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SPACE india

INDIAN SPACE RESEARCH ORGANISATION

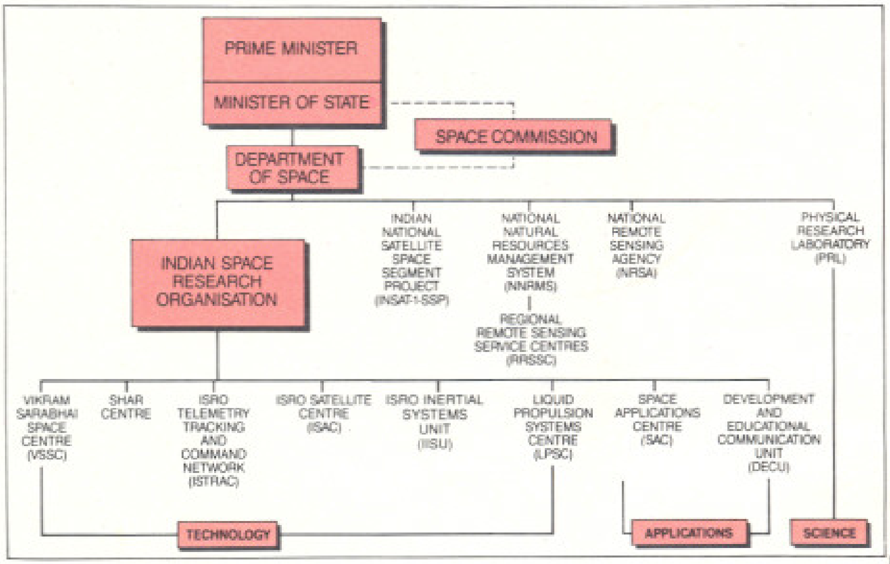
The Indian Space Programme

The setting up of the Thumba Equatorial Rocket Launching Station (TERLS) in 1963 marked the beginning of the Indian Space Programme. The Space Commission and the Department of Space (DOS) were established by the Government of India in 1972 to promote unified development and application of space science and technology for identified national objectives.

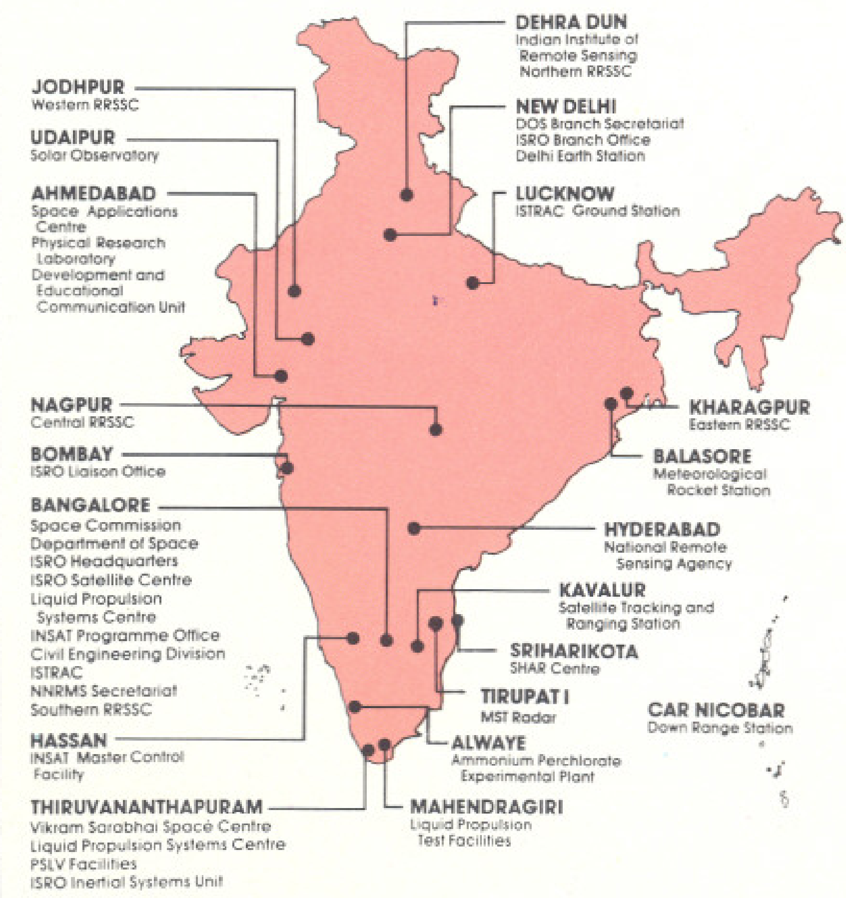
The Indian Space Programme is directed towards the goal of self-reliant use of space technology for national development, its main thrusts being: (a) satellite communications for various applications, (b) satellite remote sensing for resources survey and management, environmental monitoring and meteorological services and (c) development and operationalisation of indigenous satellites and launch vehicles for providing these space services.

The Indian Space Research Organisation (ISRO) is the research and development wing of DOS and is responsible for the execution of the national space programme. ISRO also provides support to universities and other academic institutions in the country for research and development projects relevant to the country's space programme.

Both the DOS and ISRO Headquarters are located at Bangalore. The development activities are carried out at the Centres and Units spread over the country. ☐



SPACE CENTRES AND UNITS IN INDIA



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April–June, 1991

SPACE India is published quarterly by the Indian Space Research Organisation for limited circulation. Articles appearing in *SPACE India* may be reproduced accompanied by the credit line "Reprinted from *SPACE India*" along with the date of issue.

Editorial/Circulation Office:
Publications & Public Relations Unit,
ISRO Headquarters, Antariksh Bhavan,
New BEL Road, Bangalore-560 094
India.

Printed at Thomson Press, Faridabad, India.

UN-ESA Workshop on Basic Space Science

The United Nations-European Space Agency (UN-ESA) Workshop on Basic Space Science for the Benefit of Developing Countries was held at ISRO Satellite Centre, Bangalore, during April 30 - May 3, 1991. The workshop, hosted by Indian Space Research Organisation, was organised with the objective of establishing and strengthening regional mechanisms of co-operation, in accordance with the recommendations of the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE-82)

The workshop, first on basic space science, was inaugurated by Prof M G K Menon, President, International Council of Scientific Unions (ICSU). Prof U R Rao, Chairman, Space Commission, Government of India, delivered the Keynote address. Dr N Jasentuliyana, Director, Outer Space Affairs Division of the United Nations, addressed on behalf of the world body. About 70 delegates including 40 from foreign countries participated in the workshop. The delegates were selected from amongst qualified persons nominated by their respective governments in the ESCAP and ESCWA region. Twenty Indian and foreign experts were invited to deliver the lectures during the workshop.

Ambassador Mr. Chinmaya Rajaninath Gharekhan (left) permanent Representative of India to the UN and Mr. Vasiliy S. Safronchuk, Under-Secretary-General for political and Security Council Affairs signing the Agreement on April 24, 1991 concerning the Workshop on Basic Space Science. (UN Photo 177743)

Since scientific, economic and social progress of any country is strongly interrelated, pursuit of basic science is important in finding solutions to the problems of development. The purpose of the workshop at Bangalore was to:

- create and improve awareness of scientists about current and future scientific and technical aspects of basic space science,
- enhance national capabilities to develop programmes and to undertake research activities in basic space sciences,
- enhance scientific co-operation amongst the developing countries including exchange of scientific information,
- foster international collaboration,
- explore avenues of eduation, training and research on space science subjects and
- create an international core group of scientists to pursue the above objectives of the workshop.

The main topics covered under the Plenary Session touched upon the importance of basic space science for developing

At the inaugural function. (From left to right) Dr. K. Kasturirangan, Director, ISRO Satellite Centre; Prof. U.R. Rao, Chairman, Space Commission, Govt. of India; Prof. M.G.K. Menon, President, ICSU; Dr. N. Jasentuliyana, Director, Outer Space Affairs Division, UN and Mr. M.G. Chandrashekar, Scientific Secretary,ISRO.

A section of the audience during the inaugural function.

Welcome address by Dr. Kasturirangan, Director, ISAC.

countries and international co-operation. The technical sessions included topics under planetary environment, their atmosphere and space plasma processes, solar system science and planetary exploration, space astronomy and astrophysics.

During the concluding session of the workshop, Prof U R Rao said that the Indian space programme could serve as a model for other developing countries for planning their space research activities.

