Indian Remote Sensing Satellite, IRS-1A

A forerunner for operational era

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BACKGROUND

The Indo-USSR cooperation is undoubtedly one of the best examples of international cooperation in Space. For India, this collaboration played a catalytic role in the early years of building capability in satellite technology and greatly assisted in accelerating the Indian efforts of using space technology for national development. These cooperative efforts essentially got a boost with India signing an agreement with the Academy of Sciences of the USSR on 10th May 1972. USSR assigned the practical implementation of the Agreement to DB Yuzhnoye, under its Interkosmos programme of doing joint research with other countries. The agreement culminated in the successful launch of India's first satellite, ARYABHATA, on 19th April 1975 by a Soviet rocket carrier Interkosmos from Kapustin Yar cosmodrome. ARYABHATA was followed by launching by USSR of two experimental earth observation satellites, BHASKARA-1 & 2 in 1979 and 1981 respectively from Kapustin Yar. In addition to the free launch, USSR supplied the reaction control system, solar panels, thermal paints, chemical battery and tape recorders, besides providing TTC support from the Bears Lake station near Moscow. BHASKARA missions provided valuable experience in a number of inter-related disciplines of space-based remote sensing system for resource survey and management such as understanding how to configure, design and qualify a remote sensing platform and to devise a compatible ground segment for data collection and in-orbit mission management as well as demonstrating the methodologies for using remote sensing technology for specific applications.

Thus, the genesis of the Indian Remote Sensing Satellite-1A (IRS-1A) can be traced to BHASKARA 1&2 and various initiatives taken during the period around them. The long term planning of Indian Space programme itself had envisaged the realisation of an operational capability in remote sensing using space-based platforms as one of the high priority items. As a part of evolving this strategy, ISRO had conducted in 1970s a number of aerial flights, developed a variety of sensors, ground-based data processing and interpretation hardware & software as well as carrying out a number of demonstration studies. Data from the American LANDSAT 1& 2 satellites launched in 1972 and 1975 were also used in a number of demonstration studies, more regularly so once a data reception from these satellites were formalised at NRSA in 1979. This was around this time that the framework for Indian Remote Sensing satellite was conceived and conceptualised. ISRO realised the importance of involving the end-users right from the beginning of the planning process. With this in view the Joint Experiment Programme (JEP) was taken up in 1978 in association with user Ministries. It was yet another significant step along with the successful completion of experimental BHASKARA missions that aimed at laying a foundation for an Indian Remote Sensing Satellite.

Further, early 80s also saw the emergence of the unique institutional strategy, namely the National Natural Resources Management System (NNRMS), wherein the traditional techniques as well as the remote sensing technology were integrated to provide timely, accurate and specific information on natural resources to decision makers at various levels. As a part of preparatory activities of NNRMS, around 60 well-defined experiments to demonstrate the utilisation of remote sensing in various application areas were conducted. NNRMS itself came into being through a national conference held in May 1983 with the participation of various Ministries and the Planning Commission, with Department of Space identified as the nodal agency. Mid-80s also saw feverish activities around the country in establishing facilities in many States as well as developing educational courses towards capacity building in anticipation of the Indian Remote Sensing Satellite programme. As a pre-investment to the proposed launch of IRS-1A, an IRS Utilisation Programme (IRS-UP) was also launched with 16 projects identified to address specific stated areas of natural resources management; with the data from LANDSAT satellites used initially for appropriate methodology definition in each case in anticipation of similar data from the planned IRS missions. The country was, thus, well prepared by these systematic steps taken in advance to the very launch of the IRS-1A satellite.

