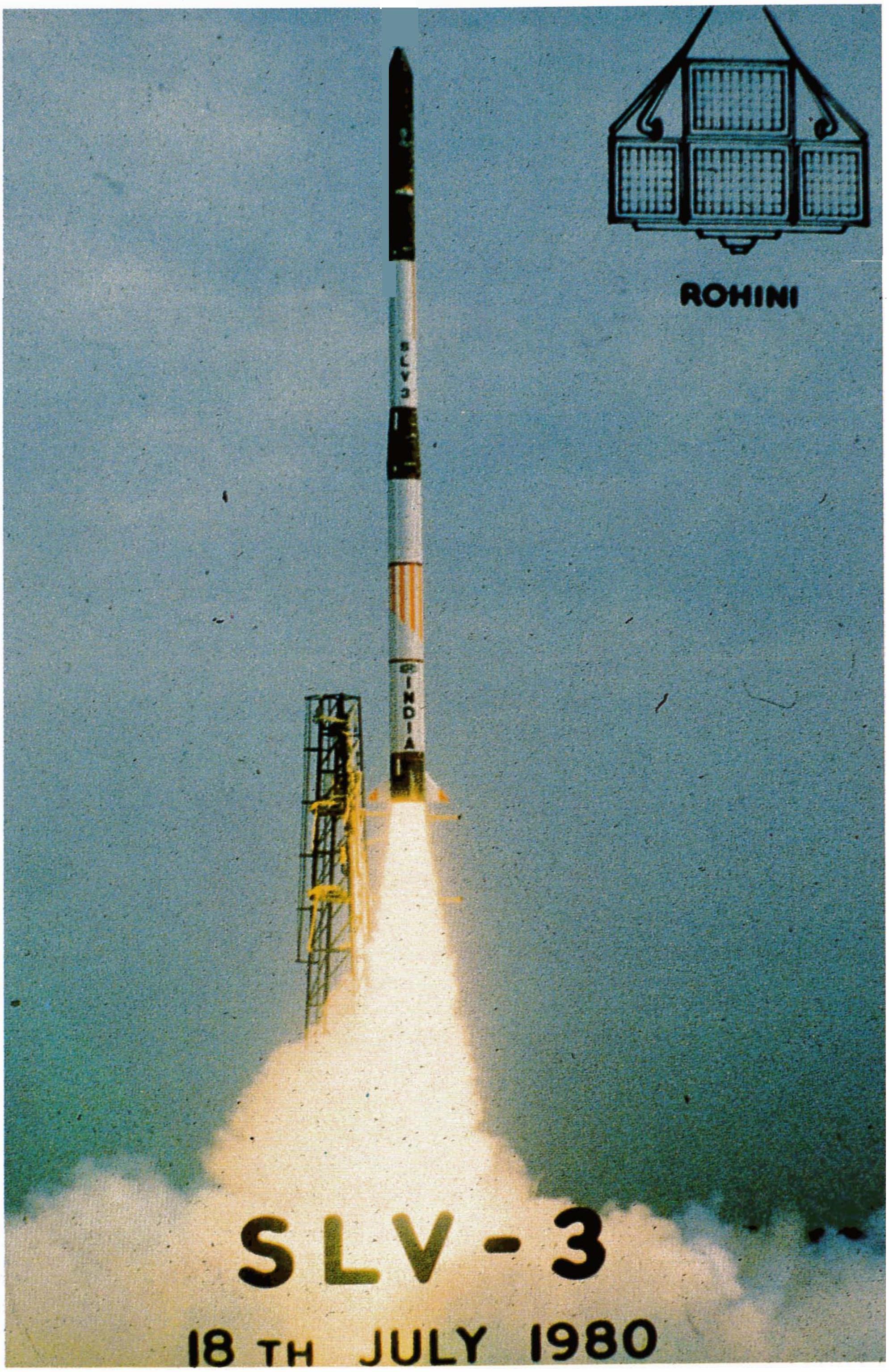

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