Several recommendations were made by the participants for creating necessary infrastructure, national data centres and mechanisms of international co-operation to benefit developing countries in pursuing space science research. It was specifically pointed out that scientific data from IUE satellite which has been archived by ESA could be made available to astronomers and astrophysicists in developing countries. A suggestion was made for establishing a suitable communication system, including E-mail associated networks, for information flow between scientists of different countries. It was proposed to constitute a core group of scientists from member countries who would work out details of actions to be taken by UN Committee on Outer Space for the implementation of the recommendations made in the workshop.

The workshop was very productive in terms of scientific discussion and future possibilities for developing countries. The United Nations is expected to pursue the recommendations of the workshop. □

United Nations Address

by

N. Jasentuliyana
Director,
Outer Space Affairs Division
United Nations

(Extracts)

International cooperation, formally and informally, has always been central to scientific progress; and scientific research has been a particularly good example of productive international cooperation. Scientists from developing countries, however, have frequently encountered difficulties in fully participating in the international scientific community, in part due to the very limited resources at their disposal for equipment and personnel, but equally because of the difficulties of keeping in touch with the international scientific community.

The objective of this Workshop is to promote communication between scientists working in space research, both within this region and internationally, discuss recent developments in space research and to address some of the specific problems facing space scientists in developing countries. An important result of the Workshop will be a set of conclusions and recommendations that will be formulated by the Working Groups. A report on the Workshop will be submitted to the United Nations Committee on the Peaceful Uses of Outer

Space for its consideration.

Space research, of course, is not new. It did not begin with the space age, but goes far back into history. Indeed, peoples in all parts of the world have speculated about the nature and the meaning of the heavens for as long as we have traces of civilization. We should note here that India has a long history of scientific astronomical observations.

Both nationally and internationally, the concept of economic development has generally focussed on technology and applications rather than on science and research. And as a result, national and international development programmes, such as those of the United Nations, have not given adequate attention to promoting scientific research and international cooperation in science.

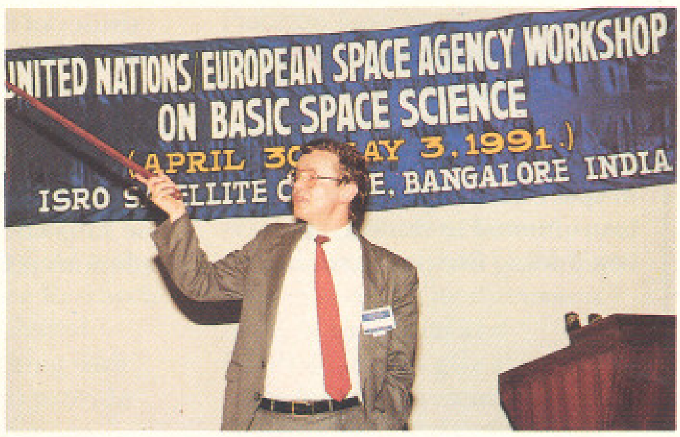
There are three aspects of scientific research that make it a vital element in any developing society. The first aspect of science is its cumulative nature, its commitment to using past knowledge in order to gain new knowledge. While science and technology are often thought of as destroyers of tradition, science is in fact more respectful of tradition than many other areas of human culture in which old beliefs are often summarily rejected in favour of the latest fashion. When the international culture of modern science is introduced to a traditional society, the conflict can be quite disruptive culturally. Science is by its nature critical. While respecting existing knowledge, science is constantly evaluating that knowledge in order to find ways to improve and extend it. For people who are dogmatically attached to existing knowledge, that critical approach can be disturbing, but it is essential to development.

The other element of science is its collective or communal nature. Scientists cannot work alone. Even if the actual research activities are individual, which is increasingly rarely the case, scientists must have communications with other researchers in their field. And it is increasingly essential that they have worldwide communications with others working in their field. The scientific community is one of the best examples in the world of international cooperation, of people working together towards a common goal of general public interest. When international cooperation in science is subjected to limitations, as is unfortunately not unusual, it is almost always over the objections of the scientific community. The scientific community is generally committed to the ideal of international cooperation; and the struggle to maintain and expand that cooperation is an important commitment that needs to be encouraged.

These principles of scientific research, namely, building upon past knowledge, a critical approach to existing knowledge, and the collective efforts of a community are the basis of this Workshop. The promotion and encouragement of these three principles through the Workshop and the efforts of the members of the scientific community who are participating can make a significant contribution to the intellectual, cultural, social and economic development of their countries and of the world. The scientific community contributes to economic and social development both through the concrete results of their work and through the promotion of the general principles of scientific research.

While all scientific research is

Dr. B.S.N. Prasad of Mysore University conducting a course on UVB measurements.



Dr. H.J. Havbold (UN) giving a talk on Neutriono and Gravitational wave Astronomy.

United Nations Committee on Peaceful Uses of Outer Space (COPUOS)

The United Nations Committee on Peaceful Uses of Outer Space (COPUOS) plays a key role in regard to UN activities in matters concerning outer space. The Committee, with a membership of 53 countries, has the mandate to discuss the state-of-the-art and future developments in the peaceful uses of outer space, to review international co-operation and to study means to implement programmes which promote such cooperation. The Committee also studies legal problems that could arise from exploration and exploitation of outer space in the international context. It organises exchange and dissemination of information relating to space activities.

Since its establishment in 1959, the committee has taken several important steps to promote systematic and orderly growth of space activities. It was instrumental in drafting and concluding five international treaties, namely:

- treaty on principles governing the activities of States in the exploration and use of outer space, including moon and other celestial bodies
- agreement on the rescue of astronauts, return of astronauts and return of objects launched into outer space
- convention on international liability for damage caused by space objects
- convention on registration of objects launched into outer space
- agreement governing the activities of States on the moon and other celestial bodies.

The Committee has contributed to several resolutions adopted by the UN General Assembly on these subjects. These resolutions relate to the principles of direct international television broadcasting via satellite and remote sensing from space. The Committee has carried out several scientific, technical, economic and social studies relating to space technology and its applications. It has also given impetus to an international education and training programme by establishing and guiding the UN programme on space applications. The Committee organised two international UN conferences in the past - the recent being the UNISPACE-82 held in Vienna in 1982. The Committee and its subcommittees are currently deliberating on several vital issues such as use of nuclear power sources in outer space, definition and delimitation of outer space, rational and equitable use of geostationary orbit and follow-up of UNISPACE-82 recommendations.

based on cooperation that crosses political boundaries, international cooperation is more important in space research than in many other scientific disciplines. While international cooperation in space research has been extensive, and in many respects exemplary, there have still been many obstacles to the full participation of scientists from developing countries in space research. Participation here of scientists from both developed and developing countries and the focus of this meeting on the specific problems of scientists in developing countries provides a good opportunity for exploring ways to promote cooperation that is more fully international.

A major form of international cooperation in space science has been through advanced education. Education, therefore, is one of the most widespread forms of cooperation. The attendance of students from developing countries at educational institutions in developed countries serves not only to educate those particular students, but as an important means of transferring knowledge from the developed to developing countries. Exchanges of faculty members between institutions in developed and developing countries is also an important form of cooperation.

Advanced education in space science must be built on more basic scientific education. International assistance in providing basic textbooks and other educational materials at more elementary levels could contribute to the long-term growth of space science in developing countries. One form of international cooperation that has been receiving more recognition in recent years involves scientists who are originally from developing countries but who are now working in developed countries. These international scientists, familiar with research conditions in both developed and developing countries, represent a resource of great potential.

The so-called "brain drain" from developing to developed countries and the resulting loss of highly skilled human resources from the developing countries is, of course, a serious problem that needs to be addressed. Efforts need to be made to promote awareness in developing countries of the importance of space science and to ensure that space scientists have the basic resources necessary to do their work. While this "brain drain" is a loss to their native country, their scientific work abroad can also serve as a resource for their country. Efforts should be made to maintain and expand their contacts with their professional colleagues in their country of origin. The scientific agencies in both their native and adopted countries, as well as international organizations such as the United Nations, can support this process.

There are a number of international scientific organizations dedicated to promoting the exchange of information between scientists working on space research. The major international organization in this field is the Committee on Space Research or COSPAR. The United Nations will be working with COSPAR and IAF to provide some financial support to scientists from developing countries to enable them to participate in that Congress. Another important international organisation is the International Centre for Theoretical Physics in Trieste, Italy. While the ICTP does not specialize in space science, it does support some theoretical work in the area. The Outer Space Affairs Division is planning to cooperate with the Centre to expand support of space science in developing countries.

