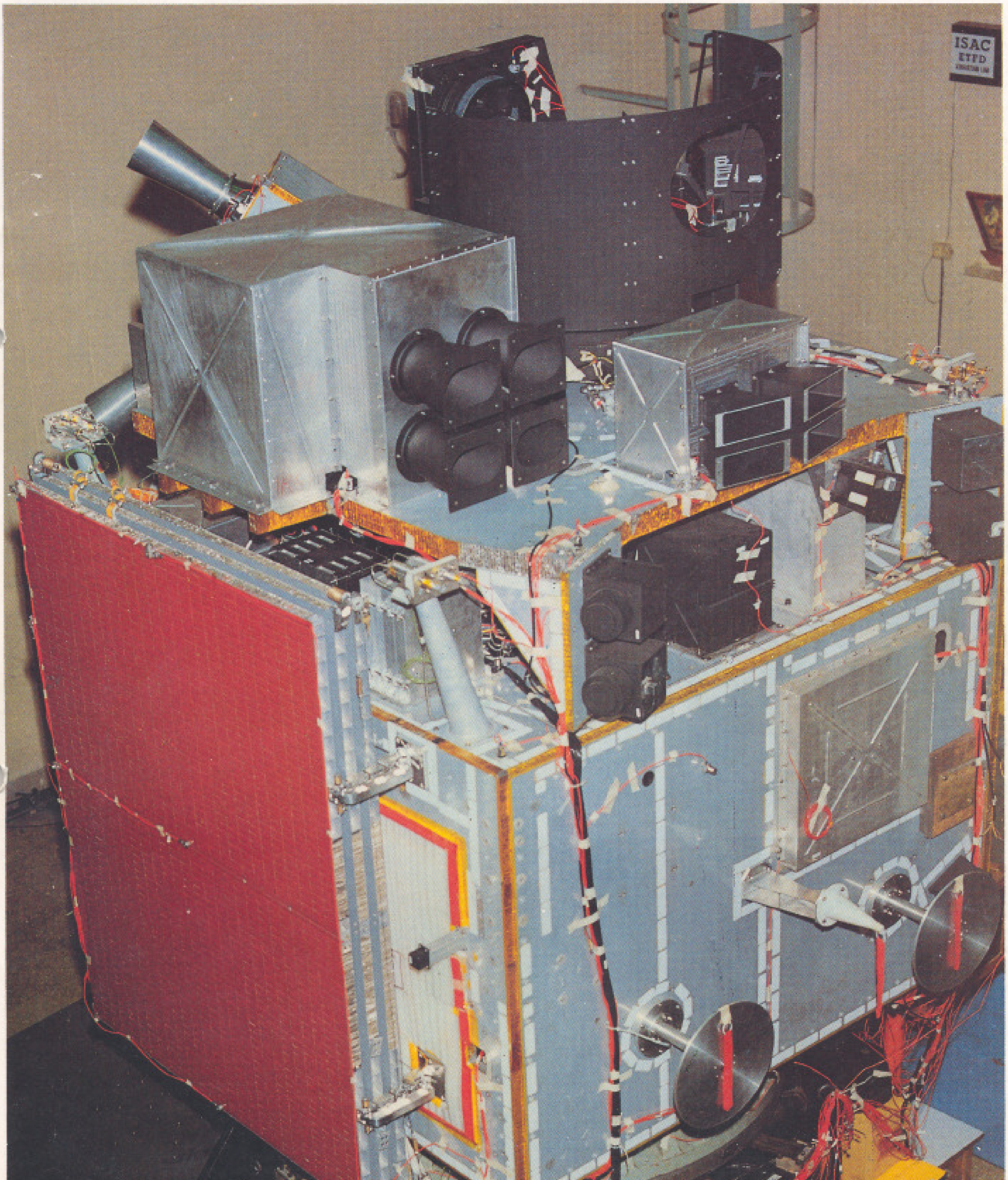
OCT '93 — MAR' 94

SPACE india



INDIAN SPACE RESEARCH ORGANISATION

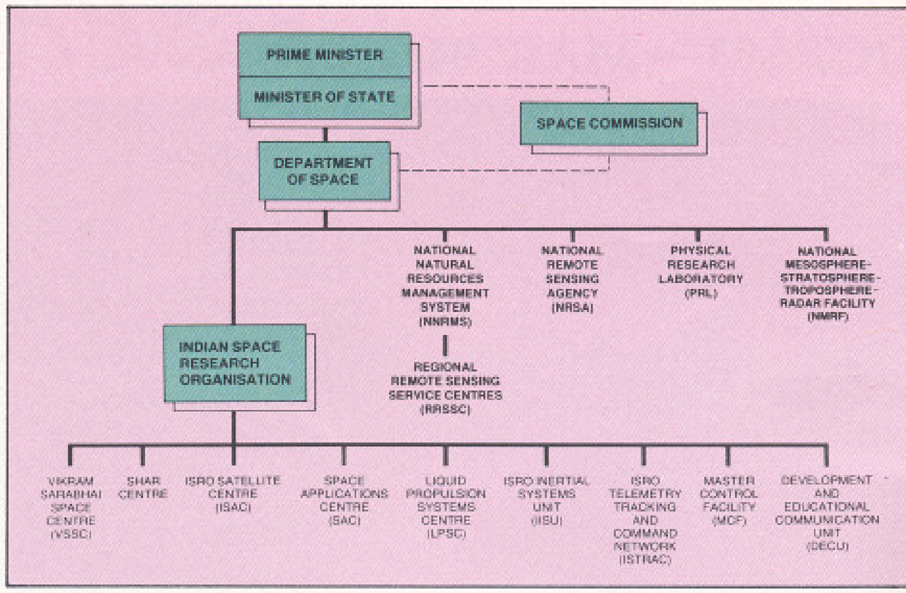
The Indian Space Programme

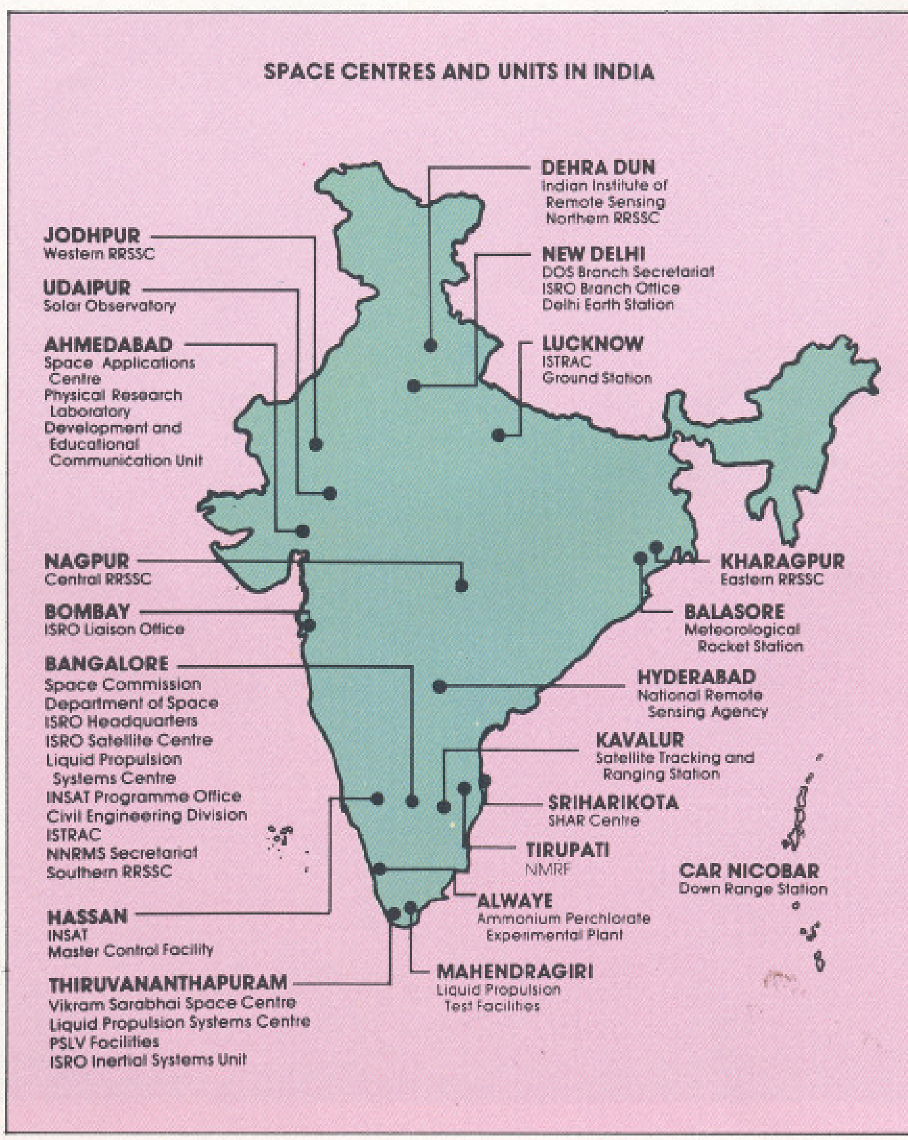
The setting up of the Thumba Equatorial Rocket Launching Station (TERLS) in 1963 marked the beginning of the Indian Space Programme. The Space Commission and the Department of Space (DOS) were established by the Government of India in 1972 to promote unified development and application of space science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

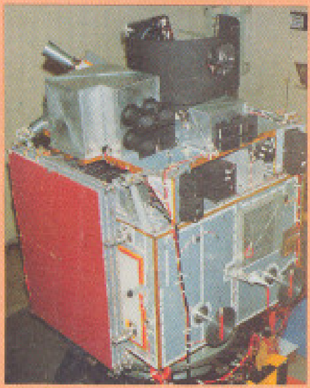
The Indian Space Programme is directed towards the goal of self-reliant use of space technology for national development, its main thrusts being: (a) satellite communications for various applications, (b) satellite remote sensing for resources survey and management, environmental monitoring and meteorological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







FRONT COVER

Structural, Thermal, Engineering Model (STEM) of IRS-1C undergoing vibration test at ISRO Satellite Centre, Bangalore.

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Oct '93 – March '94

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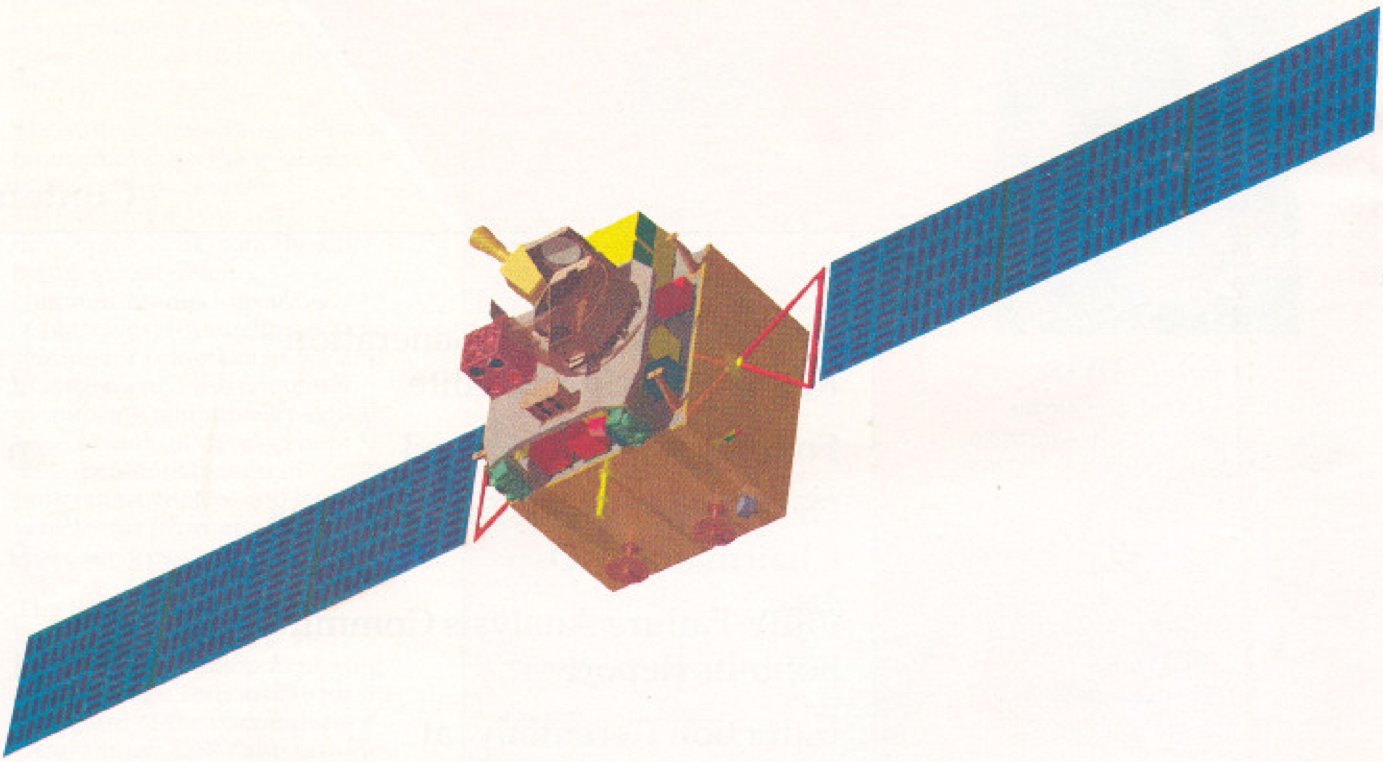
IRS- 1C
–The Second Generation Remote Sensing Satellite



The Indian remote sensing satellites, IRS-1A and IRS-1B, have become the mainstay of the National Natural Resources Management System. The data from IRS find applications in agricultural crop acreage and yield estimation, drought monitoring and assessment, flood mapping, ground water targeting, landuse and land cover mapping, wasteland management, urban planning, mineral prospecting, forest resources survey and management.