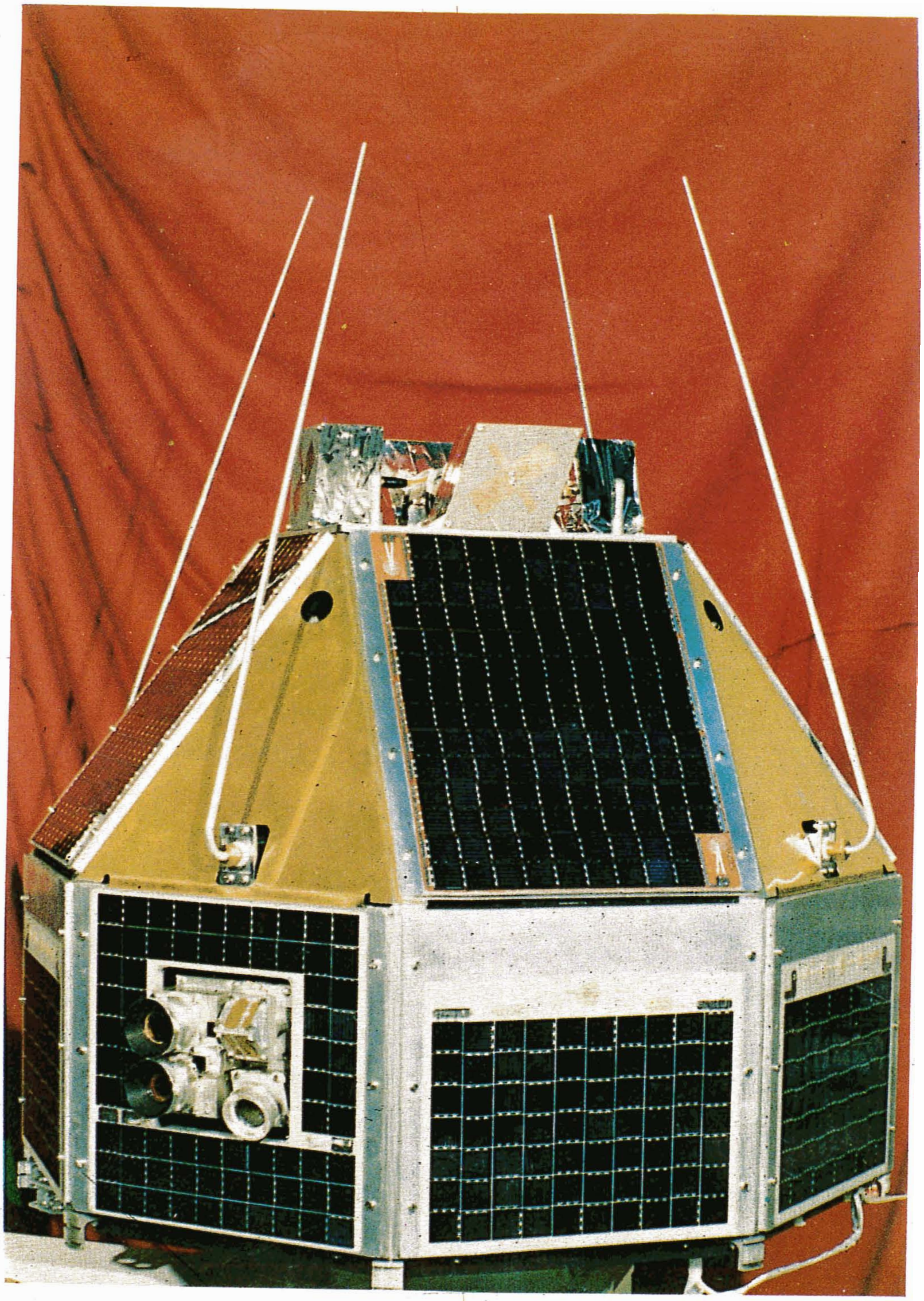

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