ESA has been a generous supporter of the United Nations Programme on Space Applications, through such Workshops as this, through fellowships for study at European space facilities and through special projects. ESA has also had major bilateral projects and programmes with developing countries, including extensive cooperation with India.

One of the main purposes of this meeting is to bring together space scientists from the developing countries of the Asian region to discuss their common problems in doing space research.

Among developing countries in the Asian region, China and India have capabilities for building and launching satellites, while Indonesia and Pakistan have experience in the design and operation of satellites. Countries in the region also have facilities for astronomical observation and data processing. These regional capabilities could provide an important basis for cooperation. The discussion here, both formal and informal, might give rise to ideas for space research projects using these facilities and including participation of other countries in the region.□

Inaugural Address

by

M. G. K. Menon

President

International Council of Scientific Unions

(Extracts)

It was in 1957 that we saw the launching of Sputnik – the advent of space age. Since then we have seen spectacular advances and we can only marvel at what has actually taken place. While the advent of space research itself was unexpected and took the world by surprise, nobody could have, at that point of time, predicted all that was going to happen.

Space has indeed transformed the society. Let me go back very briefly to what has happened in India. Dr Vikram Sarabhai was interested in cosmic rays, particularly its time variations. In those days, prior to the space age, all one could do was to have detectors on ground and, based on the information these provided, to unscramble and try to find out what was happening in space in relation to solar terrestrial phenomena with all the complications of the intervening atmosphere. In 1957, when the Sputnik went into space, we could get rid of this mask of atmosphere over

our eyes in looking into space. And that was essentially the first sense of excitement. So a lot of what was talked about then was science based on space programme. This is where, I believe, lies the importance of basic research in providing leaders, thinkers and visionaries at the frontier. This is what happened when Dr Vikram Sarabhai, while working in cosmic rays, thought of space research to solve what might be then considered relatively small issues. He convinced himself about the space programme for development and great opportunities it presented for the future in terms of telecommunication, broadcasting, remote sensing, etc. And so the thrust of the Indian space programme has gone along these lines.

However, work on space science also moved with what was then available. It moved ahead with programmes using balloons and rockets launched from the Thumba Equatorial Rocket Launching Station. They of course enabled us to do relatively limited things because a rocket spends only limited time in space. But this opened up interesting opportunities to study the equatorial electrojet and the like due to the special geographical location of Thumba.

There have been other developments I would like to mention. The first of the Indian satellites designed, Aryabhata, was essentially a satellite for science and not for applications. Its successors, Bhaskara series and IRS satellites, were meant for space applications. But the ones launched by Indian rockets – the Rohini satellites – are also

Prof. M.G.K. Menon inaugurating the workshop by lighting the lamp.

meant for space science missions. Therefore one has had an interest not just in application areas but also in space science. One of the interesting space science experiments, namely, Anuradha, on cosmic rays was carried out on board the US Space Shuttle by an Indian research group. This experiment was designed to study the cosmic ray phenomenon in outer space and demonstrated what could be achieved by the Indian scientists availing international opportunities.

I think there is no doubt in anybody's mind that science and technology constitute the key to development. One cannot just progress unless one has powerful capabilities in science and technology. That is the only basis for self reliance and for dealing with the challenges we face today. It is also true that you cannot have science and technology in the sense of it being given to you from outside. It cannot be gifted. It has to be evolved and this was the conclusion which was fully spelt out in 1979 at the United Nations conference on science and technology for development.

Sometimes there is a feeling that basic science implies only astronomy, astrophysics, high energy physics, etc. I would like to extend the concept and say that there is an enormous amount of basic work in the areas which relate to geosciences in the broader sense. Today, as a result of experiments such as the Earth's Radiation Budget (ERB), it is possible to do very complex analysis using General Circulation Models (GCM). We need to do this if we wish to understand the earth's atmosphere and climate. We ought to be able to build GCMs. The whole range of international programmes under the ICSU, COSPAR, etc, support basic science very significantly. There are also areas which are not directly in the basic science areas, for example, the World Climate Research Programmes (WCRP), the International Geosphere Biosphere Programme (IGBP), etc. All these programmes are based on joint international cooperative endeavours. It is the whole middle atmosphere with aspects relating to chemistry, aerosol, chemical constituents and the major problem relating to ozone for which one has SAGE-1, SAGE-2 and the SAM-II satellite experiments. The area relating to global climate change calls for continuous data with atmospheric soundings on temperature, moisture, sea surface temperature, snow cover mapping, sea ice cover, vegetation index, albedo, ozone, etc. It involves analysis of enormous amount of data, enormous amount of complex interlinkages and a lot of mathematics now only possible with the computers available.

All planets upto Neptune have now been visited and there is an enormous amount of information relating to these both in terms of fly- bys as well as orbiters. A great deal of our previous perceptions have changed with regard to the distant Venus and its similarity to earth and so on. One has seen the marvelous features of the comet Halley rendezvous. The launch of Space Shuttle Atlantis took place during April this year with the Gamma Ray Observatory (GRO), the 17 ton satellite. The next observatory is the AXAF on X-rays and finally what is being proposed is the Space Infrared Telescope Facility (SIRTF).

The GRO costs 600 million Dollars and the SIRTF will cost 1,300 million Dollars. One can consider, perhaps, one per cent of these costs which nobody will miss, becomes available for carrying out scientific activities in the developing countries because that is the driving force which is necessary. Unless this happens, all of these will only be planned and done essentially in the developed countries by the scientists there.

To mention only a few highlights of results, the Cosmic Background Explorer which is in operation since 1989, has provided spectacular results and so also the Horizon 2000 and the Soviet MIR space station experiments. But all these are essentially on the basis of two features that, apart from the optical window which was explored and which is also heavily blanked by the atmosphere, the other windows that were totally inaccessible have now become available. The infrared, the low energy gamma ray window and the cosmic ray low energy window call for long term observations. And that is now possible with satellites carrying tens of tonnes of payloads and of life time of the order of 5 years and more with massive detectors mounted on them.

But what is the coupling between these new opportunities in space science, or science based on space capability, and the scientists from developing countries? The coupling can only come about if one can have groups in developing countries which are adequately funded and have opportunity to work on challenging problems and not just hear about them. It is not necessary that one should have very large programmes. The Japanese programme, for instance, with regard to space is one of the most exciting. Japan has, over a period of two decades, launched 19 satellites and all these are essentially science oriented rather than application oriented. They have been able to produce remarkable results in X-ray astronomy at a cost of the order of 70 million Dollars each. Now they have X-ray satellites, Solar satellites, Comet Halley missions, Solar terrestrial studies, etc, apart from engineering developments and launchers. Therefore there is a signal or message that on targetted areas it is indeed possible to work out experiments and I hope that countries like Japan, which are on this pathway, will find it possible to involve the developing countries in these exercises.

There are many areas of science which can be done and will be done in developing countries. But I do believe that the developing countries should not be left out of areas which are quite clearly very exciting, which represents some of the deepest problems – astronomy, astrophysics, cosmology – and have been areas which have had always the highest public interest. There again one is concerned with the giant system of enormous cost but all this, in my view, ultimately represent a heritage of humankind. It is for the United Nations or for large regional organisations such as ESA to try to bring together the national structures in which this can truly be made available to all those who are capable in terms of intellectual abilities to use it and to benefit from it. ICSU is meant for bringing scientists together but not the governments. The forum where governments come together is the United Nations. The fact that this particular meeting is sponsored by the UN as well as ESA, would enable some progress in that direction. □

Keynote Address

Importance of Basic Science for Developing Countries

by

U. R. Rao
Chairman, Space Commission
Government of India

(Extracts)

Importance of Basic Space Science Research

Since the launching of the first sputnik in 1957, the remarkable discoveries made have resulted in a quantum jump in our understanding of interplanetary space, planetary astronomy, astrophysics and our own planet earth. The phenomenal developments that have been witnessed in terms of application of space technology to the development of planet earth and its environment are a vivid demonstration of the human intellect and the tremendous progress that has been made in the field of space sciences.