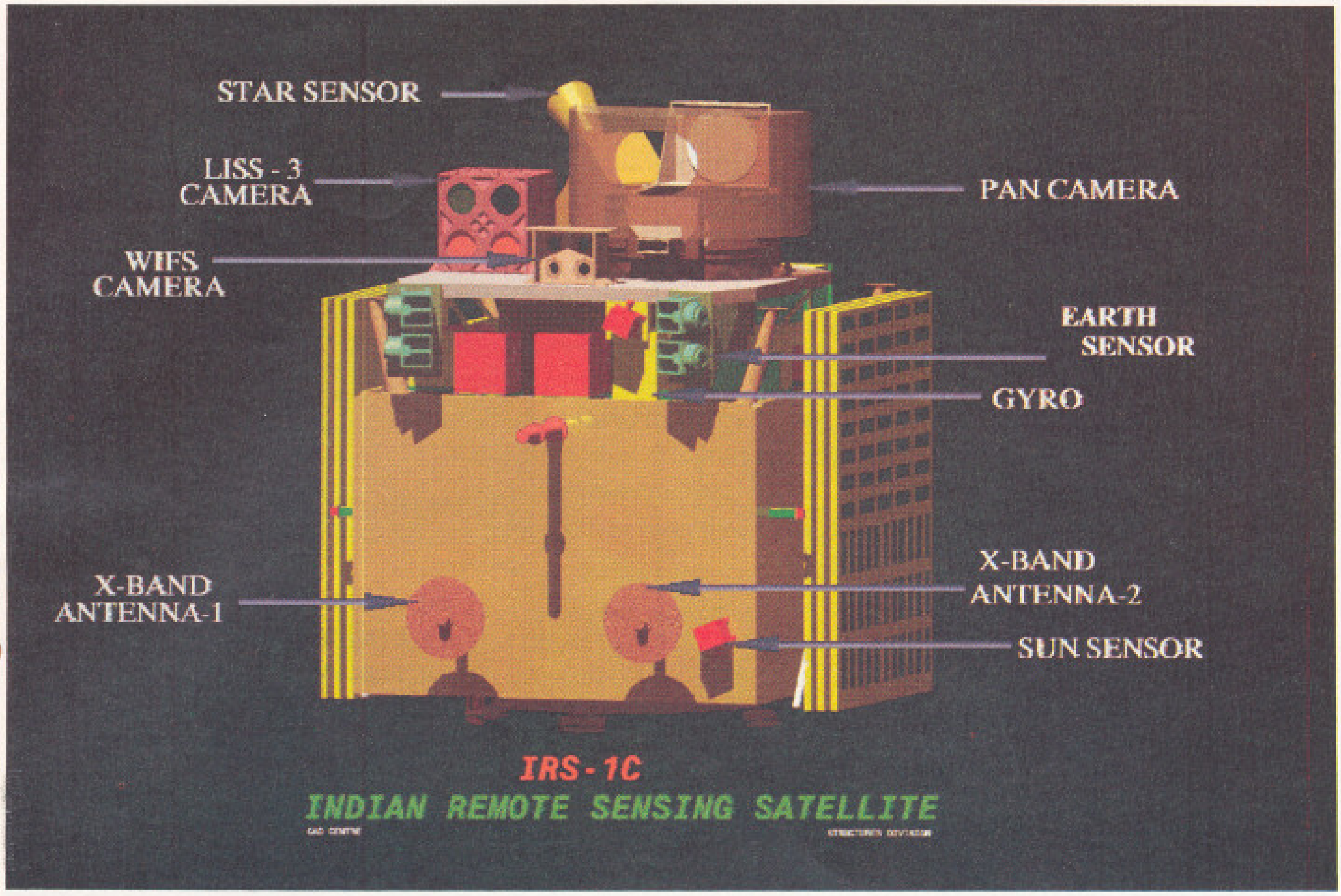
In order to continue and enhance the services of IRS system, the development of the second-generation satellites in the series, IRS-1C and IRS-1D, has been taken up. Tests on the Structural, Thermal, Engineering Model (STEM) of the IRS-1C spacecraft are in progress. IRS-1C is scheduled for launch in 1995.

Besides ensuring continuity in remote sensing data, IRS-1C will have improved spatial resolution, enhanced spectral coverage, more frequent revisits and stereo viewing capability. The main payloads of IRS-1C include:

- a multi-spectral Linear Imaging Self-Scanner (LISS-3) operating in the visible and near-IR bands with a spatial resolution of around 23 m and Short Wave IR (SWIR) band with a resolution of 70 m
- a Panchromatic camera (PAN) with a resolution better than 10 m with stereo viewing capability and
- a Wide Field Sensor (WIFS) operating in the visible and near-IR bands with a resolution of 188 m.

The satellite will carry, on board, recording equipment.

The 1,350 kg, IRS-1C satellite will be placed in a polar sun-synchronous orbit of 817 km altitude. The satellite will cross the equator at 1030 hours local time in

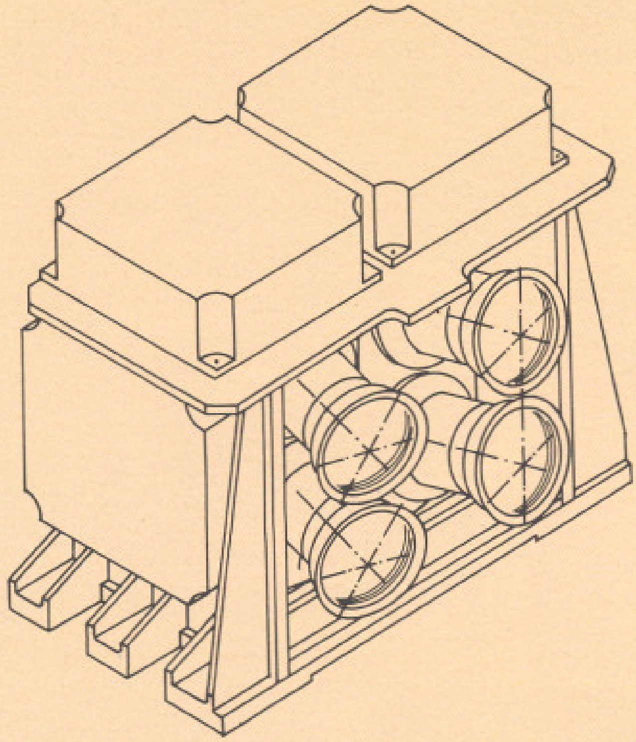


IRS-1C Mission

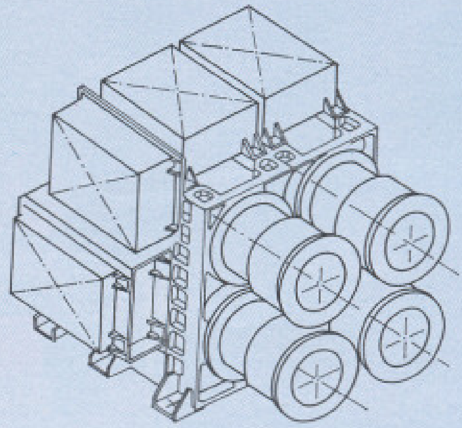
Orbit	:	Polar Sun-synchronous
Altitude	:	817 km
Inclination	:	98.7 °
Eccentricity	:	0.004.
Period	:	101 minutes
Local Time of equator crossing	:	10.30 am (descending node)
Repeat cycle	:	24 days (for LISS-3)
	:	5 days (for WIFS)
Revisit	:	5 days (for PAN)

IRS-1C PAYLOADS

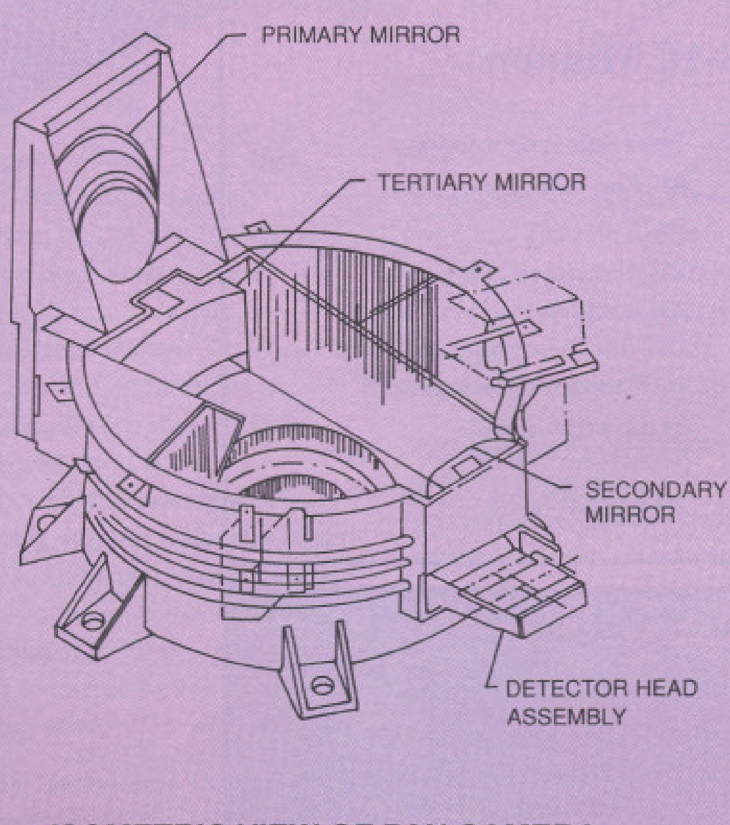
	PAN	LISS-3		WIFS
		VNIR	SWIR	
Spatial Resolution (m)	10	23.6	70.8	189
Swath (km)	70	142	148	774
Spectral band (Microns)	0.5-0.75	0.52-0.59 0.62-0.68 0.77-0.86	1.55-1.7	0.62-068



WIFS CAMERA



ISOMETRIC VIEW OF LISS-3 CAMERA



ISOMETRIC VIEW OF PAN CAMERA

the descending node. The ground track shift between any two successive repeat cycles (each repeat cycle comprising 341 orbits) will be maintained within ± 5 km.

IRS-1C main platform structure consists of four vertical panels and two horizontal decks supported on a central load bearing cylindrical shell. Most of the major main-frame subsystem packages are mounted on these panels and decks.

To meet the stringent requirements of thermal and alignment stability of the payloads, the Payload Platform (PPL) is thermally isolated from the main platform by a CFRP cylinder. Besides accommodating the payloads, PAN, LISS-3 and WIFS, the PPL accommodates the earth sensors and the star sensors.

A Payload Steering Mechanism helps rotate the Panchromatic camera (PAN) about the roll axis of the satellite. During the launch phase, the PAN camera is held down on to the PPL and released after the injection of the satellite into the orbit.

A solar array of 9.6 m^2 consisting of three panels mounted on two sides of the satellite generates a power of more than 900 W. Two Nickel-Cadmium batteries, 21 Ah each, power the satellite during the eclipse and during peak power periods.