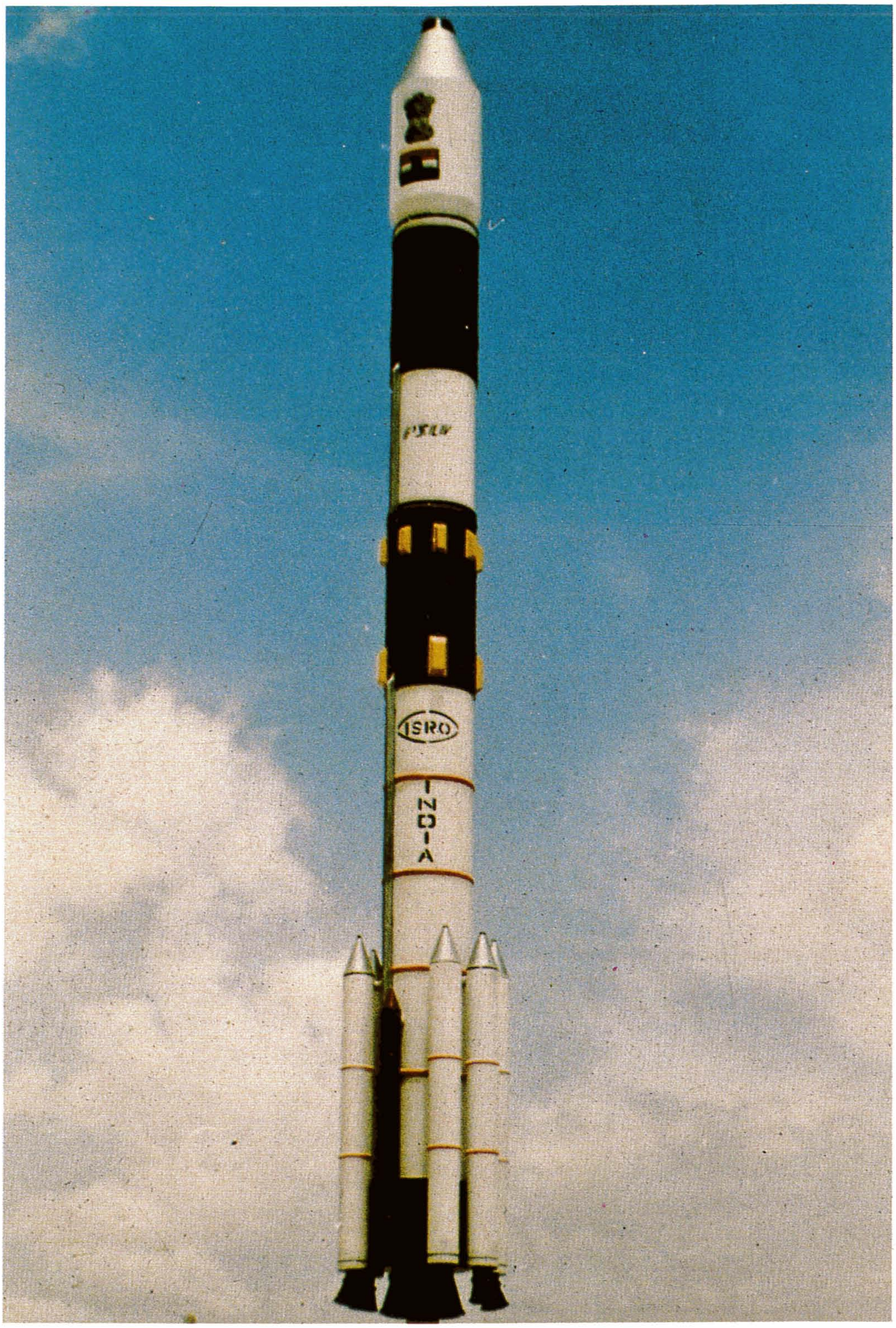

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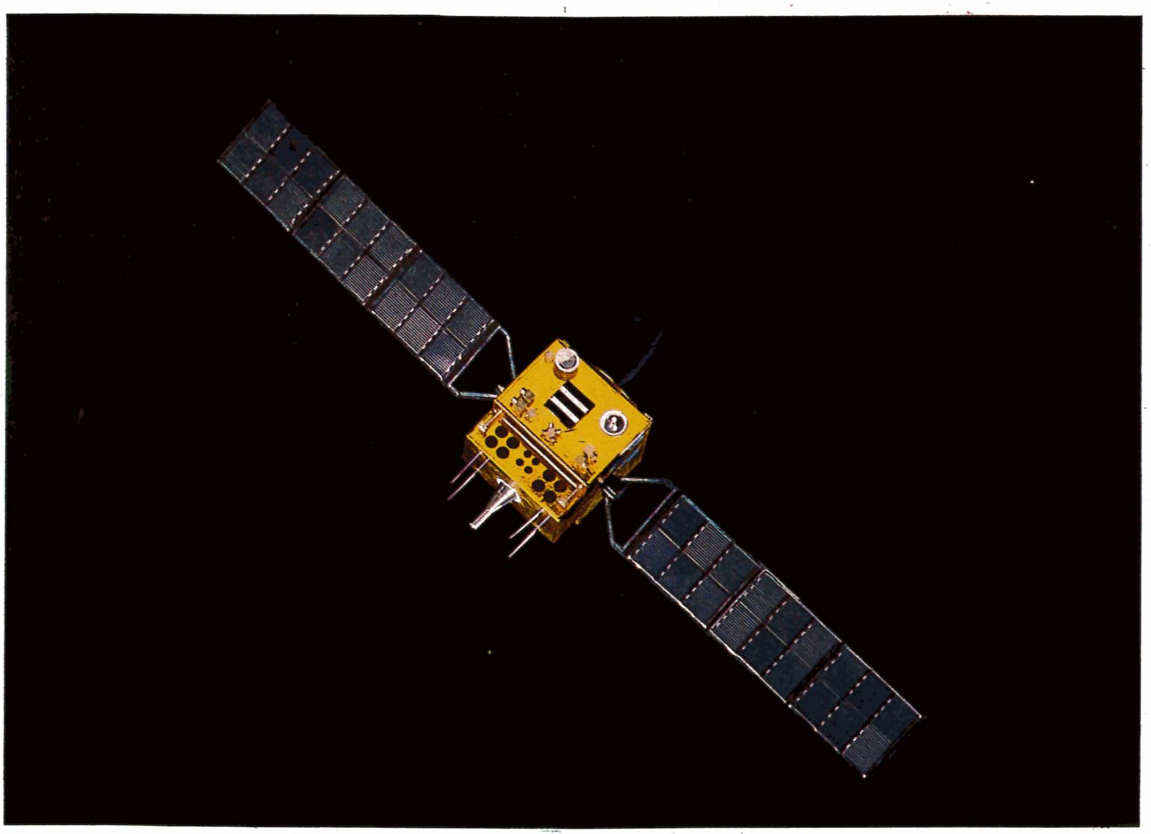