Going into space provides three important possibilities–a vantage point in space for making observations in the entire length and breadth of electromagnetic spectrum; ability to use space technology for real development of all nations by looking at the environment, natural resources, meteorology and through space communications and the gamut of applications which have become so vital to development;

and availability of the space environment itself to carry out extremely important experiments particulary in the field of microgravity, space biology where space is essentially free from the gravity induced convection. More than anything else, space for the first time has provided a new vision of our planet – a global village cutting across all artificial boundaries.

In less than 40years, the outcome of space research has far exceeded the initial expectations. From lunar landing, planetary missions, operational communication satellites to orbiting space stations, it has been like a tapestry of dreams-come-true for Lucian, Johannes Keppler, Francis Godwin, Cyrano de Bergerac, Jules Verne, Arthur C. Clarke and many other visionaries. In Clarke's words "Our civilisation is no more than the sum of all the dreams that earlier ages have brought to fulfillment. And so it must always be, for if men cease to dream, if they turn their backs upon the universe, the story of our race will end". Imaginative thought process which forms the essence of science is fuelled by such dreams.

The rapid development of sophisticated technologies for meeting the requirements of space research was the first step which led to the utilisation of same technologies for earth directed exploration and space applications in the areas of communication, meteorology and management of natural resources. This again emphasises the paramount need for supporting and nurturing basic research which undoubtedly has to provide the lead even for later development of application programmes of relevance to each nation without which a self-reliant national base of scientists cannot be developed.

For the first time since the space age bagan, we have realised that the intervening space between the sun and the earth is not a mere vacuum but full of plasma; the solar wind continuously pouring out of the sun with a velocity of 400-600 km per sec. It is the interplay of the radially flowing solar wind with the electromagnetic field in the interplanetary space that is responsible for a variety of phenomena seen on the earth such as aurorae, magnetic storms, ionospheric storms, etc. resulting in communication black-outs. Eventhough the connection between the solar flare occurrence and the fluctuations in earth's magnetic field and earth currents were suspected by Carrington as early as 1859, even an eminent scientist like Lord Kelvin ridiculed the entire idea in 1885. By 1930, thanks to the work of Chapman, Ferraro and Alfven, the connection between solar activity and terrestrial phenomena was put on firmer basis and the concept of ring current in the upper atmosphere was understood. Likewise the significant work of Bierman and Lust on the acceleration of comet tails provided the first evidence of solar wind which was put on a theoretical background by Parker. The evidence of solar wind, resulting from outward and radical coronal expansion (exceeding Alfven velocity) combined with the rotation of sun, stretching the inter-planetary field in the form of Archimedean spiral came from extensive space observations.

Solar System Studies and Space Plasma Physics

The remarkable achievements that have taken place since then have shown, for example, the structure of the magnetosphere, the magnetopause, the magneto-tail (>150 earth radii) and the heliopause (well beyond 150 sun-earth distance) and the importance of magnetic reconnection through which particles can come into the vicinity of the earth. Notwithstanding, there are a number of problems we still have to understand, such as how the magnetic energy is converted – whether it is on the sun, on the interplanetary plasma or in the magneto-tail. How is the magnetic-energy converted into particle energy? How do the particles get accelerated in the shock fronts? While it is clear that when two opposite magnetic polarities collide, magnetic lines merge and produce the energy, it is not clear how this energy gets really transferred.

Although the motion of the charged particles in the electromagnetic fields was known, the discovery of the Van Allen belts could only be accomplished by space probes. Today we have a far better understanding of the planetary surfaces, their atmosphere, the runaway green house effect on the atmosphere, moons and rings around Jupiter and Saturn. But we have to clearly understand how the runaway greenhouse effect on Venus occurs. The question we can ask in reverse is whether such a runaway greenhouse effect can occur on the earth's atmosphere as the carbondioxide goes on increasing. The movement of the atmospheres, the channel like features of the Martian surface, the atmosphere of Titan which consists of nitrogen and methane and the possibility of aerosols precipitation building upto tens of thousand of tons of tar on Titan, the magnificient ringlets around the Saturn are but a few of the panoramic views that have been exposed to. The awe inspiring discoveries in astrophysics which include X-ray and gamma-ray astronomy, pulsars, quasars, neutron stars and black holes have virtually revolutionised the field of astronomy.

Space Applications Through Satellite Commnications and Remote Sensing of Earth's Resources

Space technology for the first

time, has provided the possibility of interconnecting the entire planet with satellite communication. Many new innovations such as use of small terminals, emergency communication, mobile communications, rural telegraph, sound broadcasting and TV have become a reality because of satellite communications. The world is moving steadily towards personalised communication, utilising the enormous capability of satellites in different bands of the electromagnetic spectrum which have now become available.

In the field of remote sensing and meteorology, we have gained a better understanding of meteorological phenomena because of the availability of global imagery from space which are crucial to understand the cloud movements, cloud physics and weather circulations. Microwave remote sensing with its all weather capability, to be achieved with the launching of European Remote Sensing satellite (ERS), could be another milestone in the dictionary of remote sensing terminology soon. These microwave remote sensing satellites, including the follow on satellites such as RADAR-SATand SEASAT, have the capability to provide valuable information on ocean dynamics, ocean atmosphere, boundary layer phenomena and ocean temperature distribution. Ocean temperature distribution has already been successfully used all over the world as also in India for locating fish schools. Sustainable development of land can come only by appropriate utilisation of satellite remote sensing imageries, backed up by aerial imageries and ground truth where necessary, to provide advance and detailed information on drought, vegetation index, forestry, land and water resources and the environment. Combining the vital data inputs from space with meteorological information and conventional statistics of socio-economic importance have been used extensively to evolve integrated development strategies at micro levels.

Space Research in India

India, fortunately, had an excellent heritage in the field of space research from the very beginning, through successful experimentation using ground based ballon and rocket based techniques. The pioneering research on upper atmosphere by Prof.S.K. Mitra, the development of nuclear field by Dr. H.J. Bhabha and the utilisation of cosmic ray variations for understanding the electromagnetic state of the interplanetary space by Dr. Vikram Sarabhai and his co-workers formed the foundation for the development of space research in India. The discovery of diurnal, semi-diural and 27 day variations in the cosmic ray intensity, measured on the ground and through the asymptotic cones of acceptance, connecting these through variations of galactic cosmic rays with interplanetary field structure by Dr. Sarabhai and his colleagues including the present author, and the cosmic ray experiments carried out by Prof. Menon and his colleagues established the need for developing a sounding rocket station at Thiruvananthapuram, near the geomagnetic equator.

The Space Programme in India started almost three decades ago through the establishment of the Thumba Equatorial Rocket Launching Station (TERLS), later dedicated to United Nations, for carrying out the investigations of the upper atmosphere of the astrophysics. Soon it was clear that space held a tremendous promise for providing practical benefits to the nation. After carrying out a number of experiments and gaining expertise using satellites provided by other nations like ATS-6 of NASA, the Symphonie of the Franco German Consortium, etc. India embarked on an ambitious programme of developing its own capability in satellite technology for applications in remote sensing and communications and rocket technology for launching its own satellites.

Today, India has successfully launched 13 satellites starting with Aryabhata in 1975 and culminating in the state-of-the-art Indian Remote Sensing Satellite (IRS) series and multipurpose geostationary INSAT series of satellites for communications, TV broadcast and meteorology. The second remote sensing satellite, IRS-1B, is going through its final tests and it is expected to be launched by the end of August this year. The first of the second generation multipurpose satellite INSAT-2A, is scheduled for launch during the beginning of next year. While INSAT satellites have virtually revolutionised communication and TV broadcast in India enabling more than 75 percent of the country's population to have access to educational and entertainment programmes, innovative uses of meteorological imagery combined with communication capabilities have enabled the country to have an effective locale specific disaster warning system which has been responsible for saving thousands of people during cyclone/flood conditions. The application of IRS series of satellites for carrying out remote sensing from space and use these imageries for providing vital inputs of relevance to forestry, realtime monitoring of floods, advance forecast and monitoring of drought, management of ground and surface water resources, delineation of wasteland, agro-climatic regioning etc.,has led to the evolution of integrated development strategies at micro level leading to overall development of the nation.

International Cooperation in Space Research

No country can prosper unless it builds a self-reliant team in science and technology and cease using imported technology as a black box. With the increasing awareness of the global connecting of weather phenomena and its effect on environment, sustainable development cannot be realised unless we understand the physical phenomena affecting the geosphere-biosphere activities as well as the effect of human intervention on the natural eco-systems. Understanding of the forcing functions which are responsible for the geosphere-biosphere interactions, development of geo-physical models and their sensitivity tests and validation of models using observational data involve substantial amount of the basic research.