SCOPE OF INDIAN REMOTE SENSING SATELLITE PROGRAMME

The Indian Remote Sensing satellite programme was towards going in for an semi-operational / operational satellite-based remote sensing system that would serve as the bedrock for the NNRMS programme by directly contributing to the data and information needs of natural resources management in the areas of agriculture, forestry, geology and hydrology; and thus, would serve to supplement and aid, strengthen the existing conventional methods towards realisation of an optimally efficient resources management system for the country. The principal components of the IRS system were envisaged as indigenous realisation of (i) a state-of-the-art three axis stabilised satellite in polar sun-synchronous orbit with suitable multi-spectral imaging sensor and other electrical and mechanical systems; and (ii) ground segment for in-orbit satellite control including tracking network around the world with associated hardware and software; and (iii) ground systems for data reception, processing and dissemination system with associated hardware and software elements for generation of products and services meeting user demands. The mission objectives were accordingly drawn up.

MISSION TRADE-OFFS AND REALISATION OF THE SPACECRAFT SYSTEMS

The scope and the mission objectives were translated into a set of meaningful mission parameters such as those related to payloads, attitude stability of the platform, and orbit characteristics to name only a few. Being the first semi-operational/operational mission for remote sensing applications, a lot of studies were undertaken to identify essential mission parameters and the very system choices thereon.

India being predominantly agriculture oriented country, agriculture was considered to be the prime application while working out the specifications of the payloads and mission parameters for IRS-1A. The important payload parameters of relevance include spatial resolution, spectral coverage & bandwidth, radiometric sensitivity and the repetitive coverage of the country. With the then available technology in mind and in tune with the average agricultural field sizes, the spatial resolution was fixed as 36 metres. It was also closely in tune with the internationally available LANDSAT Thematic Mapper datasets. For many other applications, it was felt that around 70 metres will suffice which was closer to the LANDSAT MSS data. Thus, payloads with two different spatial resolutions viz., 36 m and 72 m were chosen for IRS-1A. One of the momentous decisions taken at that time was to go in for electronic scanning for imaging purposes using the then introduced Charge Coupled

Devices (CCD), with individual refractive optic system for each spectral band maximising tits signal to noise performance, rather than choosing the mechanical scanners and beam splitting used by the LANDSAT missions. This decision enabled a more compact payload configuration with high figure of merit index; with advantages of lesser data rate requirements and associated savings in power, weight & volume, with improved reliability. The low and medium resolution cameras were christened as Linear Imaging Self Scanner-1 & 2 (LISS-1 &2) respectively; with two identical LISS-2 cameras providing meeting the overall swath requirements.

Four spectral bands in the visible and near-IR region were chosen for both LISS-1 & 2, similar to the corresponding bands of LANDSAT TM as large scale IRS UP demonstration applications were carried out as the pre-Project activity as mentioned earlier. These spectral bands and the bandwidths met most of the applications to be covered as part of the stated scope and mission objectives.

In regard to the radiometric resolution, 128 grey levels (7 bit) was chosen after extensive studies based on the 6-bit information available in LANDSAT MSS and 8-bit in LANDSAT TM (and SPOT-1), such as the impact on data rates and other related aspects including the effects of atmosphere and solar zenith angle variations. Later IRS missions went on to improve the radiometric resolutions to 10-12 bit level based on specific user requirements.

One of the important requirements for remote sensing applications is the temporal resolution or repetitivity cycle as it is known. Periodic systematic coverage of the whole country was one of the driving forces as well. Considering that LISS-1 & 2 payloads were using linear 2048 elements CCDs with a pixel size of 13 micron, a polar sun-synchronous circular orbit of 900 Kms was chosen. Also there were many other considerations including lower orbital decay or drag, and less frequent orbit corrections. From this orbit, the payloads could generate 148 km swath which enables the country to be covered in a contiguous fashion in 22 days. This also means that the a given area, IRS -1A will have a repetitive coverage once in 22 days, which could be improved further later, by placing the next IRS satellite, namely IRS-1B, in orbit in such a way that together, a repetitive coverage of 11 days could be achieved. This parameter also became an important point for discussion with the USSR team while fixing the launcher and its dispersion characteristics.