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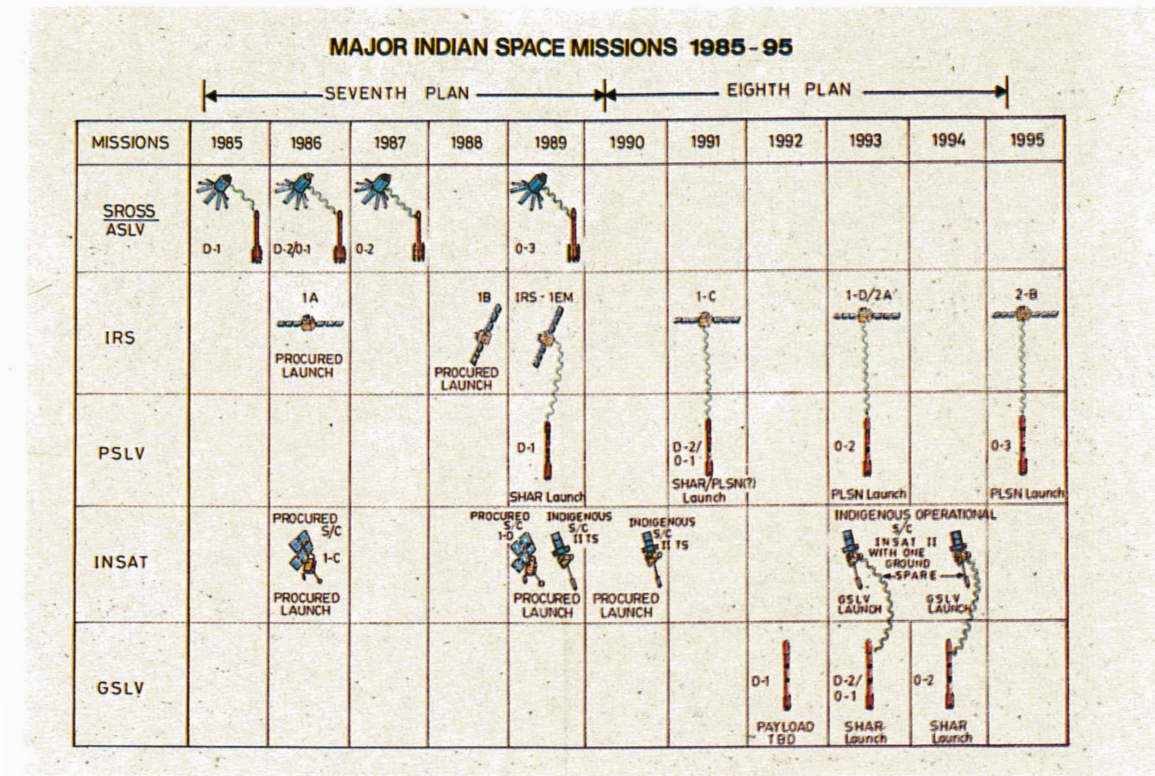