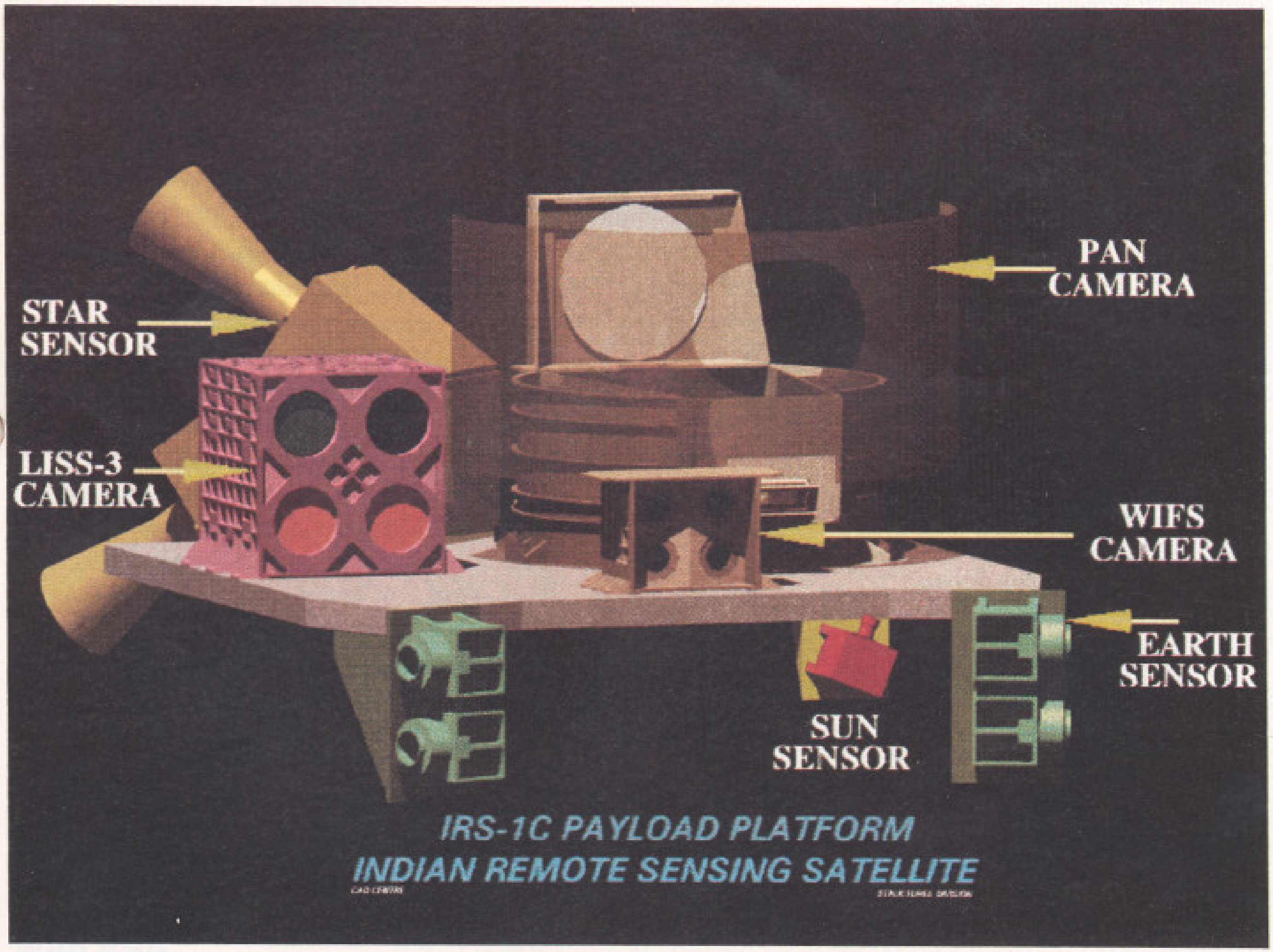
The Telemetry, Tracking and Command (TTC) system is configured around an S-band coherent transponder and has capability for simultaneous tone ranging and commanding in the uplink and simultaneous telemetry and ranging in the downlink on a single carrier.

The Attitude and Orbit Control System (AOCS) is configured around a zero-momentum system using four reaction wheels, three of which are mounted in the orthogonal directions and the fourth skewed at an angle of 54.7^{o} with all the three axes. In the normal mode, all the three orthogonal wheels are 'on' and the skewed wheel provides redundancy to any one of the three wheels. The attitude measurement sensors include sun sensors, earth sensors, star sensors and dynamically tuned gyros while the control actuators include magnetic torquer and monopropellant reaction control system.

The various sensors available on board IRS-1C, used in conjunction with data from other satellites covering different regions of the electro-magnetic spectrum, will open up new vistas in application of remote sensing. With the availability of data in the Short Wave IR, it will be possible to provide information on water-stress and pest infestation.

A unique combination of sensors in IRS-1C will improve the crop yield forecast accuracies and crop health monitoring.

Use of high resolution data of IRS-1C will help establish a detailed digital cartographic data-base which will be of immense value in analysing problems associated with development at micro level, ultimately leading to integrated sustainable development. □



Four Agreements Signed

With EOSAT Co, USA

The Department of Space (DOS) and EOSAT Co, USA, successfully concluded a commercial agreement under which EOSAT will receive and market the Indian Remote Sensing Satellite (IRS) data on a global basis. EOSAT is a major marketing agency for remote sensing data reception and dissemination in the world and for US governmental agencies, including the National Aeronautics and Space Administration (NASA). The commercial agreement was signed by Prof U R Rao, Secretary, DOS, and Dr Arturo Silvestrini, President, EOSAT, when they met during the International Astronautical Federation Congress in Graz, Austria, on October 21, 1993. The Antrix Corporation Limited, under DOS, will handle this agreement.

On signing the agreement, Prof U R Rao said, "Data from the presently operational IRS-1A and IB satellites, have been utilised in India for many developmental applications and the agreement with EOSAT is an important step to further enhance their applications globally. Having built up an immense capability in the design and construction of communication and remote sensing spacecraft and their applications for developmental activities, the agreement with EOSAT provides a great opportunity for India to share its knowledge and experience in using space technology with other countries".

Prof U R Rao (left) and Dr Arturo Silvestrini exchanging the documents after signing the agreement on October 21, 1993

"The agreement between India and the US commercial company represents a historic event for the remote sensing community," said Dr Arturo Silvestrini, President and CEO of EOSAT. "IRS data are one of the best sources of remote sensing information. We look forward to working with India to expand the availability of IRS digital products and to increase the number of ground stations that will receive IRS data," he added.

The agreement has come after a series of technical evaluations by EOSAT of data from the two Indian satellites, IRS-1A and IRS-1B, to convince themselves of the superior quality of the data.

Recognising that the second-generation IRS-1C satellite is better than the present LANDSAT satellite and is as good as the next generation US and French satellites which are expected to be realised much later than the IRS-1C, scheduled for launch during 1994-95, EOSAT has agreed to receive IRS-1C data at the US station on a commercial basis. Also, as a part of this agreement, USA will be receiving IRS-1B data at its ground station at Norman, Oklahoma. EOSAT also expects to establish, commercially, four to five ground stations, during the next two to three years, in other countries as well to receive IRS data.

Under the agreement, DOS will be selling a host of ground receiving systems, data processing software, etc, which will be of additional commercial value. EOSAT will also be selling data pertaining to other countries received in India from IRS-1C directly at the National Remote Sensing Agency ground station at Hyderabad as well as from the on-board tape-recorder.

The IRS data, presently from the IRS-1A and IRS-1B, and from the IRS-1C to be launched during 1994-95, are expected to be in great demand, especially in the context of the loss of the LANDSAT-6 satellite immediately after its launch on October 5, 1993.

IRS-1A and IRS-1B, launched in March 1988 and August 1991, respectively, provide imagery from two cameras, Linear Imaging Self Scanners, LISS-1 with a resolution of 72.5 m and LISS-IIA and LISS-IIB both with a resolution of 36.25 m. LISS-1 provides a swath of 148 km, while the composite swath of LISS-IIA and LISS-IIB is 145 km. The cameras operate in four spectral bands in the range of 0.45 to 0.86 micrometres. The imagery are available with a repetitivity cycle of 22 days. IRS-1C will have an improved camera operating in three spectral bands in the visible and near- infrared regions with a ground resolution of about 23 m and an additional camera in the middle infrared region with a ground resolution of 70 m. It will also have a camera in the panchromatic band with a resolution better than 10 m. Besides, a wide field sensor operating in visible and near-infrared region with a resolution of 189 m and swath of 774 km will be incorporated.

The commercial agreement with EOSAT is a significant milestone for the Department of Space in its efforts to benefit commercially from the capabilities built up over the years in the high technology area of space.

With ESA

ISRO and the European Space Agency (ESA) signed, on November 11, 1993, a renewal Agreement for Cooperation in the development and application of space technology for peaceful purposes. The renewal agreement was signed by Prof U R Rao, Chairman, ISRO, and Mr Jean Marie Luton, Director General, ESA, at Antariksh Bhavan, Bangalore.

ISRO and ESA have a long standing cooperation in space for mutual benefit since the signing of the first agreement for cooperation in 1979. Specific areas have been identified for cooperation. In the remote sensing applications, cooperation in land and oceanographic applications, monitoring of tropical rain forest, snow-melt studies, soil moisture study, etc, will be pursued. Possibility of including each other's payloads in ESA and ISRO satellites will also be explored. In the satellite communication area, the topics for cooperation include

Prof U R Rao and Prof Rene Pellat signing the agreement for cooperation at Antariksh Bhavan, Bangalore


Prof U R Rao (left) and Mr Jean Marie Luton exchaning the documents of Agreement for cooperation at Antariksh Bhavan, Bangalore

navigation satellite system, mobile satellite systems, tele-education, sound broadcasting, antenna pattern shaping networks and on-board processing and switching.

Exchange of information about processing of microwave remote sensing data, on-board computers, space debris, radiation environment monitoring, etc, is also envisaged. Cooperation in the space science will include exchange of data on scientific satellites, ground-based and space-based observations and conceptualisation of payloads for future scientific missions. In the area of Telemetry, Tracking and Command Systems, ISRO and ESA will cooperate in providing support for each other's missions.

With CNES, France

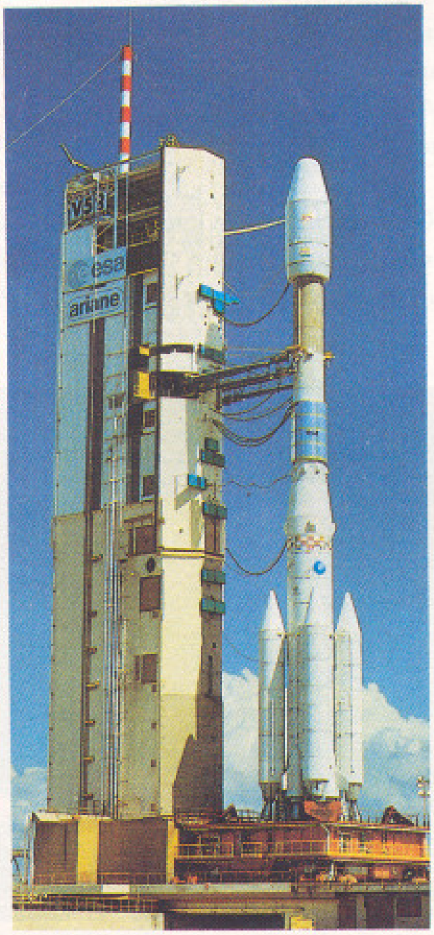
Also, ISRO has signed an agreement for cooperation with the French space agency, Centre National D'Etudes Spatiales (CNES) on November 17, 1993, for exploration and utilisation of Outer Space for peaceful purposes. This agreement was signed at Antariksh Bhavan, Bangalore, by Prof U R Rao, Chairman, ISRO, and Prof Rene Pellat, President, CNES.

ISRO and CNES have a long standing cooperation in space under an agreement signed between the Government of India and the Government of France in June 21, 1977. The present agreement seeks to strengthen the cooperation in several areas including:

- satellite and balloon programmes for space research and applications;
- studies related to satellite communications, satellite remote sensing and satellite meteorology
- operation of satellite ground stations and satellite mission management and organisation of training programmes and exchange of technical and scientific personnel to work jointly for examining specific issues.

INSAT-2C, D Launch Services

The Department of Space signed an agreement with the Arianespace on March 4, 1994 for launching INSAT-2C and INSAT-2D in 1995 and 1996 respectively. The agreement was signed by Prof U R Rao, Secretary, Department of Space and Chairman, Indian Space Research Organisation and by Mr Ch. Bigot, Chairman and CEO, Arianespace.



Since INSAT-2C & 2D will not be carrying the meteorological payloads, they will carry additional transponders which enhance their communication capabilities. For example, they will carry three Ku-band transponders; further, the C-band transponders on board INSAT-2C, D will be more powerful than those on board INSAT-2A and INSAT-2B. Also, for the first time, in the INSAT system, mobile satellite communication servicing will be introduced. Thus, with the launch of INSAT-2C, D, there will be significant enhancement both in the quantity and quality of space communication already being provided by the INSAT-1D, INSAT- 2A and INSAT-2B. □

Dr Kasturirangan Takes Over as Chairman, ISRO

Dr Krishnaswamy Kasturirangan has taken over the Chairmanship of the Indian Space Research Organisation (ISRO) from Prof U R Rao, on March 31, 1994.

During the last one decade, Prof U R Rao had led the Indian space programme bringing it up from the experimental-cum-developmental stages to the current operational phase, characterised by the uninterrupted space services being provided by the INSAT and IRS series of satellites. Prof Rao also played a key role in bringing the launch vehicle technology in ISRO to the threshold of self-reliance. Perhaps, the most significant contribution of Prof Rao is the great emphasis he laid on the down-to-earth applications of space technology to the developmental problems of the country. Thus, Prof Rao leaves an enviable legacy to his successor Dr K Kasturirangan, known more popularly as Dr Rangan.