While every developing country may not be able to afford a space programme of its own, even small countries cannot only carry out ground-based experiments of relevance but also utilise the data from the international space systems for application to solve their specific problems. It is in the interest of developed nations to encourage such activities considering the global nature of weather and climate. I hope that UN-COPUOS will be able to influence the developed countries to set apart a small percentage of their GNP for assuring international cooperation in the area of space. The assistance could be directly in terms of funding or through providing opportunities to the

India's Contribution to the UN-COPUOS

As a member of the United Nations Committee on Peaceful Uses of Outer Space (COPUOS) since its inception India has been playing a key role in the evolution and execution of activities of this important Committee. With its vast experience in the development of space technology and applications, India has been contributing significantly to the promotion of international cooperation in the field of outer space. The Thumba Equatorial Rocket Launching Station (TERLS) near Thiruvananthapuram was dedicated to the United Nations as an international sounding rocket range way back in 1968.

India has initiated a programme called Sharing of Experience in Space (SHARES) during UNISPACE-82 conference under which persons from several developing countries have been receiving training in space applications in India. Indian experts have contributed actively to the studies undertaken by COPUOS on important matters related to space science, technology and its applications.

India organised a UN Workshop on Space Applications during 1985 at Space Applications Centre, Ahmedabad.

scientists from developing nations to participate in international observations. In this context I may quote from a major recommendation of UNISPACE-82 — " Space technology offers the potential to spur economic and social development of all countries. It is by no means the complete solution to the country's problems. Neither can there be any generalised prescription for the use of space technology. However, it is often a more effective alternative for achieving the given goal and can sometimes bring about a qualitative change by doing things not possible through more conventional means. In this connection international cooperation should be seen and conceived as a major instrument in assisting all the countries, especially developing countries, to derive the optimum benefit from the application of space technology. However the future of each country, should rest primarily upon itself".

Unfortunately action in forging effective international cooperation is very slow. In this age of space, continuing droughts and hardships in many parts of the world such as Ethiopia, Mozambique and parts of Asia and Latin America are unpardonable. Surely, there is no greater crime to humanity than allowing recurrence of drought year after year and it is surprising to note most of the nations in South Africa have no satellite ground stations for receiving data and no access to the space remote sensing imageries.

I hope that the UN - COPUOS, International Astronautical Federation (IAF) and Committee on Space Research (COSPAR) will act as catalysts in enabling all nations to benefit from the unlimited potential of space research. Since last four years, IAF has been conducting special current event sessions on topics of relevance to developing countries. These sessions, which are supported by IAF and UN-COPUOS, have focussed on the disaster management, drought management, flood management and forest management at micro and macro-level. The next IAF will focus on the agricultural management aspects as related to the developing nations. Such efforts must not only be encouraged but also sufficiently increased to enable scientists from many developing countries to participate in these fora where they can interact with other scientists and translate what they learn into practice.

The development of space industry is another area where there are many developing countries today with some capabilities but they must be allowed to compete. Truly, China has tremendous amount of space capability. India has built up a modest capability. Brazil has built up a capability. Pakistan and Indonesia have been building small parts of the ground station systems and have their own communication satellites. Many of these developing countries need low cost equipment. To this effect there was a major recommendation made in the UNISPACE-82 that UN must have an inventory of such equipment and should provide information services so that high pressure salesmanship does not push very costly equipment which are often not required by the developing countries. We have been requesting the UN to consider the possibility of providing such services under its aegis to make sure that unbiased opinion is provided.

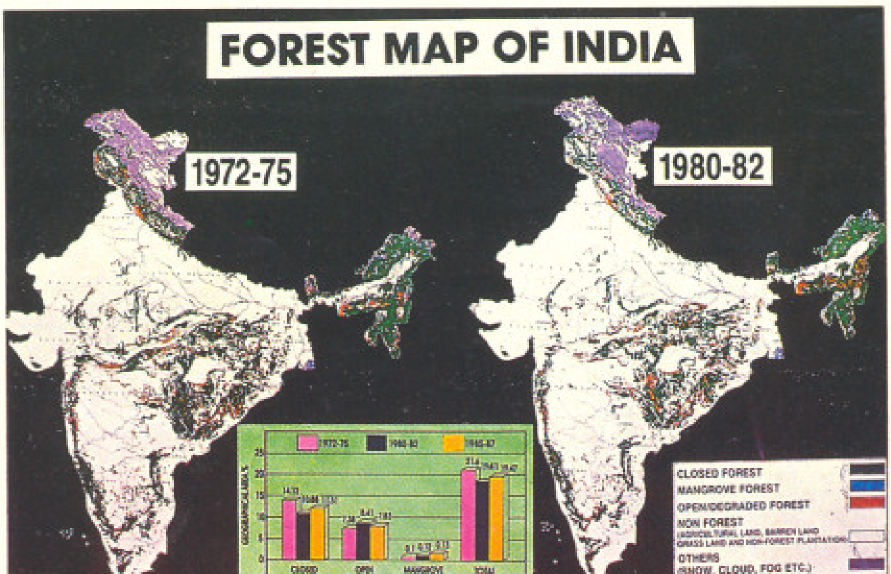
India, on its own initiative, has proposed a programme called the PEACE (Protection of the Environment for Achieving a Cleaner Earth) involving international series of satellites for environment in which both developed and developing countries can participate. The proposed satellite would be built and launched under international collaboration with payloads contributed by many countries including developing ones. Even a very poor developing country can put up a simple yagi antenna and start receiving the data of relevance to them. India is assisting Mauritius for setting up a remote sensing centre which can become a centre of activity for Mauritius to solve their specific problems. Since irrespective of the nature and identity of the polluter the global environment as a whole gets affected, a programme like PEACE would be ideal for encouraging all nations to take timely corrective action to achieve sustainable development.

Conclusion

I want to end my address with a quotation of Dr. Vikram Sarabhai, the founder of space programme in this country, which is applicable to all developing countries in the world

- "We do not have the fantasy of competing with economically advanced nations in the explorations of the moon, or the planets, or manned space flight. To us there is no ambiguity of purpose. We are convinced that if we are to play a meaningful role nationally and in the community of nations we must be second to none in the application of advanced technology to the real problems of man and society".☐

Satellite Data for Forest Management



Sustainable development of the world to meet the demands of growing population without affecting the global climatic and ecological balance needs immediate attention towards monitoring and management of our natural forests. While there is considerable debate on the accuracy of quantitative prediction of global warming due to increase in the concentration of carbon dioxide and other 'greenhouse' gases, it is certain that fossil fuel burning and deforestation result in the global increase of carbon dioxide emission, decrease of photosynthesis, land erosion and increase in carbon sediments. These have long term effects on global temperature, and land degradation besides leading to a possible irreversible modification of climate and ecology.

Over the last 50 years, the global forest has depleted by about 50 per cent. The present estimated forest area of about 4,100 million hactares (m ha), comprising 2,850 m ha, of closed and 1,250 m ha of open forest, is being depleted at the rate of 0.6 per cent per year.

The depletion is more severe in the developing countries with large population density, which have hardly 2,200 m ha of forest (1,350 m ha closed and 850 m ha open) providing less than 0.6 ha per capita as against 1.35 ha per capita in developed countries.

Deforestation, being primarily due to exploitation by man, is intimately connected with the population density. Consequently the pressure on forests is greatest in the developing countries which account for over three quarters of the global population. In addition to the use of forest products for firewood, timber, paper and other industrial purposes, conversion of forest land for agriculture and construction, a major cause of deforestation, particularly in the developing world, is shifting cultivation or 'Jhumming' which is extensively practised in Africa and Asia. Jhumming involves rotation of fields instead of crops in which relatively short periods of continuous cultivation are followed by long periods of fallows. Annual deforestation in Asia itself, where Jhumming is practised by over 30 million people, is about 1.8 m ha. In India, shifting cultivation accounts for about 0.5 m ha of deforestation annually.

Space remote sensing has provided a quantitative means for monitoring the growth and degradation of natural forest, effects of deforestation on soil, watersheds, underground water recharging and green-house gases. It is possible to monitor periodically the extent and type of forest and to provide information on soil classification and soil degradation characteristics, the latter being of great significance for watershed management.