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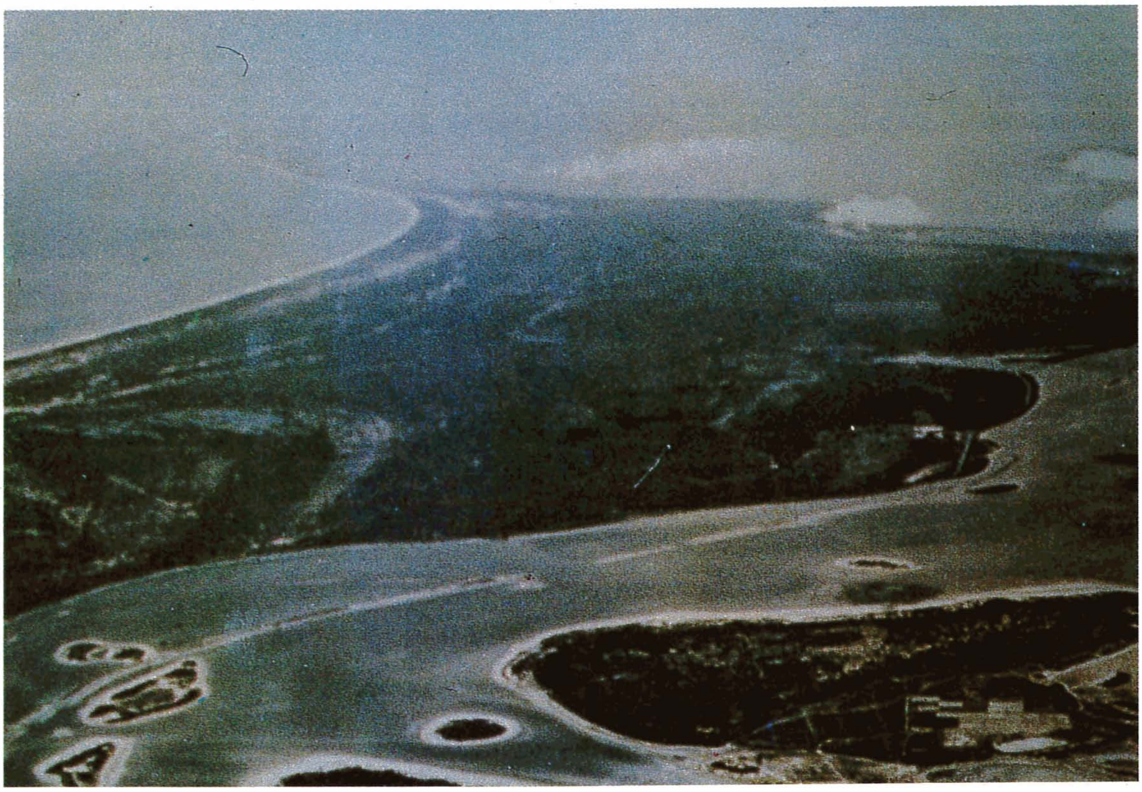