A very close associate of Prof Rao, Dr Rangan brings with him rich and varied experience as a researcher, as a designer, a Project Director and finally as the Director of the ISRO Satellite Centre (ISAC), Bangalore. During his more than two-decade association with ISRO, Dr Rangan was deeply involved in the development of satellite technology right from Aryabhata, the first satellite built by India. He directed the design, development and operationalisation of the Indian Remote Sensing satellites, IRS-1A and IRS-1B, which are today the mainstay of the National Natural Resources Management System set up by the Government of India. As the Director of ISAC, Dr Rangan also oversaw the development of the indigenous second generation communication satellites INSAT-2A and 2B. A recipient of many national awards, Dr Rangan is a member of a large number of professional bodies both within and outside India.

Both Prof U R Rao and Dr K Kasturirangan spoke to '*Space India*' on the eve of change of leadership at ISRO. Excerpts from these interviews follow:

Interview with Prof U R Rao

Q: You have been at the helm of affairs in ISRO and DOS during the most crucial phase, namely, the operational phase of space services. What do you think is the single most important achievement of ISRO during the last one decade or so?

A: I think the single most important achievement of ISRO is to operationalise the space services and take them to the common man in the remotest corners of the country. This of course means that, for the first time, a real linkage is being forged between the applications, the satellites and the launch vehicles we make. While it is true that launch vehicles have been put into the gear and they are under way to really become operational for the first time, we see our vehicles having linkage with our satellites like INSAT and IRS which are the ones used primarily as work horses for providing the services. Therefore, you see integration of the entire space programme which is able to provide space services on a totally self-reliant basis.

Q: Nobody's professional life is completely free of frustrating moments, however brief they are. Was there any such frustrating experience in your professional career? If yes, would you feel free to elaborate upon it? Conversely, what was the happiest event in your professional career?

A: I don't think there is any frustrating experience! Yes, when the PSLV did not succeed or when ASLV failed, one certainly felt very bad but then that is part of life! But one never gets away from thinking "if I had done such and such a thing may be it might have worked". One always has the worry because often things which you have just overlooked or not given enough care, some minor thing, might lead to trouble. But I wouldn't say frustration and, in my case, I am never satisfied! I think we should have done much more; one always feels that there are so many things which you could have done yet not been able to do. There is always a feeling of restlessness in this process and may be it is all part of life as I said earlier; if one feels contented one would never make any progress.

> **" .... if one feels contented one would never make any progress."**

Well, I think the happiest moment is when the programmes which we have made reach the targeted beneficiaries and they have produced a sea change in their own life style. And when you can demonstrate and convince yourself and others that, notwithstanding the very highly sophisticated technology, our programmes are rooted on the ground and are really to benefit the people. As for instance, in the programme for sustainable integrated development which has been taken up for implementation in certain areas, when the villagers would themselves come and say that they would like to do the work because for the first time they see the barren land becoming green and because they are able to get water and so on. Or when the disaster warning systems enabled the government to evacuate large number of people, something like 1,70,000 people; many lives were saved.

The satellite communication, when it is used for reaching remote and inaccessible areas and the television particularly for education -- these are the things which certainly bring a great amount of satisfaction because we are not doing things just for the sake of prestige but because they have direct relevance to the common people.

Q: You took over the reigns of ISRO from Prof Dhawan about a decade ago; how did you feel at that time about the legacy you had inherited?

A: It was a fantastic legacy and in many respects Prof Dhawan's time was as exciting as it was in Dr Vikram Sarabhai's time, when we had just started some of these activities. But it is Prof Dhawan's time during which we established satellite technology; the satellite programme started in 1972. And SLV programme was launched which meant that we had made a move in the rocket technology as well. We had built up tremendous capability and infrastructure and the confidence that we could go from those experimental systems to operational systems. Take for example Aryabhata, a technological satellite or experimental satellites like Bhaskara-I and Bhaskara-II, or APPLE which was an experimental communication satellite. These certainly gave us the confidence to move on towards the operational systems of the INSATs and the IRSs. And, likewise, SLV and ASLV were essentially experimental vehicles. We knew obviously that we could not do much in space technology with 40 kg capability. But ASLV was designed for proving many of the technologies relevant to the PSLV class of launch vehicles and the conceptualisation of PSLV had been accomplished with a view to getting into the operational system. So, in ten years, what we have done is to build upon it (Prof Dhawan's legacy) and provide the operational status to this system.

Q: People in ISRO, especially the elderly, are fond of talking about "ISRO Culture" — the implication being that in ISRO we do things differently from and more efficiently than in other government organisations. How would you describe this so-called "ISRO culture"?

A: ISRO culture, in my opinion, is rather difficult to really describe, one has only to feel it! This is what Dr Sarabhai had exclusively worked for. Where you have total freedom - and you can see this in our reviews, technical expositions, where even the youngest member of the team can get up and say to Chairman, "it is wrong!" This sort of free technical discussions and reviews are part of the space systems development everywhere else and the amount of freedom and opportunities people have is totally unlimited. Of course, you may find some people grumbling about this but by and large the culture of the Department is that you have such great amount of freedom.

" ..... in (last) ten years, what we have done is to build upon it (Prof Dhawan's legacy) and provide the operational status to this (space) system."

Q: You maintained that we have quickly achieved "operational status" in the satellite technology, but not yet in rocketry. We know, of course, that rocketry is a closely guarded technology because of its military implications. Further, rocketry is an inherently risky and expensive sort of game. Besides these, do you think there are other reasons for this? Don't you think we have to go a long way before we achieve operational status in launch vehicle technology?

A: No. I do not think so. Historically we started the sounding rocket programme with solid propellants. Probably things could have been different if we had started not with the solid propellants but with the liquid propulsion in the very beginning itself. But one must look at the then- prevailing scenario and our own capability and infrastructure at that time. We find that from the very establishment of Thumba as an equatorial launching station, our attention was directed to building the solid propellants and sounding rockets, and from then we went on to the SLV and so on. So partly historical. But one must recognise that the rocket technology is an extremely complicated technology and as you yourself said things are not available. In fact, everything had to be developed by ourselves and we had to establish data bases. And the development of PSLV which is the operational vehicle, of course, one could come to that phase only after having developed SLVs and ASLVs; so that we were able to take to something like 130 tonne solid boosters — a very major task and a quantum jump from what we were doing earlier. When you come to the design of PSLV, it is my opinion that, given the constraints that we have, it is one of the best designs. But you can also see the amount of effort that has gone into the design of

GSLV. How many designs have we gone through before selecting the final design to make sure that we have a proper heritage and the expertise which is already developed and totally used in this process and to make sure that we reach our goal as quickly as possible and have a cost-effective optimum design! For the first time we have started thinking of making sure that our launch vehicles will be competitive in the world market both in terms of their performance, reliability and also in terms of cost. And therefore we have come a long way. Today we are on the right path. I see that the next flight of PSLV will be a success and it is a fantastically good vehicle and it has shown itself to be a very rugged vehicle in spite of the fact that we did not have a total success, the very first time. But it is clearly proven that it is a fine vehicle and the GSLV is even a better vehicle having only three stages, and therefore we must be able to move very fast.

Q: There has been widespread criticism both in the media and in ISRO itself, about the cryo-deal with the Russians. Are we soft-pedaling the Russian deal?

A: No. We are not soft-pedaling on the deal. The fact of the matter is that long ago, we decided to go ahead with the development of cryo on our own. And, unfortunately, this has not been brought out very clearly. But since we had very little expertise we took up a pre-project funding. Under that we developed a one tonne pressure-fed engine. Only then we went to the Space Commission for approving the project for a totally indigenously developed cryo. But well before that, knowing our interests in this area, not at our initiative but at their own initiative, General Dynamics (USA), wanted to sell the cryo engine in the first phase and then talk of the cryo technology transfer in the second phase. But the cost was very prohibitive. So we said we would go on our own. And this was approved by Space Commission. Later an initiative came from Arianespace, the offer included technology transfer but again the cost was prohibitive. But just before going to the Cabinet for approval of the indigenous development of the cryo stage, the Russians approached us with a deal which was very good and the result was that just for 235 crores of Rupees, we would get the total cryogenic technology and including supply of two engines; we could save at least some 2 to 3 years of developmental time and the risk is much less because we are going to the people who have already developed this type of engines. Till October end of the 1993, things went on very well, notwithstanding the fact we had been subjected to embargo by the US, which is totally uncalled for. Firstly, nobody uses cryogenic engines for missiles and, secondly, if they wanted to object they could have done so earlier and they knew fully well that for the last 5 years people have been approaching us — and one and a half years after the contract was signed with the Russians they (the US) woke up! Anyway commercial motives are behind all these. But the Russians reneged on the contract invoking the *force-majeure* clause. We had very tough negotiations with the Russians and we are getting a few more engines from them in lieu of the technology transfer and on the basis of the technology transfer till October 1993, we should be able to go ahead and probably take 2 more years, till 1998, to make it on our own. In the meanwhile the stages procured from Russia would enable us to move fast (in the GSLV programme).

Q: Do you seriously believe we can launch GSLV in 1996-97?

A: Yes. We should have the first launch in 1997 and then onwards we should have launches regularly because the stages given by the Russians will be available. But before that we should be able to develop our own engine. We have started setting up test facilities — the integrated plant (for liquid hydrogen) has been developed, one tonne engine has been tested and many designs have been completed and up to the end of October 1993 technology transfer had been available to us.

Q: Are you satisfied with the progress made by Antrix Corporation? Do you intend to give a new push; if so, how do you intend to do it?

A: Antrix has started off very well. Of course it is for the new Chairman to see what is to be done. We certainly have to give push. We have made many

> **".... Many of the industries who are the leaders in the satellite and rocket technology have come and seen our facilities and have been impressed and I hope that in the next couple of years we must be able to really give a very big push to Antrix."**

contracts, and joint collaborations; for example, for the Malaysian satellite. We have finalised the contract with the EOSAT Co, USA for the marketing of IRS data, etc. Many of the industries who are the leaders in the satellite and rocket technology have come and seen our facilities and have been impressed and I hope that in the next couple of years we must be able to really give a very big push to Antrix.

Q: But our designers and engineers do not seem to be bothered much about being commercially competitive. How do you intend to solve this problem?

A: Commercially we are going to be competitive. Today I do not think there is any problem in being commercially competitive because unlike in manufactured goods where the low cost of Indian labour does not make much of a difference since most of the manufacturing processes are automated, in high technology what is important is the value added. If you look at any high technology item like in space, for example, satellite technology or rocket technology, the value added is 70 per cent and this is all in the engineering man-hours for designing, qualification, fabrication, testing and documentation. These are some of the things which are extremely important in space because they allow you to trace the very heritage of this system. This is where the cost goes up. Since our own salary structure is much less when compared to what it is elsewhere, we should be able to compete. Today in any of the items, we certainly can very boldly say that we will supply systems at 70 per cent of the cost quoted internationally. However, one problem is that there are

L to R : Prof U R Rao, outgoing Chairman; Dr Kasturirangan, the new Chairman and Prof S Dhawan who was the Chairman earlier to Prof U R Rao

sophistications required particularly in terms of weight. We have to reduce weight in some of the areas. This is something which is very important.

Q: Is there anything which you always wanted to do, like say, writing books, but could not do because of pressure of work or lack of time?

A: There are many things which I wanted to do, but have not been done. Not because of lack of time. One should be able to do anything. I hope that I can do much more science. In the last 10 years my scientific output hasn't

"..... Having worked in this department one has a much broader perspective of what is required for this country .... because space gets into almost every aspect of it."

been the same as it was before. And I hope I can do a lot of writing. Having worked in this department one has a much broader perspective of what is required for this country not only in terms of space technology, but in terms of industrial policies, embargoes, missile technology, etc., because space gets into almost every aspect of it. Often I have been accused that when I talk, I talk more like an agriculturist than a space scientist!

There are many things to be done.......

Q: Could you be more specific?

A: There is nothing specific. But we are trying to push, in the international space fora, the holding of the next UNISPACE Conference. We had two UNISPACE Conferences, one was in the 1970s and the other in 1982. But both these conferences were approached by the member countries as something where the developing countries ought to share the experience of the developed countries and try to imbibe some elements of space technology into their cultural fabric so that they could use space for their development. The idea was that the developed countries were trying to assist the developing countries in improving their own lifestyle using the best technology available. But today we are not talking of the same thing. During the last 10 years we have learnt about the increase of carbon-dioxide, the effect of the CFCs, the ozone hole and the global warming, the El Nino and so on ......

***Q**: But the so called developed countries who are preaching us are mainly responsible for degrading the environment ...*

A: That is very true. if you look at the amount of carbon- dioxide which is put into the atmosphere or the CFCs .... the contribution of the US is more than 10 times that of the developing countries. The question now is not just finding out who the culprits are! Certainly they must be asked to pay certain amount of money but that alone is not sufficient. We have to see how to tackle the problem. Now take a developing country, which is probably providing food security to their own people by improving agricultural production. They are forced to cut the forests. Now you can't tell them that this (cutting down trees) must be stopped unless we are able to provide them an alternative. So you come to a point where it is in the interest of the entire world to see that the sustainable development occurs all over so that the ecological equilibrium and the greenhouse equilibrium are maintained. If this has to be done, we need to have a better understanding of the problems. Now what is actually happening is technological imperialism in the name of producing more, particularly during the liberalisation process. This is what foreign companies are doing. They finally leave you with land totally unfit for agriculture. Unfortunately developing countries cannot afford the R&D money needed, for example, for non-CFC route. Again you see an exploitation of developing countries. We want to make sure that there is an equilibrium process so that the developing countries are able to obtain solutions at a cost which is affordable by them. And that they are not being exploited! And it is not in the interest of the developing countries alone but in the interest of the developed countries as well to ensure that sustainable integrated development takes place.