Deforestation, diseases, fire and land degradation are the major issues in the forest management. Satellite remote sensing can directly indicate the severity of deforestation. Also it has proved to be useful for site and species identification for afforestation, disease control and real time identification of active fires and nearby waterbodies for fire extinction.

This technique can also help in the assessment of vulnerability to fire which depends upon forest types, climate, etc. Soil erosion, landslides and avalanches are the main forest degradation processes and satellite remote sensing can provide important clues for these; besides it can contribute to the development of models for understanding functional aspects of various natural cycles and processes in the ecosystems and wildlife habitats. Models

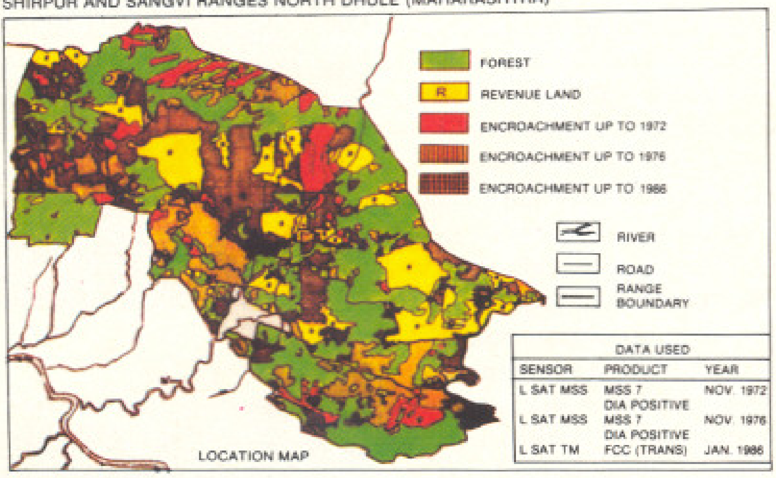
Jhumlands

Soil errosion due to deforestation

Satellite Data for Forest Encroachment Detection

Some time ago, when the Forest Department of Maharashtra Government wanted to evict illegal encroachers of forest land in the North Dhule forests, the encroachers filed a writ petition in the Bombay High Court to restrain the Department from evicting them. But the High Court passed orders in favour of the Forest Department and further refused to grant any relief to the petitioners. The interesting part of the case, however, is that the judgement was based on authentic information on encroachment derived from satellite data.

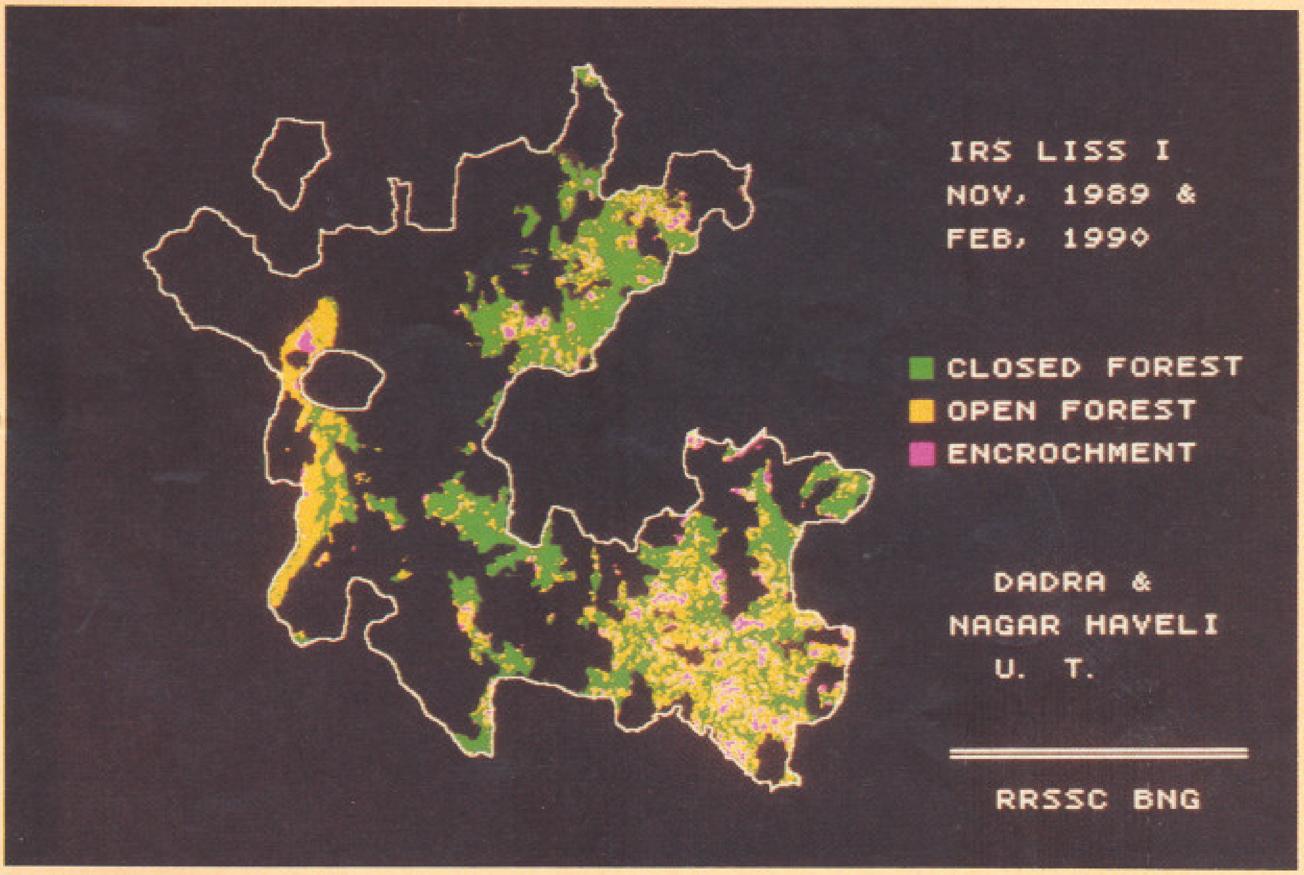
ENCROACHMENT SPREAD
SHIRPUR AND SANGVI RANGES NORTH DHULE (MAHARASHTRA)



The encroachment area maps prepared using satellite data for the years 1972, 1976 and 1986 in the forest ranges of Shirpur and Sangvi provided sufficient evidence to convince the High Court that the forest land had not only been encroached upon but also immense damage had been caused by the encroachers.

The forest lands are generally encroached upon by people living in the vicinity of forests and forest dwellers/tribals who prefer for cultivation more fertile forest land to other unoccupied government lands.

As per a Forest Survey of India study conducted in 1987, seven lakh hectares of forest land are under encroachment. Many states and union territories have officially diverted as much as 2.6 million hactares (m ha) of forest land to agriculture during the period between 1951 and 1980. In addition, large areas of



unoccupied non- forest government lands have been allocated for agriculture. Yet, attempts to encroach government forest land for cultivation continue. Before the enforcement of Forest Conservation Act in 1980, states like Madhya Pradesh, Maharashtra, Karnataka and Gujarat used to regularise periodically the unauthorised occupation of forest lands for cultivation.

Multi-date satellite imagery provide reliable and unbiased means to locate any encroachment of forest area. The method involves preparing forest cover maps for any base year, transferring the maps on to the Survey of India topo sheets to ensure correct geo-registration and then comparing subsequent date satellite data with the base data to decipher the changes occurring between the two dates. Using digital change detection methods, forest encroachments can be successfully identified. Even if the encroached lands are used for cultivation, it is possible to identify the encroachment by properly classifying the landuse categories using the satellite data for two seasons Kharif and Rabi.

It was through following such methodology that encroachment area maps were prepared using satellite data for the years 1972, 1976 and 1986 in the forest ranges of Shirpur and Sangvi. These were produced as evidence for sorting out the writ petitions in the Bombay High Court.

In another case-study in Dadra and Nagar Haveli union territory the encroachment areas have been identified using Indian Remote Sensing Satellite (IRS-1A) data. An area of 1,247 ha has been found to be encroached upon in this union territory.

Teak Plantation in Uttar Kannada, Karnataka.

for assessing the impact of the state of forest on the adjoining ecosystems can also be developed.