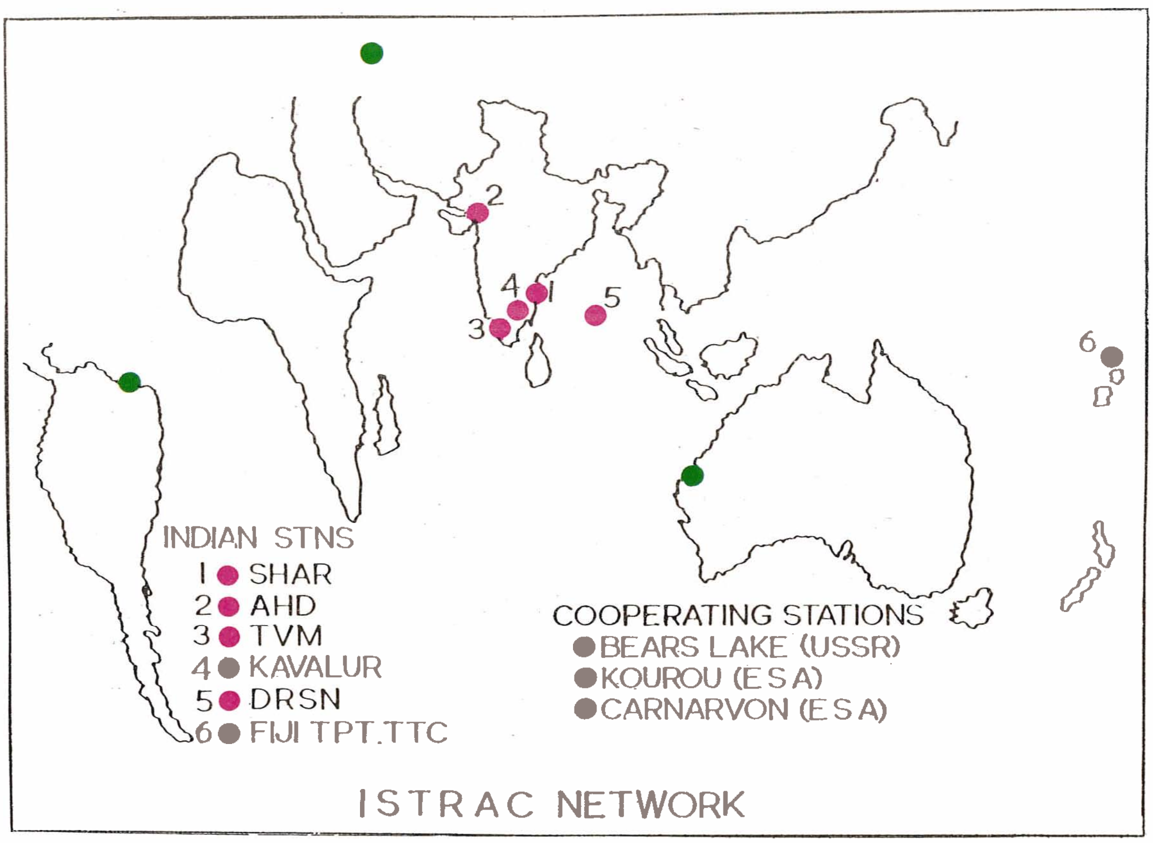

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