"........So you come to a point where it is in the interest of the entire world to see that the sustainable development occurs all over so that the ecological equilibrium and the greenhouse equilibrium are maintained."

***Q**: And you want these issues to be discussed at the next UNISPACE Conference?*

A: That is right. And the second most important is that of hunger, I am one of people who believe that the world is going to suffer from chronic hunger, unless there is a new green revolution. And a new green revolution which ensures sustainable integrated development at watershed levels. This work, we are trying to attempt in this country. Unless we are able to improve the agricultural production, there is no way to provide food security. What had happened during the last green revolution was that one had gone in for large scale irrigation and large scale use of chemical fertilisers with inadequate drainage. This had happened all over the world including India. With the result, the soil salinity has gone up. Food production did increase in the developing countries but it has come to a certain saturation limit. Soil fertility has decreased to such an extent that it has become counter productive. Now if you have to break this trend you have to bring in a green revolution that does not follow the classical method but takes into account the new development to ensure that in this process the ecology and environment and soil are not spoiled at all. This is something very important and very difficult to do.

***Q**: How do you foresee the future of ISRO?*

A: It is always difficult to look at the futuristic thing and predict. Certainly, in the next coming decade, we will have PSLV and GSLV. But what is most important is that we will get on to sustainable integrated development which involves not only the utilisation of the various technologies but also involves the education, particularly of the rural woman. That is the real thing to do! Precisely for this purpose we have conceived the GRAMSAT, totally dedicated to rural development. And I hope that the first GRAMSAT model will be ready for flight hopefully by the end of this decade or by the beginning of 2001.

And science cannot be ignored. While we cannot afford to spend lot of money on science I do not see any reason why we should not have one good dedicated mission.

At a felicitation function. Left to Right : Mrs Dhawan, Prof S Dhawan, Prof U R Rao, Mrs Rao and Dr Kasturirangan

In terms of technology development there are many more things to come. We are going to see mobile communication, using INSAT-2C. It should become a very common thing since this is not the age where one has to wait to get information. Once we have the workhorses, like the PSLV and GSLV, we must talk of newer vehicles, more efficient and powerful vehicles.

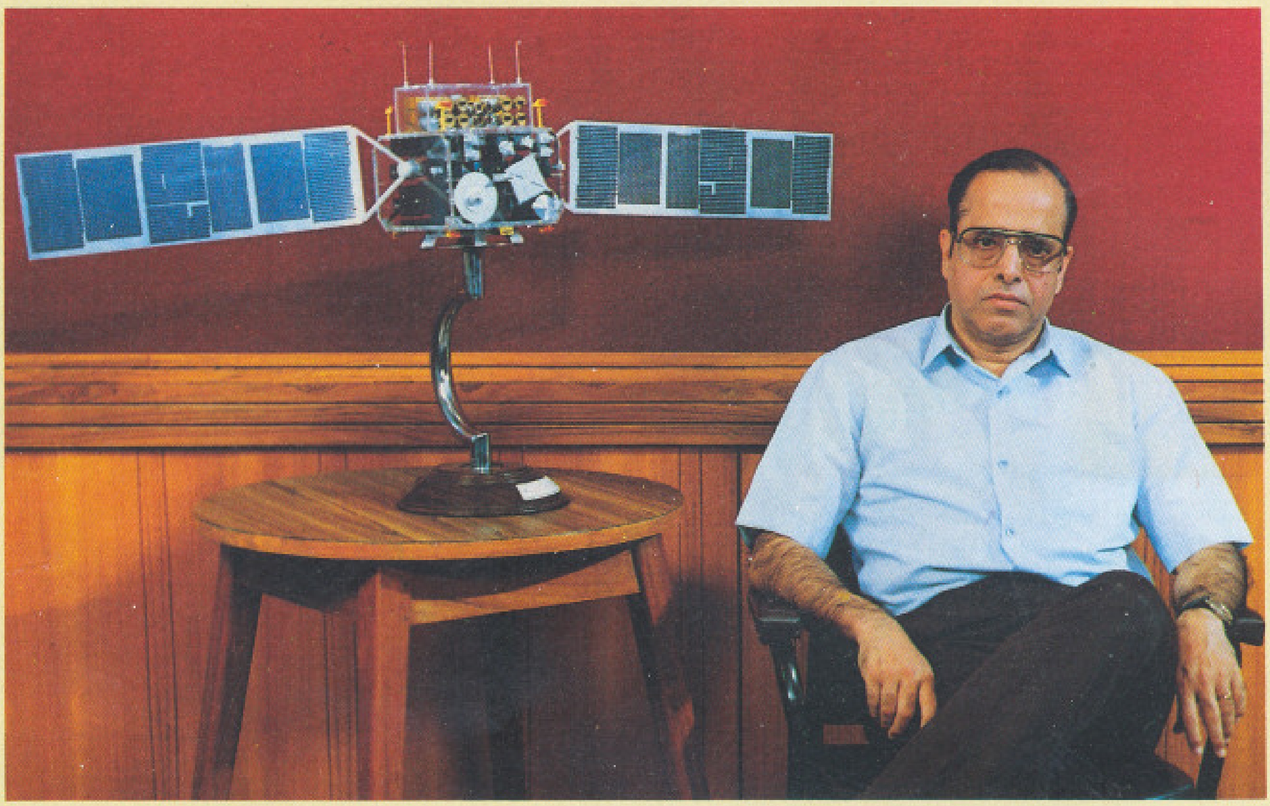
" ..... We are going to see mobile communication, using INSAT-2C. It should become a very common thing since this is not the age where one has to wait to get information."

And, may be 20 years later, we would be probably talking of setting up a space power station.

Q: *If you are asked to give your colleagues a one-line message, what will it be?*

A: If I have to give a one-line message I would say work, work very hard because I think it is only through our dedication and work that we can build this organisation and keep it up-to-date. □

Interview with Dr Kasturirangan



Q: *Congratulations, Dr Kasturirangan. While wishing you all success in your efforts to lead the Indian space programme, we would like to know what is on the top of your agenda?*

A: Yes, at the top of my agenda is getting the ASLV off the ground in the next one month or so and getting nothing short of full success of the mission; this means that necessary reviews are conducted and that all elements are tied up properly.

The second priority is, of course, the PSLV which is fast moving towards launch during the second half of this year. There are several things to be got ready before moving to SHAR where we have to see that the integration and other related activities are completed on time. The next priority is to ensure that all preliminary actions leading to design, development and fabrication of the elements of GSLV in the next one or two years are completed so that the programme can move smoothly without any procedural or technical hitch. While I would like to put the priority for this just behind PSLV, we should target the first launch of GSLV in the early 1997. These are my immediate priorities.

We have, on the satellite side, both the IRS-1C and INSAT-2C getting ready for launch in the middle of next year. Many of the aspects related to the development of the satellites are under control. We do not see any criticality regarding launch of these satellites ...., I would say that the more important priority will be for the launch vehicle programme.

> **"..... priority will be for the launch vehicle programme."**

Q: *There are some criticism that in ISRO technology is pursued at the expense of science, or shall we say that there is benign neglect of science? Do you agree?*

A: I don't think so. I can say that we have a fairly vibrant scientific programme which is being pursued by two or three major institutions or set-ups. First is the Physical Research Laboratory where space science is pursued and they have several ongoing research programmes in astronomy, planetary physics, geophysics and so on. PRL is a laboratory fully funded by the Department of Space. Then you have the Space Physics Laboratory, Thiruvananthapuram, which is one of the very active centres for atmospheric research. Then you have the recently commissioned Mesosphere-Stratosphere-Tropo-sphere, that is MST Radar facility in Gadanki near Tirupati which is a national facility of the highest capability in atmospheric studies and ionospheric studies particularly of the structure and dynamics of the upper atmosphere. Then you have activities of astronomy going on at ISRO Satellite Centre, Bangalore; they have even successfully flown one of the payloads recently for detection of gamma rays.

Q: Any plans for science programme like planetary Missions?

A: When you talk of an interplanetary mission you are really talking of a scale of investment and a scale of activity which is several orders higher than what one is accustomed to be spending in a launch vehicle or a full satellite programme. In this connection there are two possibilities. For example, to test flight GSLV, you can have a mission scenario like injecting the spacecraft into an interplanetary trajectory while you are still proving the GSLV technology. Mission part of this scenario could be a GTO kind of an orbit or you inject satellite at a lower orbit in an inclined fashion or put it into a transfer mode which provides the necessary velocity to get into an interplanetary escape trajectory. In such a mission, besides stages, many other aspects of the GSLV system get tested. Some preliminary studies have been done both at ISAC and VSSC like determining the trajectory for going to Mars, to Venus, to Mercury and so on; but much more needs to be done in a more rigorous fashion. One could start investment in terms of study and not in terms of money. The other possibility would be to explore international cooperation where a right idea of an Indian scientist to fly a payload which could provide some very novel measurements or look for new information could become part of the interplanetary mission. This is very much tied up with the Indian scientists coming up with an idea which is so good and so competitive scientifically that it will be accepted as a mission opportunity .....

" ..Some preliminary studies have been done both at ISAC and VSSC like determining the trajectory for going to Mars, to Venus, to Mercury and so on; but much more needs to be done in a more rigorous fashion. One could start investment in terms of study and not in terms of money."

Q: ... But have our scientists been told to work for such proposals?

A: This has already been conveyed to many scientists in the country. Probably they think that there is no point in working for something that has a low probability of getting through! But I feel that the message has been with the Indian scientists that a good idea for a mission opportunity not only for interplanetary studies but also for planetary studies, even for studies related to earth and its environment, astronomy, which cannot be carried out with the Indian launch vehicles or satellites, could certainly be explored outside.

Q: It is widely acknowledged that while we have achieved a fair degree of success in satellite technology and its applications, we have yet to go a long way in rocketry. What do you think are the reasons for this?

A: I would say that what we have done so far in rocketry is very substantial particularly if one sits and evaluates the last PSLV flight and look at everything that has been validated in that flight, I would say that it is substantial progress for a vehicle of that class and complexity. But we have some difficulties; I do not think these difficulties are unusual in any launch vehicle development programme. You do simulations on the ground, analyse on the ground, test on the ground; there are regimes of flights for which you synthesise all these data and then try to create an equivalent situation. There are always small departures, sometimes critical; I would specifically say that in the context of separation dynamics, the regimes of coupling between aerodynamics and structure and controls. This is the reason why many countries have adopted the method of going initially for suborbital flight and then for orbital flights. But we think it is a good strategy to take the risk in the initial phase of our programme itself and not do any suborbital flights and go straight for the orbital flight. Data from all these

Passing on the bouquet (baton?) - Prof U R Rao - presenting bouquet to the new Chairman, Dr Kasturirangan, while the former Chairman, Prof S Dhawan looks on

kind of flights would be the basic inputs for the operational launch vehicles. I think both SLV and ASLV provided some very vital information in many of these areas in the actual flight conditions. Most of the technologies are validated fully in the successful flight of ASLV in May 1992 and the recent flight of PSLV. I think this is a good basis for us to work tor the future successful missions.

" .... if one sits and evaluates the last PSLV flight and look at everything that has been validated in that flight, I would say that it is substantial progress for a vehicle of that class and complexity."

If you take the totality of the accomplishments and the knowledge we have gained from these flights I do not think that we have done as badly as it is made out to be.

One more point is the turn-around-time between flights; where problems are encountered in a flight and the corrections are to be made in the subsequent flight, and a reflight, especially during an experimental phase of a vehicle programme, the turn-around-time is intrinsically a little longer and I do not think that is a matter of concern because it would become much shorter in the operational phase.

***Q**: It is no exaggeration to say that whatever ISRO has achieved so far had all been foreseen by Dr Sarabhai, or to put it differently, we could not go beyond what Dr Sarabhai had planned for us. What do you think ISRO should be doing, say, ten years from now?*

A: This is a question that has been occupying our minds over the last several years. The important thing is that the operational systems for resources survey and meteorology and communications, including TV broadcasting, have come to stay in this country and space is definitely a major component in these endeavours. That will obviously set the goals for several missions which we will undertake in the coming years. If you are referring to something much beyond then there are several possibilities. Certainly areas like navigation, ocean remote sensing as well as new types of sensor systems like the synthetic aperture radar, are things that we need to address, once more, in the context of our country's needs. In technology, one has to really work for heavier satellites especially for communications because orbital slots and frequency management is complex; colocation is one strategy, but it has its own complexities. The idea of LEO (Low Earth Orbit) communication satellites has also been examined by the Department, especially for mobile and personal communications. This has proved to be attractive on a global basis, and that is what organisations like Globalstar and others like them are trying to market. In our national context we need to address this a little more carefully unless we become a part of a global consortium which owns such systems. On the technology side I would particularly mention, as a vision for the future, reduction of the cost of the space transportation. We are talking now of US $30,000 per kilogram for reaching a GSO (Geo-Stationary Orbit). Is it possible to bring it down by a factor of 10? In which case one would start exploring concepts like single stage to orbit transportation, long burning cryogenic engines, air-breathing engines and so on.