Even for sustaining the available forest wealth, the total biomass requirement for fire wood, timber, paper pulp, etc, have to be carefully evaluated and balanced against the available fire wood/forest produce. Any sustainable development strategy must not only ensure adequate afforestation to make up the shortfall to avoid further deforestation but also lead to eventual increase in the forest wealth.

Since operationalisation of satellite remote sensing for resources survey was taken up in India during late seventies, a major application has been forest resource survey. With a multispectral data analysis system set up at National Remote Sensing Agency (NRSA), Hyderabad, US EROS data is being used for forest resource survey on an operational scale. The analysis involves identification and delineation of forest cover types and development of techniques to extract quantitative information for forest resource protection and conservation. US Landsat data have been analysed to prepare forest resource maps for the states of Nagaland, Tripura, Arunachal Pradesh, Mizoram, Meghalaya and Assam. Major forest types like evergreen, semi-evergreen, moist deciduous, dry deciduous or broad leaved and coniferous, shrub, grassland, etc, and some specific types like shorea, bamboo, oak diperocarpus, messua ferria, pine, etc, have been identified and delineated on these maps. In addition, areas affected by shifting cultivation prevalent in the region have been demarcated.

The study has also been extended to other parts of the country. The survey carried out for Andhra Pradesh and part of Uttar Pradesh has revealed that further categorisation of dry deciduous forest could be done to delineate tree associations dominated by certain species. Forests have been categorised in terms of relative amount of teak, areas having understorey bamboo and very specific types of forest of economic value like 'Red Sanders'.

The Landsat imagery covering the entire country for periods 1972-75 and 1980-82 have been visually interpreted to delineate closed, open and dense forests and a map on 1:10,00,000 scale prepared. The whole exercise could be completed in just three months. The maps indicate that closed forests in the country dwindled from about 14 per cent to 11 per cent of the total geographical area of the country during this period.

Information gathered through remote sensing has been used for various socio-economic studies, namely, the relationship of forest to the problems of agro-ecosystem in central Himalaya, impact of multipurpose river valley project at Idukki in Kerala on forest and environment, etc.

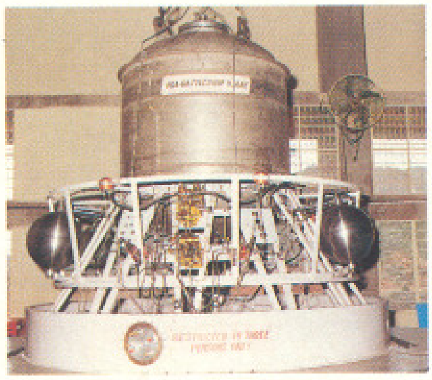
Satellite remote sensing has been used to study the impact of mining and other development projects on forests. Degradation of forest cover of Doon Valley (Uttar Pradesh) due to mining activities has been studied using aerial photographs and Landsat data.

The Landsat imageries of seven National Parks and fifteen Wildlife Sanctuaries in eastern Madhya Pradesh have been studied to bring out changes in course of time. Identification of tall grasses, short grasses, swamp grasses, marshy land and surface water bodies in Kaziranga National Park; seasonal vegetation changes in Keoladeo National Park, Bharatpur; occurrence and spread of forest fire in Bandipur-Mudumalai sanctuary belt; are some of the other projects carried out.

Thus satellite data has been playing a major role in effective management of one of our most important natural resources, the forest. The availability of data from the Indian Remote Sensing (IRS) series of satellites on a continuous basis will help the country to effectively manage its forest wealth and environment. □

PSLV Fourth Stage Liquid Propellant Motor

The Polar Satellite Launch Vehicle (PSLV) of ISRO, intended to launch the IRS class of satellites into 900 km sun synchronous orbit, uses a liquid propulsion fourth stage known as PS-4. The stage has successfully undergone a series of ground tests at component, subsystem and system level at the Liquid Propulsion Test Facilities, Mahendragiri in Tamil Nadu. A full fledged test on the flight version (except for the nozzle which was of sea level version) was conducted in February 1991. The tests were conducted both for short duration (60 sec) and long duration (more than 400 sec) incorporating the two-plane engine gimballing system and the reaction control system. Simulated high altitude test of the stage is expected to be conducted shortly.



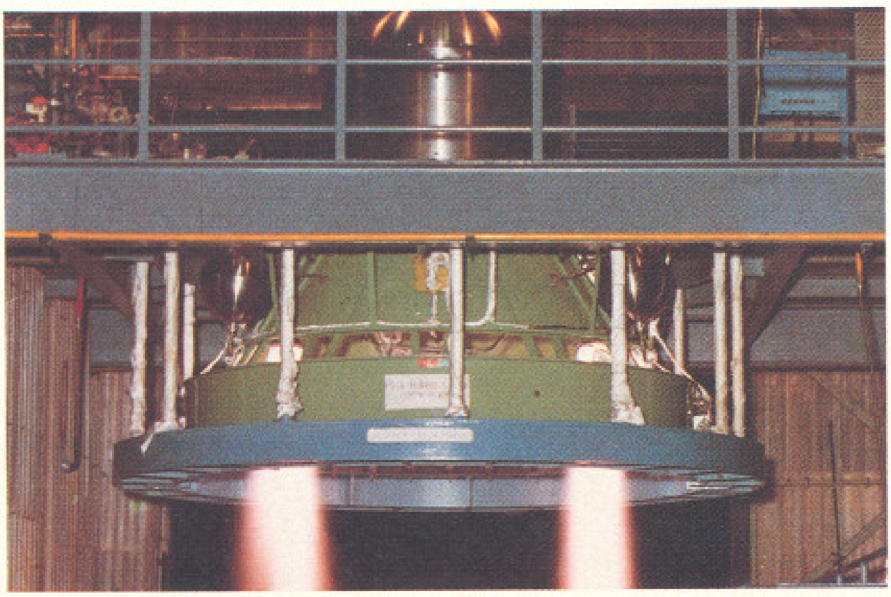
PS-4 Battleship stage

PS-4 has the following three major systems:

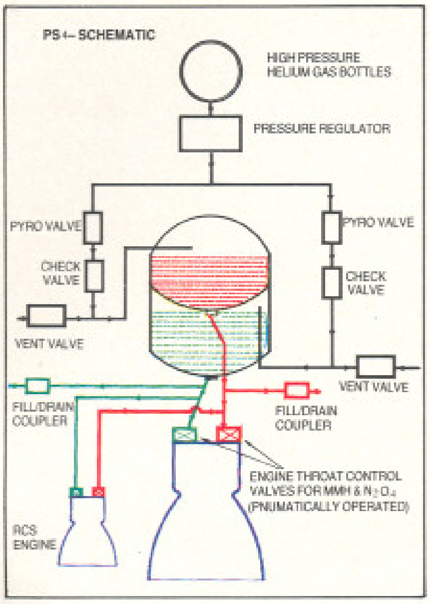
- the propulsion system consisting of two liquid propellant engines,
- the stage system consisting of propellant tankages, pressurisation system, command system, fill and drain valves, propellant acquisition system and umbilical systems and
- the control system including engine gimballing and reaction control system.

The propulsion system comprises two liquid propellant engines each of 7 kN thrust. The oxidiser MON-3 (a mixture of 3 per cent nitric oxide and 97 per cent nitrogen tetroxide) and fuel MMH (mono methyl hydrazine) are stored in separate tanks and fed through independent feedlines into a combustion chamber to burn under specified pressures.