The polar sun-synchronous orbit choice was chosen from the main consideration of providing near constant illumination for the optical resource payloads onboard the satellite. Similarly, the local time for equator crossing was fixed as 10.30 AM which would provide sufficient illumination level for the payloads and it was arrives as a compromise between the requirements for geological and agricultural applications.

For the attitude control system extensive studies were done for meeting the necessary criteria related to payload pointing accuracy, drift rate and jitter. Pointing accuracy and drift rate affect the location accuracy as well as the pixel-to-pixel registration amongst the spectral bands and the jitter affecting the quality of pixel resolution itself by affecting the point spread function. Attitude measurement targets were kept at least an order of magnitude better than the required pointing accuracies.

Similarly, mission trade-offs were conducted for all spacecraft platform consisting of the structure; thermal; power; telemetry, tracking & command (TT&C); as well as the attitude and orientation control system (AOCS). In choosing the platform characteristics, growth potential for the IRS continuation series was kept in mind. For example, by providing a structural platform for accommodating the mainframe systems while keeping a separate payload platform with its essential attitude sensing systems together, feasibility was introduced to enable reconfiguration and augmentation of the payloads in the future series of satellites without large scale effect on mainframe platform. On the platform side also similar capability extension possibilities were in-built like generating additional power of 20-30 % by minor augmentation in solar panels and battery support systems. Similarly, telemetry and data handling system were designed with features like variable format, with sufficient adaptability to various mission requirements.

A passive and semi-active thermal control system ensured the temperature control for payloads (15 to 25 deg C) and battery within closer limits (0 to 10 deg C) while for other systems it was within 0 to 40 deg C. Power system with 8.5 square metre solar arrays provided 840 watts of power at EOL, supplemented by two 40 AH NiCd batteries to support peak loads and eclipse operations. The TTC & C system operated in S-band with modulation scheme for telemetry chosen as PCM/PSK/PM and for telecommand as PCM/FSK/PM/FM. An additional VHF link with AM with an identical onboard decoder was provided as a back-up to S-band uplink as an added precaution, being the first-ever satellite mission in ISRO to have S-band systems. An S-band coherent transponder served as part of the telemetry down link and command uplink. It was also used for Doppler tracking by phase locking the transmitter downlink carrier to the uplink carrier with a ratio of 240/241 and demodulating the ranging tones for subsequent phase modulation in the S-band downlink.

The Data Handling system was in S and X-bands. The data from LISS-1 camera was converted into a PCM data stream at 5.2 MBPS was transmitted through a BPSK system in S-band. The data from each of the two LISS-2 cameras each at 10.4 MBPS were fed into I and Q channels of a QPSK modulator and transmitted in X-band.

The AOCS system comprised of different types of attitude sensors (like earth sensors, sun sensors, star sensors and magnetometers) and actuators such as reaction wheels, magnetic torquers, and thrusters for 3-axis control and maintenance of the spacecraft in orbit. The reaction control system (RCS) using mono-propellant hydrazine fuel helped in initial attitude acquisition, and other orbit/attitrude correction/maintenance activities throughout the mission.

REALISATION OF GROUND SEGMENT

The newly developed ISRO Telemetry, Tracking and Command network (ISTRAC) at Peenya, Bangalore with Satellite Control Centre (SCC) and a TT&C station using a 9 meter parabolic dish antenna served as the nerve centre for all TTC operations of IRS-1A. The functions include data reception of house-keeping systems in real time and play back modes, telecommanding in VHF and S-band as well as generation of range & range-rate information through tracking.

The payload data reception system implemented in NRSA, Shadnagar, Hyderabad with capability to acquire LISS-1 data in S-band and LISS-2 data in X-band using a 10 metre parabolic dish with a composite S/X-band feed. The signals were down converted to 375 MHz in X-band and 75 MHz in S-band, before demodulation in QPSK for X-band and BPSK for S-band. The data was recorded on High Density Digital Tape Recorders for further processing. The data products generation system at NRSA, Balanagar, Hyderabad comprising of image processing computers, special photographic facilities provided vital support in generating a variety of data products such as high density digital tapes (HDDT), 70 mm film products, microfiche, 240 mm B&W and colour prints, Computer Compatible Tapes (CCT), and False Colour Composites (FCC) for different levels of data processing and corrections such as Browse, Standard, Precision, and Special Products.