Q: *How would you describe the future of Antrix Corporation? As I see it, Antrix has to eat literally out of the hands of ISRO but I am afraid, in ISRO, our way of working is not constrained by commercial consideration. What do you intend to do to infuse some sort of commercial sense into our engineers and scientists?*

A: Antrix, as you know, was created only two years ago. So the present state of things cannot be a full judge of what would happen. No doubt, we are really competing with a very closed group of industries across the world who deal with space activities. Handful of them in the US and Europe and a few in Japan are the only people who supply space products and services to many countries. What is important is that we find that we may have to tie up with some of these agencies outside who build spacecraft and the vehicles. And obviously, if we have to break into their method of doing business, we have to be competitive in terms of cost. We find that we will be able to offer subsystems and systems at costs which are substantially lower than what is possible if they were to produce these in their own country. This might attract them towards us because the ultimate objective of most of these companies is to get a better price for the product they sell, not how they produce that particular product. So we could be subcontractors and I think that this direction is going to be pursued much vigorously in the coming months. The second thing as you said rightly is that we ourselves are not tuned to do these commercial activities through ISRO. Right now it cannot be a great attraction for the industry to undertake manufacture of a few subsystems here and there and market them simply because it is not financially viable. But I am sure that when business expands to say, several hundred millions of dollars, the industries are the ones who would come forward to take the technology from ISRO and it would be easier for Antrix to coordinate with those industries to produce these subsystems which they could supply to customers. So there could be a triumvirate sort of arrangement between ISRO, the industries and the Antrix, with ISRO doing the research and development and producing viable technology, the industries producing the hardware in larger numbers and Antrix acting as the interfacing agency.

" ... there could be a triumvirate sort of arrangement between ISRO, the industries and the Antrix, with ISRO doing the research and development and producing viable technology, the industries producing the hardware in larger numbers and Antrix acting as the interfacing agency."

Q: *Do you think everything is fine with ISRO? If not, which areas, in your view, need improvement?*

A: You can certainly say that ISRO is one of the best organisations in this country. In science and technology its accomplishments have been notable. ISRO's goals are oriented towards national development. From all these points of view and also looking at our profile, we have been able to fulfill by and large many of the commitments we made to the nation in terms of providing space services. So, that answers the first part of your question.

But you also asked me whether we could improve; certainly there is no system, indeed scientifically cannot have a system which is perfect. So obviously we need to improve and need to continue to strive towards excellence in all our efforts.

Q: Could you be more specific and say in which areas we need to improve?

A: Yes. One is, of course, the manpower which is never used fully. One has to really relook at questions like: how is the manpower deployed? what kind of individual roles are there for people? are we getting the maximum output from the total number of people we have? or is there any scope for improvement? In ISRO there are groups of technical people who have completed their commitments to our programmes in terms of development. And they would like to take up more challenging research and development tasks. So this is one area which one can look into in a more detailed way and see what kind of a plan could be chalked out.

On the other hand we have many areas in which we have yet to start work. Look at the space materials; we are still dependent considerably on foreign sources. Look at the high strength and high temperature materials and the materials for the cryogenic engines. The important thing is to see that the strength within the organisation is fully utilised. A suitable action plan has to be evolved to do this.

Q: The sort of enthusiasm one has seen in the Aryabhata days or SLV-3 days is rarely seen now-a-days. This is, of course, quite understandable because nothing excites one like the first-love! Also, the average age of ISRO personnel is slowly but surely increasing and we are not recruiting too many youngsters either. What do you intend to do to bring back that sort of enthusiasm?

A: I think we have already started some form of rejuvenation! This has to be done at different Centres. Let me tell you how the entire system has to be. ISRO is mainly dependent upon how the different Centres function. The Centres have to develop a certain type of working culture. If the working culture during the last several years has in any way suffered, we must look at what people at various levels are doing, how they are placed, what kind of roles they have and what kind of visibility they have in their own position. I want to be a little explicit in this.

" ... I want to be a little explicit in this. You make sure that besides Director (of ISRO Centres) the second and third level people are the right ones; if they have the necessary autonomy to carry out their responsibilities, and they have no other problems in allotting jobs, giving directions, and getting the work done out of the next level I think the whole orchestration can develop."

You make sure that besides Director the second and third level people are the right ones; if they have the necessary autonomy to carry out their responsibilities, and they have no other problems in allotting jobs, giving directions, and getting the work done out of the next level I think the whole orchestration can develop. These are some of the things that we should surely look at. But many steps have been taken in this context: the human resources development activity has been stepped up in the recent past in an attempt to introduce various methods of management, methods of motivation and methods of participation. But I think the strength of ISRO is going to be still very much dependent on how you allow the various layers of people to participate in reviews, participate in activities and how much visibility they can get from their immediate superiors and possibly even from higher levels. I think that our Centres probably need to pay a little more attention to these issues.

Q: If you were to give a one line message to your colleagues in ISRO what would it be?

A: India, with its multifarious problems arising from large population and the attendant ever increasing demands on its limited resources, is committed to use high technology in its development process. Space has today come to influence several facets of national endeavour in the context of overall development. Let us dedicate ourselves to preserve this glorious tradition and also to look ahead, and strengthen and, where necessary, expand the role of space so as to bring its benefits to grassroots level of India. □

PSLV Failure Analysis Committee Submits Report

The Failure Analysis Committee (FAC), constituted to look into the causes of failure of the first developmental flight of PSLV (PSLV-D1), which took place on September 20, 1993, has submitted its report. The national level FAC, chaired by Shri N Pant, Member, Space Commission, included experts from academic and R & D institutions in the country, besides ISRO.

Based on the analysis of the extensive telemetry data from the flight, and the detailed studies and simulations, the FAC has confirmed that all the major systems which had been integrated in the PSLV, both hardware and software including the giant solid booster and the liquid propulsion systems flight tested for the first time, have worked as planned and that there are no serious lacunae in the design of the vehicle; PSLV-D1 would have achieved the intended orbit but for a minor deficiency.

The FAC has confirmed that the failure of PSLV-D1 to reach the intended orbit was primarily due to a software error in the pitch control loop of the on-board guidance and control processor, which occurs only when the control command exceeds the specified maximum limiting value. The above preset limit value was exceeded due to the disturbances experienced during transition between the second and third stages of the rocket. These disturbances were caused by the programmed gimbal nulling of the second stage 3.7 seconds before the ignition of the third stage, leaving the disturbances during the above period of the second stage tail-off uncorrected and the failure of two small retro-rockets leading to a contact between second and third stages, during the separation of the second stage. The FAC has further confirmed, that in spite of the above disturbances, the PSLV rocket design is so rugged that it would have reached the intended orbit, but for the software error.

The major recommendations of the FAC, consequently are to rectify the software implementation error and to delay the gimbal nulling of the second stage by about 2.0 to 2.5 seconds.

The FAC added that the deficiencies noted are not unusual for developmental flights of a complex vehicle like the PSLV and that it should not at all be difficult for ISRO to implement the suggested modifications and operationalise the PSLV.

Preparations have already commenced for the next developmental flight of PSLV targeted for the second half of 1994. □

Induction Ceremony at Space Hall of Fame

Dr. James Halligan, President, International Space Hall of Fame, speaking on the occasion of the induction of Dr. Vikram Sarabhai. Ambassador Kanwal Sibal, Deputy Chief of Mission, Embassy of India in Washington, who received the Plaque of Honour, is standing on the left

The name of Dr Vikram Sarabhai, the father of Indian Space Programme, was inducted into the International Space Hall of Fame at the Space Centre, Alamogordo, New Mexico, on Saturday, October 2, 1993.

The induction ceremony began at 6 pm local time at the Space Centre with a fly over by a US Airforce Squadron from Hollman Airforce base. The formal induction programme started after offering silent prayers for the earthquake victims in India. The Government of India was represented by Ambassador Kanwal Sibal, Deputy Chief of Mission from the Embassy of India at Washington.

The Plaque of Honour symbolising the induction of Dr Sarabhai, was received by Ambassador Sibal with the display of Indian national flag amidst standing ovation by a gathering of about 200 distinguished personalities.

With this induction Dr Sarabhai joins the illustrious group of scientists, pioneers and visionaries known for their outstanding achievements in space technology like Robert Goddard, Verner F.Von Braun, Arthur Clarke, Yuri Gagarin and Neil Armstrong.

The Space Hall of Fame displaying the portraits of inductees on October 2, 1993.

The following citation was read out during the induction ceremony:

"Vikram Ambalal Sarabhai – Father of Indian Space Programme

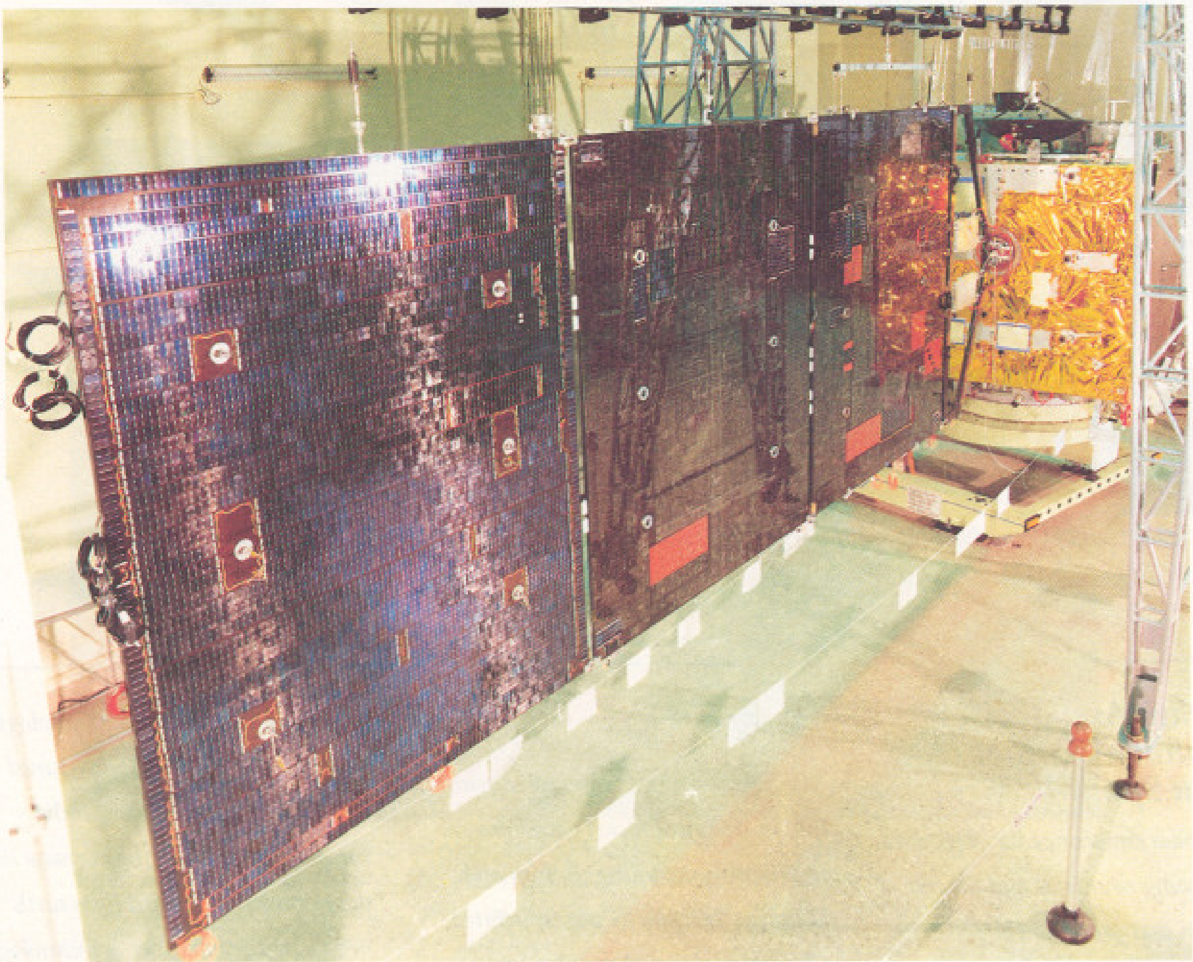
Dr Sarabhai envisioned the objectives of developing countries and the role of science in that process. He incorporated the benefits of space in all aspects of his programmes, including the use of satellite communications to educate children in remote villages. In 1947 he instituted the Physical Research Laboratory, which performs sophisticated space research. In 1962 Dr Sarabhai became Chairman of the Indian National Committee for Space Research, assuming responsibility for organising space research in India. He set up the Thumba Equatorial Rocket Launching Station in South India and set in motion the Indian manufacturing of French Centaure sounding rockets.