The pressurant used is helium

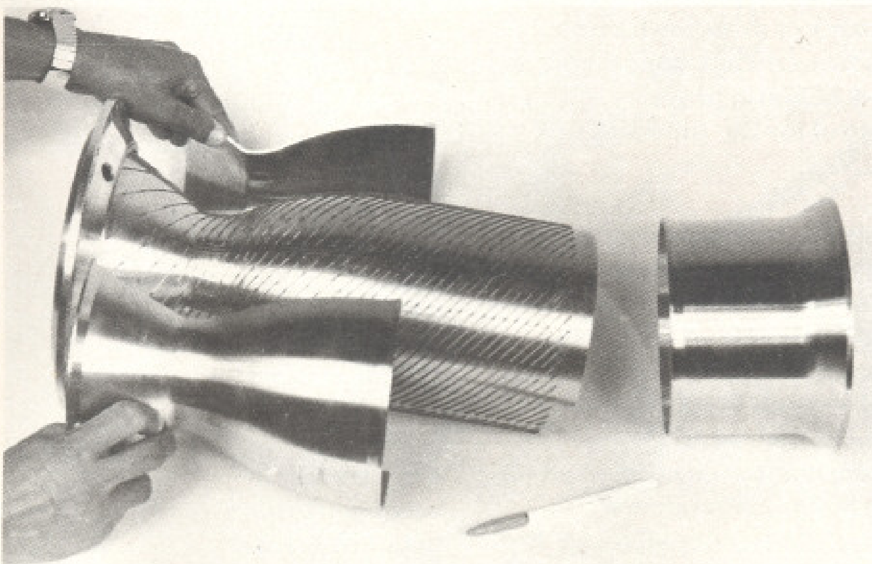


PS-4 Stage test

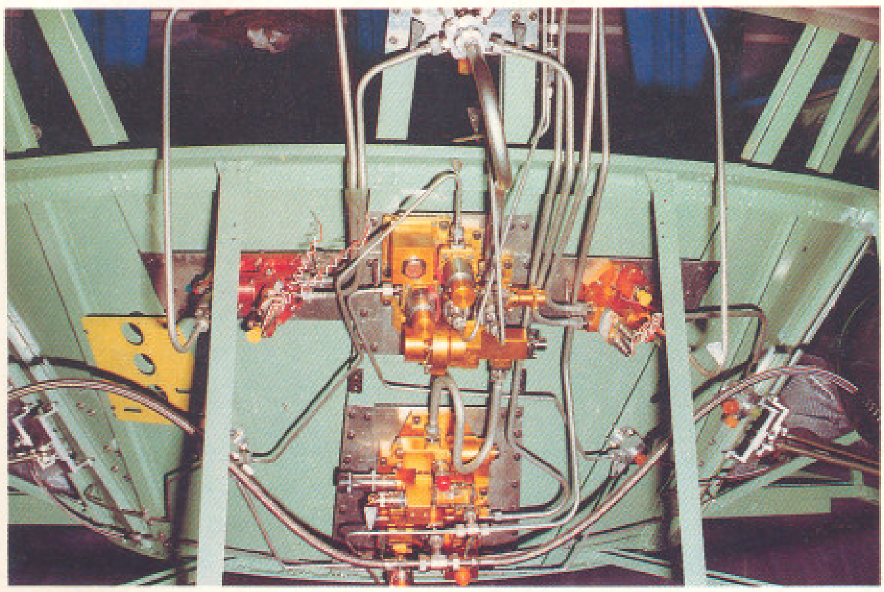


gas, stored at about 300 atmospheres in gas bottles made of titanium alloy. The valves and regulators between the helium pressure head and the propellant tanks ensure regulation and control of pressure. The propellants enter the combustion chamber of the engine only after the thrust control valves are commanded to open.

With a nozzle expansion ratio of 60 and a chamber pressure of 8 ksc, the PS-4 engines deliver a total thrust of 15 kN. The main components of the engine include about four dozens of triplet injector elements for injecting two oxidizer jets on to one fuel jet, a double-walled regenerative cooling system which uses the fuel itself to cool the combustion chamber and part of the nozzle divergent, and silicide coated nozzle divergent made of columbium alloy.



View of Regenaratively cooled engine chamber.



PS-4 Fluid components in four modules with interconnecting tubes.

The fuel (MMH) and oxidiser (MON-3) are stored in two cylindrical tanks with ellipsoidal end-domes and are arranged in tandem with a common bulk head separating them. The use of titanium alloy for its construction and common bulk head design has reduced the mass of the stage considerably.

The pressurisation system comprises four spherical pressure bottles of titanium alloy in which helium at high pressure is stored.

The command system, for 'start' and 'stop' operations of the liquid engines is designed to provide upto three firings of the engine. This multiple start/stop capability is useful for manipulating the flight trajectory to achieve the desired precision in satellite injection.

The fill and drain valves enables filling (and, if needed, draining) of propellant during launch preparation.

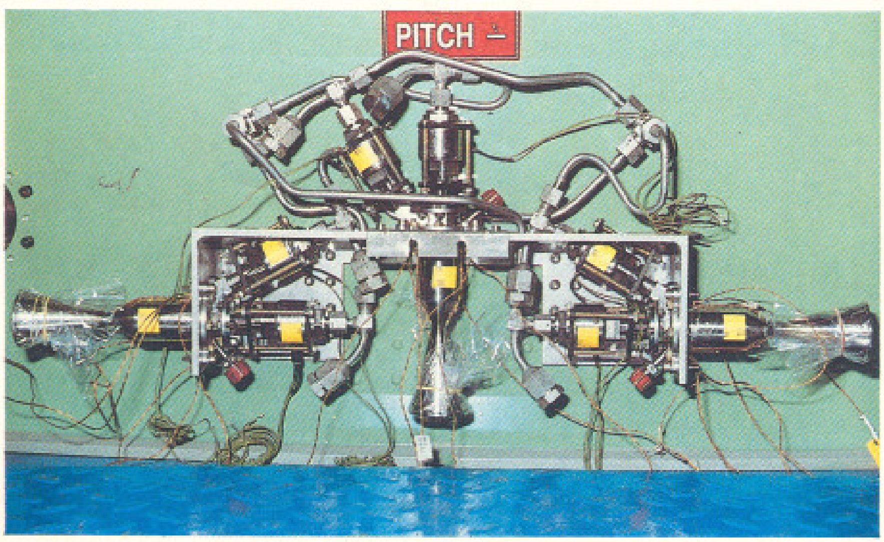
The engine operation can be terminated by commanding the thrust control valves to 'close' when propellant flow ceases. This is immediately followed by 'opening' of purge valves for the helium gas under pressure to purge out propellant both from the injector manifolds and from the double-walled jackets used for regenerative cooling. This avoids free burning of propellant and migration of propellant from one mainfold to another.

A surface tension propellant acquisition system is incorporated in the tank to prevent helium pressurant gas getting mixed with the liquid propellant during the coasting phase of the PSLV flight. It consists of a number of layers of fine mesh stacked one above the other. The acquisition system ensures that a certain minimum quantity of gas free propellant is always available for the engine to operate.

The PS-4 stage control system includes thrust phase control system and coast phase control system. The former is provided by the engine gimbal control system and the latter by reaction control system. The control is achieved by vectoring the engines in two mutually perpendicular planes (two-plane gimballing) by means of four electromechanical actuators. The engines are attached to the thrust- frame through a two-plane gimbal bearing which allows the engines to deflect in the desired direction. The reaction control system provides the control when the PSLV is in coast phase. It consists of two clusters of thrusters mounted on diametrically opposite sides. PS-4 RCS also provides roll control for the third stage of PSLV.

PS-4 Engine with Columbium nozzle extension

Over the years, the engine and the stage have undergone a series of ground tests. A single engine was tested for a cumulative burn time of nearly 900 seconds in six independent tests. A simulated altitude performance test conducted on the integrated engine with nozzle divergent extension, for short duration has given a specific impulse of about 306 sec.



PS-4, RCS thrusters modules for Pitch, Yow & Roll control.

SALIENT FEATURES

Configuration	Twin Engine with multistart capability
Thrust	7kN (Vacuum)
Weight at lift off	2565 kg
Propellant (MMH + N204)	2050 kg
Specific Impulse	305 sec. (Vac)
Burn time	400 sec.
Control	Engine Gimballing

The stage battleship version has been successfully tested for a cumulative duration of 1090 seconds. The battleship version differs from the flight version mainly in regard to tankage and skirt structures. In the flight version these structures are made of titanium and aluminium alloys which are lighter.

Liqid Propulsion System Centre is the lead centre of ISRO for liquid propulsion and is responsible for the development of PS-4 engine and all the stage systems including the reaction control systems. Vikram Sarabhai Space Centre has developed the engine gimbal control system. Hindustan Aeronautics Limited (HAL), Bangalore and Gas Turbine Research Establishment (GTRE), Bangalore undertook critical fabrication jobs. Many private industries have contributed to the development of the stage.

The development of completely indigenous PS-4 is a significant milestone achieved by ISRO in the area of Liquid Propulsion Technology. □

STOP PRESS

The second operational Remote Sensing Satellite, IRS-1B, was air-lifted to Baikonur Cosmodrome, USSR on July 18, 1991. The satellite is scheduled for launch on board the Vostok rocket on August 29, 1991.

PS-4 undergoing test.