While most of the above space and ground systems were developed indigenously, some critical elements had to be imported. Some of the major items needed from the spacecraft side were Charge Coupled Devices (CCDs); Payload Optics; Travelling Wave Tube Amplifier (TWTA); Solar Cells; and Ni-Cd batteries. From the ground segment side, the major imported component was High Density Digital Tape Recorder for the data reception station at Hyderabad.

LAUNCH INTERFACE AND THE POST LAUNCH OPERATIONS

As PSLV was not yet ready for operational launch, ISRO had to look for an external launcher for IRS-1A. Based on extensive discussions on various aspects for identifying a suitable launcher with proven capability, including technical and financial aspects, a VOSTAK launcher from Soviet Union was selected. Soviet Union, which had earlier helped in providing vital components for ARYABHATA, and BHASKARA 1&2 missions including launch at no cost came up with an offer to launch IRS-1A at a very reasonable price of just around Rs 7.5 crores. Many fruitful discussions were held with the Soviets to identify the spacecraft interface with the launcher and associated interface tests and the schedules. One would always remember the cooperative spirit displayed by Dr. L.A. Goroskov the Project Director for the launch vehicle from Licence In Torg (LIT) and his team in helping in solving many ticklish problems.

The flight model was flown from Bangalore on an Aeroflot IL-76 cargo aircraft on 24th January 1988 to Baikonur Cosmodrome. The cosmodrome operations including extensive ground checkout tests, solar panel deployment test etc., went on smoothly and IRS-1A space craft, after loading the fuel, was integrated to the VOSTAK 2M launcher and taken to the launch pad in a horizontal position. The satellite was launched successfully at 12.13 hours IST on March 17, 1988 marking a successful and satisfying culmination of the launch agreement signed between ISRO and License In Torg (LIT)..

Post launch operations went on as planned with the support of a network of TT&C stations around the world such as Bears Lake near Moscow; Fairbanks, Alaska; Weilheim, Germany; Malindi, Kenya operated by ESA.; and our own stations spread over India. The spacecraft after injection went through some of the teething difficulties in the early orbits of 3-axis data acquisition before successfully completing the same. The LISS-1 payload was switched on day-2 of the launch (on March 18, 1988) and LISS- 2 after 7 days as planned to enable the complete degassing of the HV part of the TWTA. The payload data was of excellent quality. And the era of operational remote sensing commenced in the right earnest. Rest is history!!

A FEW REMINISCENSES OF INTERFACING WITH SOVIETS

Obviously, the long years of cooperation with the Soviets and Russians made lasting friendship between the engineers and scientists from both sides, treading in the process smooth to frustrating and tumultuous moments involving hours of discussions and endless translations. Some extraordinary lessons were learnt too in the process. A few of them are brought out below:

(i) **Building margins of safety**: Though Soviets have achieved so much in space technology those days, they continued to remain conservative in approach of building design margins at every stage to take care of any eventuality of contingencies. For example, though their launch vehicle, VOSTAK has proven its launch capability in many missions their launch dispersion specifications were kept at 60 m/sec, calling for additional fuel margin in the IRS-1A accounting for possible in-plane and out- of-plane corrections in orbit. The actual performance of the launch vehicle was much better (to the order of 20 m/sec). (This abundant precaution of building additional margin came in handy in our own PSLV/IRS-1D mission later).

(ii) **Encourage Stand-by model ready**: Soviets insisted that an additional IRS-1A equivalent spacecraft model ready at the time of launch. Similarly, even a launcher was kept ready to ensure that in case of any unlikely event of launch failure, the spare model could be launched within a week or two. While this abundant precaution may look strange in a commercial world, it reflects on the value system of cooperation, the Soviets believed in.