Sarabhai was the driving force behind Indian-designed rocket development at Thumba, including Rohini and Menaka. In 1966 he was appointed Chairman of the Atomic Energy Commission and Secretary to the Department of Atomic Energy to the Government of India. A Space Science and Technology Centre was established, also at Thumba, where many young scientists and technologists today work towards the future of space and India.

Among Dr Sarabhai's contributions to space are: a second rocket range at Sriharikota, a Satellite Instructional Television Experiment Group and 13 other institutions in different areas of space research. Sarabhai's development plan for India provided for the use of innovative technologies from around the world, fine-tuned and used for the benefit of India's future. For example, he oversaw the development of applied low- earth orbit satellite monitoring technology for agricultural and forestry planning in India, now emulated around the world.

Born at Ahmedabad, Dr Sarabhai (1919-1971) was educated at the family school directed by his mother. He later studied at the Gujarat College in Ahmedabad. He received a bachelor's degree in Natural Science from St.John's College (U.K.) in 1939. In 1947 he earned his doctorate following research in photofission at Cambridge University's Cavendish Laboratory." □

Mechanisms for Deployment of Spacecraft Appendages



INSAT-2B Solar Array Deployment test

ISRO's Indian Remote Sensing Satellites and INSAT satellites carry a number of appendages such as Solar Arrays, Antenna Reflectors and Solar Sail and Boom which is deployed in orbit. The deployment mechanisms, which are mission critical, have worked flawlessly in all the satellites. The design and development of these mechanisms, involve accurate analytical predictions of the deployment dynamics of the various systems, precision fabrication and special surface treatments like anodising and dry lubrication for the various components and, elaborate test and evaluation at component level, sub-assembly level and system level.

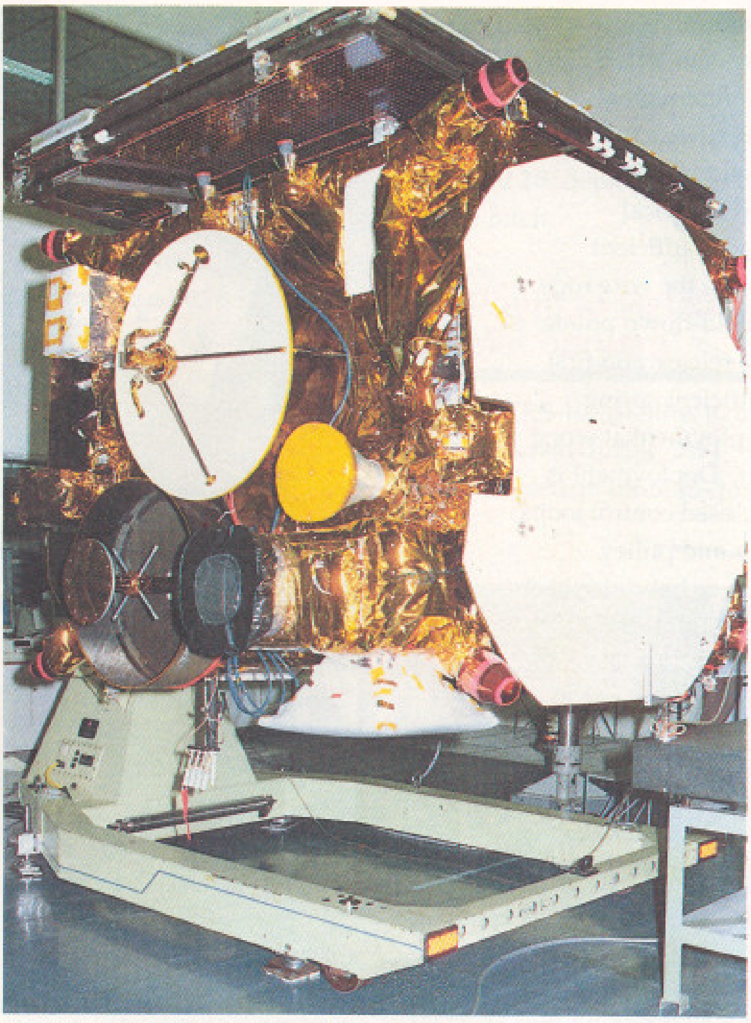
In the process of development of these mechanisms, ISRO Satellite Centre at Bangalore has built up an enviable capability to design, develop, test and qualify complex mechanisms for any type of spacecraft.

A vital element for the hold-down and release mechanisms, namely, Pyrocutter, is developed and qualified by the Vikram Sarabhai Space Centre (VSSC), Thiruvananthapuram. These cutters have both mechanical and electrical redundancies. The Pultruded Elements for the 15 m long boom of INSAT-2 have also been developed and qualified by VSSC.

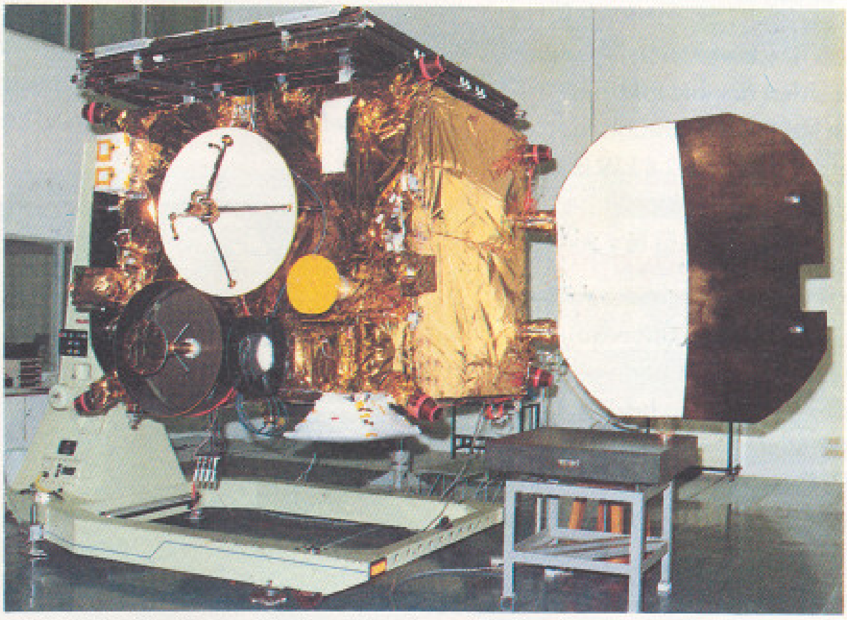
Apart from the deployment mechanisms which have already been proven on ISRO's spacecraft, a few other mechanisms have been qualified on ground, and some more are in an advanced stage of design.

Solar Array Deployment

The Solar Array for INSAT-2 consists three main panels and two side panels. Each of the main panels measures 1800 mm x 215 mm and each of the side panels measures 1800 mm x 1073 mm to generate 1050 W of (end of life) power. The Yoke and all the panels are interconnected by inter-panel hinges driven by torsion springs. The natural frequency of the deployed system is 0.30 Hz. During the transfer orbit the outer most panel of the stowed arrays generates 300 W, sufficient for the spacecraft in this phase of the mission. Full deployment of the array is carried out in two stages; first, the main panels are deployed in an accordion fashion, followed by the release of the two side panels. Only two pyro-cutters are used for each deployment. Deployment is controlled by closed control loops using wire rope and pulley mechanism. The solar array deployment mechanism, before flight, had gone through number of detailed tests at component, sub-assembly and system levels under different environmental conditions. First-motion/release was demonstrated under vacuum and worst-case temperature differentials. Sinusoidal vibration and acoustic tests in launch configuration were conducted at load levels likely to be experienced by the spacecraft during launch on board any of the available international launch vehicles. The successful deployments of the array on INSAT-2A and INSAT-2B have unambiguously established the perfection, both in design and fabrication of the mechanism.



INSAT-2 C/S reflector (stowed)



INSAT-2 C/S reflector (deployed) - using air levitation

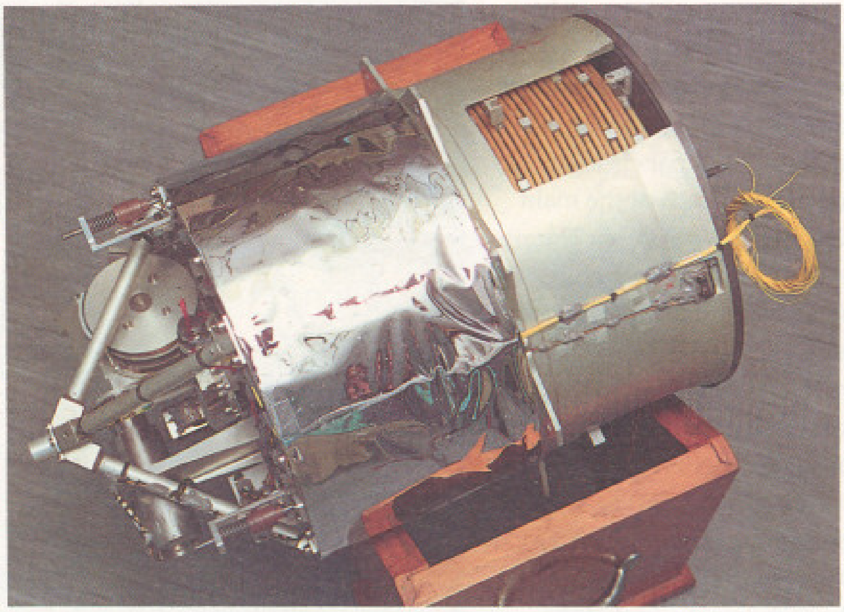
The Solar Array Deployment Mechanism for Indian Remote Sensing Satellite, IRS, consists of one yoke and three panels, each panel with an area of 1100 mm x 1300 mm and generating a power of 355 W. The Yoke and panels are interconnected by inter-panel hinges and are driven by torsion springs. The natural frequency of the deployed system is 0.35 Hz. IRS solar array deployment mechanism also uses a fully qualified pyro-cutter with mechanical and electrical redundancies and sufficient margin for cutting the wire rope. Pushers at all hold-down points ensure positive release and first motion and sufficient spring margins for deployment at worst case conditions. Deployment is controlled by closed control loops using wire rope and pulley mechanism. These have also been fully proved through IRS-1A, launched on March 17, 1988, and, IRS-1B, launched on August 29, 1991.

Besides for IRS and INSAT, solar array deployment mechanism for eight deployable panels of SROSS satellite has been developed. Each of these panels has a size of 1100 mm x 290 mm and the array, together with the eight body-mounted panels, generate a power of 100 W.

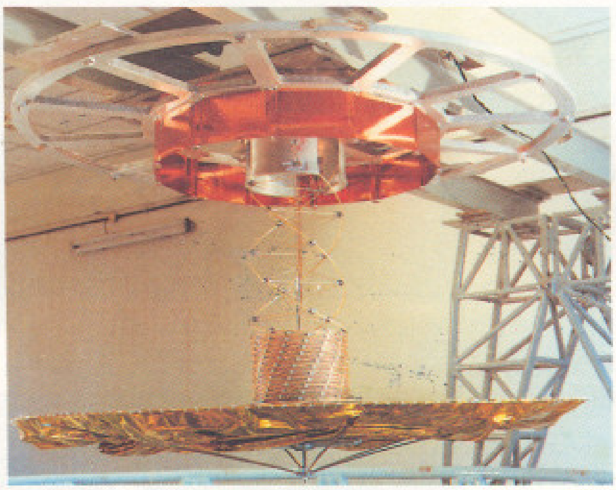
Work on flexible solar array with double-sided flexible fold-out array in split configuration to generate a power of 2.4 kW is in progress.

Antenna Deployment

The INSAT-2 spacecraft requires two antennae (offset paraboloid of 1.772 m x 1.772 m), to be deployed. Two hinges are employed for each antenna. The hinge consists of an inboard bracket attached to the satellite deck, an outboard bracket connected to reflector and a latch-up mechanism designed to ensure required pointing accuracy. The antennae have a deployed natural frequency of 2 Hz. The hold-down configuration is similar to that of solar array.



INSAT-2 coilable lattice boom inside the canister. Hold-down and release mechanism are also seen.



INSAT-2 sail and boom during vertical deployment

INSAT-2 sail and boom fully deployed

Both in INSAT-2A and INSAT-2B, antennae have been deployed successfully with unambiguous indications of all events.

A Synthetic Aperture Radar (SAR) Antenna Deployment Mechanism with five panel array with deployable backup truss structure configured around INSAT-2 bus for Microwave Remote Sensing/Earth Mapping has also been designed. It has a fixed central panel and two deployable wings of two panels each; the overall size of the array is 0.8 m x 12 m. Flatness of the deployed array is better than ± 2mm over 0.8 m x 12 m. The frequency of the deployed system is 4 Hz. A number of tests at component, sub-assembly and assembly levels have been completed for this mechanism. A full-scale model in aluminium alloy sections has been fabricated and tested. Design and development of the mechanism with CFRP panels and struts are now in progress.

Solar Sail/Boom

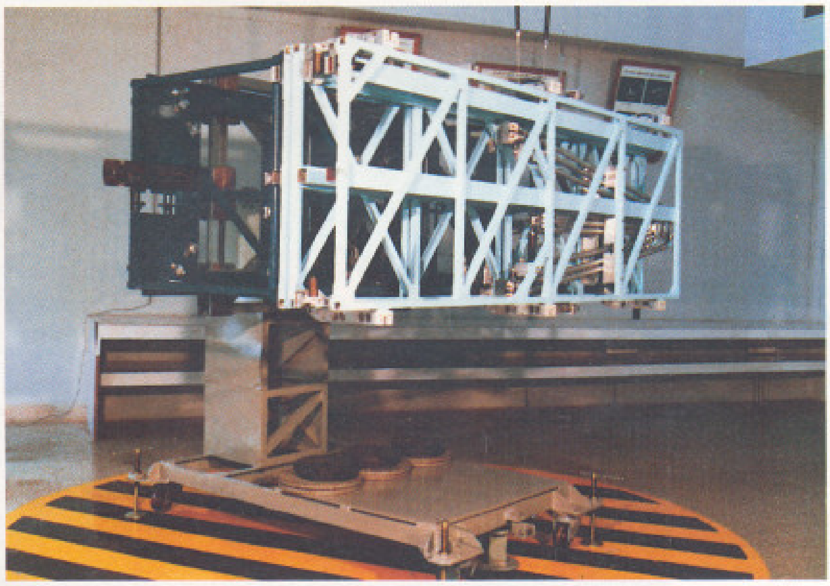
INSAT-2A and 2B spacecraft also employ Coilable Lattice Boom with a Sail attached at the end, which serves to counteract the solar torque imbalance due to the unsymmetric solar array configuration. The Boom is of 0.26 m diameter and 15 m long, made of pultruded elements. Compactness achieved is 1:50 (ratio of stowed to deployed length). Mass is 0.24 kg/metre. The whole boom is housed inside a canister. The boom is deployed by stored strain energy with a controlled release through a lanyard connected to a geared motor. The boom is pre-twisted to minimise thermal distortion. The straightness of the boom is better than 30 mm. Deployed natural frequency with sail is 0.35 Hz.

The sail has its frustum of cone about 4.2 m high, 1.5 m diameter at bottom and 0.78 m diameter at top. Made of Aluminised Kapton film, the sail is folded so as to ensure smooth unfolding and avoid entanglement during deployment in space. The total mass of the sail, boom and canister is 12.2 kg.

The boom with sail of INSAT-2A and 2B deployed in orbit without a hitch.

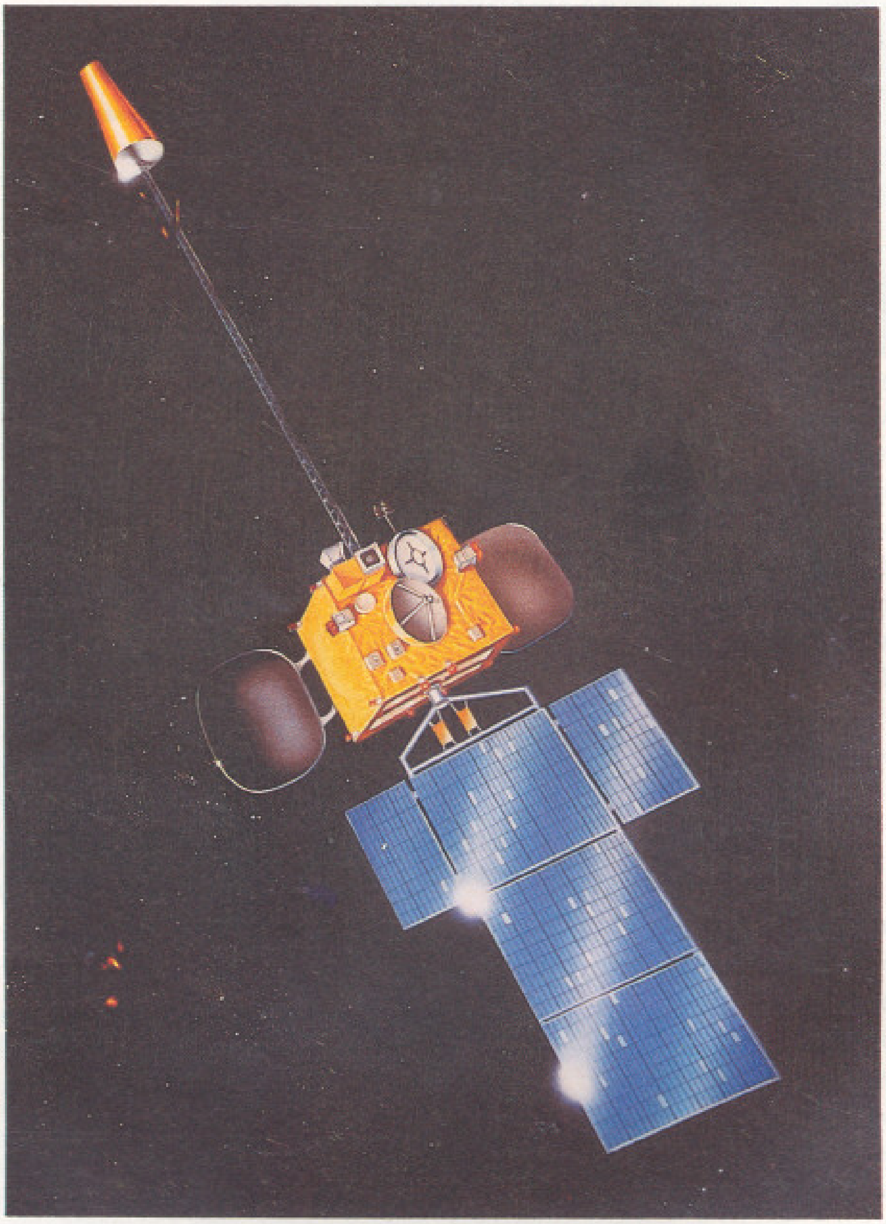
Payload Release Mechanism

For IRS-1C satellite, to be launched during 1994-95, a mechanism for hold-down and



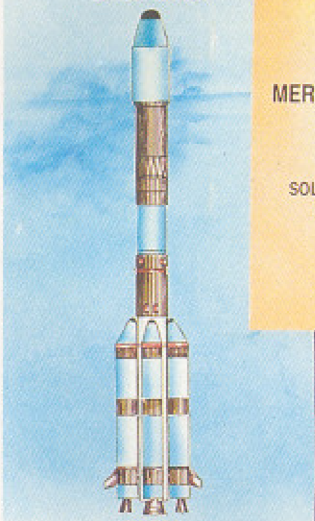
Full size SAR antena model with one wing (stowed)

Full size SAR antena with one wing deployed release of the 120 kg steerable camera payload has been developed. It consists of six discrete point hold-down mechanisms employing bolt and plunger with a single release system. Each hold-down block can be loaded up to 10,000 N, to take care of the launch loads. □



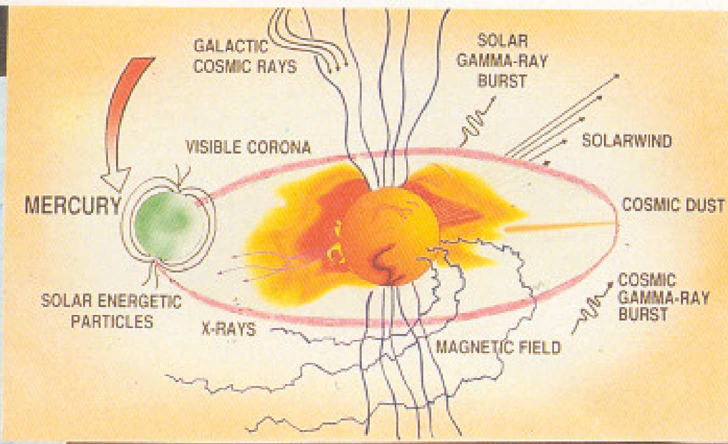
INSAT - 2A/2B with all appendages deployed

LAUNCHER



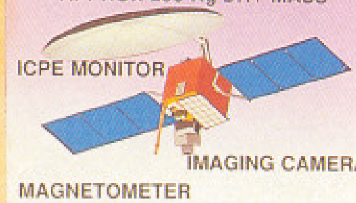
GSLV

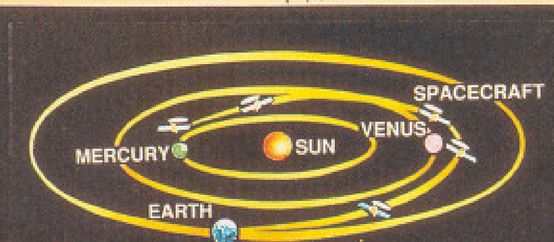
PUTS THE SPACECRAFT INTO A 300 KM CIRCULAR PARKING ORBIT LATER BOOSTED TO HELIOCENTRIC ORBIT



SPACECRAFT

APPROX 250 Kg DRY MASS





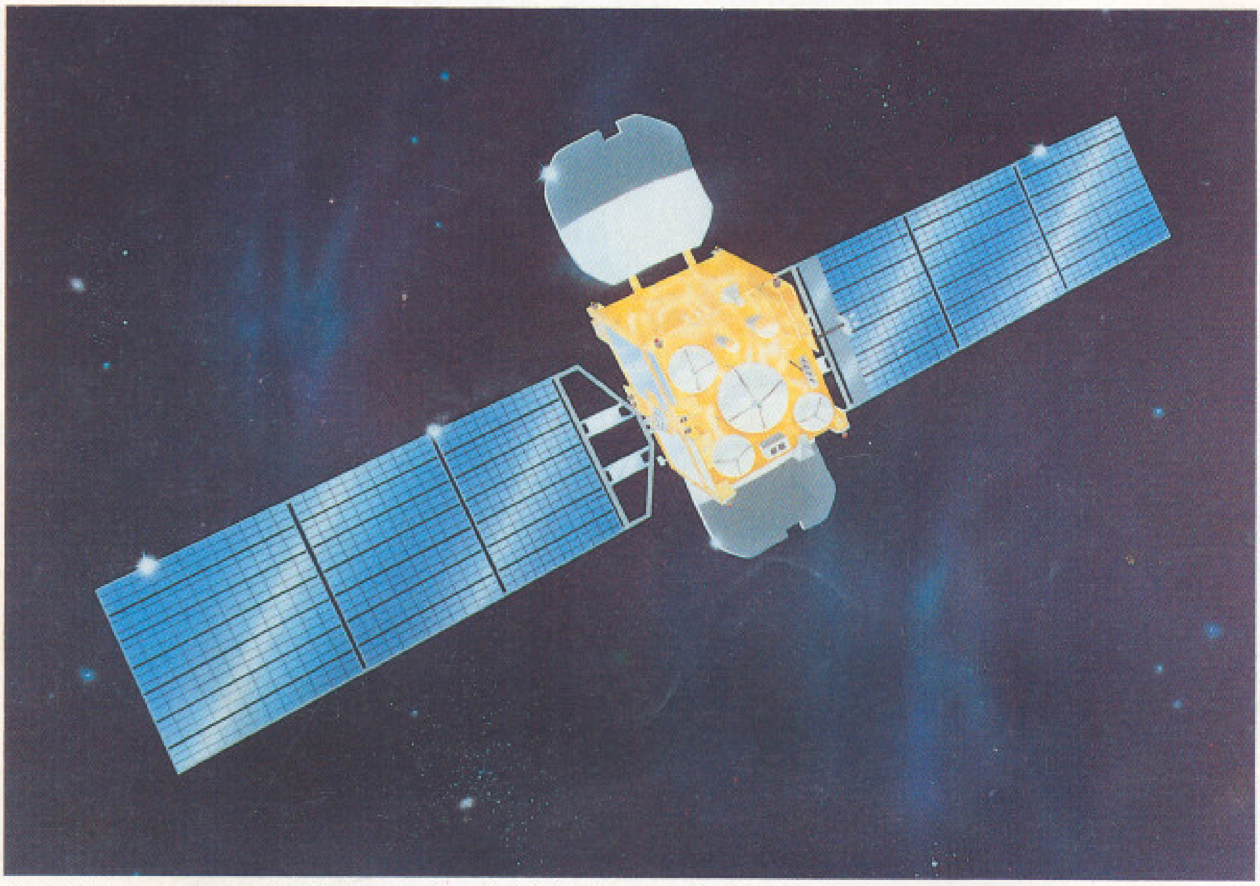
TRAJECTORY

VENUS MERCURY FLY-BY

EXPERIMENTS

- SURFACE IMAGING EXPERIMENT USING CCD CAMERA.
- MAGNETOMETER
- INTERPLANETARY CHARGED PARTICLE ENVIRONMENT MONITORING
- SOLAR PHYSICS EXPERIMENT

A MISSION TO VENUS AND MERCURY



An artist's concept of INSAT-2C to be launched by Ariane Launch Vehicle