(iii) **Belief System**: On a lighter side, the traditional belief system in ‘luck’ persisted in the Soviet side too, though working under a Communist system. When the integrated launcher was moved in horizontal position to the launch pad, the senior personnel from both the launch vehicle and the spacecraft side were expected to walk along with the vehicle, touching it all the away, even as it was snowing and misty on the day of IRS-1A launch. That ‘human touch’ to the inanimate vehicle as it is towed to the launch site makes one feel humble and respectful to that value system they cherish!

(iv) **Respect to the Designer**: In the block-house where the spacecraft and launch vehicle team converge for the final launch operations, it is seen that one window is kept reserved for the original designer of VOSTAK system to have the last peep of the vehicle before it takes off. This is yet another value system of respect which attracted our attention.

(v) **Closer view of the launch**: Yet another outstanding part of the confidence Soviets display on their vehicle performance is to allow the viewing of the launch from outside the block-house just around 800 metres from the launch pad. Even as this experience of witnessing the launch very close, feeling the ground shaking and hearing the thunderous roar was exciting, one cannot but notice the enormous confidence Soviets had in their vehicle performance.

CONCLUSION

IRS-1A mission symbolises the first major step taken by the country to develop a state-of-the-art operational capability in remote sensing addressing on an end-to-end basis; from the user requirements to realisation of space & ground segments in a systematic manner meeting all the mission specifications, thus, establishing the ‘APPLICATIONS DRIVEN BUT NOT LAGGING BEHIND IN TECHNOLOGY’ motto of ISRO in an emphatic manner. The success of IRS Programme with IRS-1A and its follow on satellites such as IRS-1B, IRS-P2, IRS-1C/2D and TES; and the later RESOURCESAT (including RISAT-1), CARTOSAT, and

OCEANSAT series of thematic satellites was essentially due to the extraordinary commitment displayed by the young engineers and scientists, working in a matrix management style of ISRO and the continued team spirit displayed by them in building a robust and reliable spacecraft bus and payloads of international standards. If today ISRO is hailed as one of the most performing organisations meeting the developmental needs of the country and is well-respected in the international arena for space technology applications, IRS-1A could be rightly termed as the fore-runner which set the benchmark for these acclaims.

Soviet Union and its successor Russia helped significantly at critical initial stages of the Indian satellite programme both on a cooperative and commercial basis. While ARYABHATA and BHASKARA 1&2 were launched on a cooperative basis at no cost, IRS-1A and the follow-on satellites, IRS-1B and IRS-1C, were launched on commercial arrangements, before PSLV became operational to meet the launch requirements of all the future IRS missions and much more.

In this long standing cooperation on space, the stellar role played by the following doyens from USSR Academy of Sciences and many other institutions including their scientific and commercial establishments like DB Yuzhnoye, Licence In Torg (LIT) and Glavkosmos (GK) still remains fresh in our mind:

Academicians: Prof. Boris Nikolaevich Petrov, Prof. Vyacheslav M Kovtunenko, Prof. Novikov, and Prof. Kotelnikov;

Project Directors, Dr Anatoly Popel (Bhaskara), and Igor Nikolavich Goroshkov (IRS-1A) and their dedicated teams.

Academician Prof. Aleksei Fyodorovich Bogomolov (Director, Moscow Power Institute & Bears Lake Ground Station) and Dr Perminov (Chief, MPI & Bears Lake),

Dr Lev Alexandrovich Krasnov (Bears Lake), Dr Kira K Belostoskaya (Antenna Expert), Dr Oleg Popkov (Orbit & Trajectory expert)

&

Prof. Alexandr Ivanovich Dunaev (Chief, Galvkosmos) and Dr Vasin (Glavkosmos)

.... to name only a few.

Through this article, we pay our respects and tributes to the above pioneers and many others from Soviet Union and Russian side, who were part of our initial journey which enabled ISRO to take up more complex missions later, both in the launch vehicle and the satellites domains.

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