EARTH OBSERVATION PROGRAMME OF INDIA – CATERING TO NATIONAL NEEDS OF SUSTAINABLE DEVELOPMENT

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Abstract

Civilian Earth Observation programmes have demonstrated the utility of space-based data to a variety of users - specifically those associated with the natural resources management. Its future will depend upon how the systems meet the demand of monitoring global environment; mapping, charting and geodesy; long-term global change research and assessment; monitoring and managing the renewable and non-renewable resources and national security applications. The future Earth Observation Systems (EOS) will have to take into consideration the aspects relate to the globalisation and standardisation of programmes world-over; data continuity and the need to monitor processes rather than events. Technological changes are also going to re-define many of the concepts of observation from space and issues like spatial resolution, spectral resolution and temporal resolution may no more be a concern for observation systems.

In the Indian context, with the launch of IRS-1C, in December, 1995 and IRS-1D in March, 1997, user services have been significantly enhanced. Based on a thorough analysis, the observation needs of the future are planned and presently systems design and implementation are underway. The Need Analysis has been done keeping in mind the Global change applications; Mapping and Cartographic applications; Natural Resources and Environmental management applications etc.

The paper discusses the strategy adopted for assessing the future requirements and also for defining the future Indian missions – which are applications specific solutions. The candidate payloads, platform details of these missions are discussed in the paper. A decade profile of Indian Remote Sensing missions has been defined which addresses the concept of continuity, operational missions and the advanced missions upto 2005. The impact on utilisation accruing from these proposed missions has also been assessed.

1.0 INTRODUCTION

Viewing the Earth from Space emphasises the global nature of our planet and its resources and also the fragility of the environment to change from both natural and man-made resources. The human-race faces the conflicting challenge of an increasing population and limited natural resources. On the other hand, it is imperative to maintain the environment for the future generations. This necessitates the development of natural resources to meet the immediate needs of the present population and the requirements of the future generations without in any way endangering the ecology and environment - thus recognising the fact that economic growth and environmental protection are inextricably linked.

Earth Observation (EO) satellites provide the vantage point and coverage necessary to study our planet as an integrated, interactive physical and biological system. The key areas where EO data is of use is Global environment change monitoring, management of renewable and non-renewable resources, resources mapping, geo-positioning applications and also for strategic applications of national security.

The trend in EO observation is towards contributing to sustainable development by serving as environmental and economic drivers for growth and development. Trends are towards:

a) Obtaining high resolution imaging of land and water features - oriented towards replacing aerial photography missions so as to address local-level resource management

b) Intensification of observation of solid earth, atmosphere and oceans as an integrated system for understanding the Earth processes and global change.

Over the past decade, India has increasingly turned to satellite remote sensing to gather data about the Earth's atmosphere, land and oceans. The programme has evolved into an operational programme from the early seventies, when the experiment to detect Coconut wilt disease using aerial survey data was conducted in Kerala, through an experimental phase of remote sensing missions - Bhaskara I and II, during 1979 and 1982 respectively and the Joint Experiment Programme (JEP) - initiated to dove-tail the users requirements with the sensor technology and development of applications packages.

With the launch of IRS-1A in March 1988, IRS-1B in August 1991, IRS-P2 in October 1994, IRS-1C in December, 1995, IRS-P3 in March, 1996 and IRS-1D in march, 1997, remote sensing data services are continuously available to the users. The thrust has also been on applications of the data to support key sectors of development - land and water resources management, coastal and marine resources, forest management, agricultural crops monitoring, flood and drought management, environmental monitoring, geology and minerals etc.

Further, IRS data is also being distributed in the international market as part of an agreement between Department of Space (DOS) and EOSAT Co. of USA under which IRS data is being received at various international ground stations.

2.0 SUSTAINABLE DEVELOPMENT – ISSUES AND CONCEPTS

Man's dependence on environment is reflected in the pursuit of progress, comforts and security which causes mores stress on the environment. As a result, the life-sustaining mechanisms are stretched to limits and this poses a challenge to the society as a whole. The rapid increase in greenhouse gases in the atmosphere, large-scale deforestation and its impact on bio-diversity, land degradation and pollution have become local as well as global concerns. Locally, the impact is felt in the changes in climate, agricultural productivity and loss of bio-diversity, social patterns and culture etc. These problems are compounded in the developing countries - mainly because of the rapidly growing population and serious shortage of resources.

The fundamental aspect of sustainable development lies in the paradigm of scientific innovation and economic determinism within the physical limits imposed by ecological systems on economic activity. At the root of this concept is the fact that the environment does pose a limit for development and economic activity and a balance must be struck between environmental constraints and developmental activity. The economics of development must expand within ecosystems that have limited regenerative capacities. The need is for a full integration of environmental and developmental issues for decision-making on economic, social, fiscal, exploitation and regeneration of natural resources and other policies {1}.

2.1 Towards sustainable development

Within the framework of sustainable development, planning needs also to oriented towards addressing both short-term and long-term implications and needs to address:

a) natural resources optimisation in developmental projects so as to minimise the impact on environmental degradation from the inputs of natural resources.

b) integrated rather than sectoral developmental approach. Planning based on the sectoral approach, with separate financial allocation made for different sectors of economy, like agriculture, forestry, etc. fails to recognise the multi-dimensional interlinkages between various natural resources and environment and hence produces results/plans which would be not sustainable.

c) adopting natural boundaries defined by river basins/sub-basins as a planning unit rather than an administrative unit which does not take into consideration the boundaries of resource transgression.

d) stress needs to be on determining different alternatives and selection of the most sustainable solution for development.

e) people's participation for a proper definition of the developmental needs/requirements.

2.2 Information needs

For effective planning and development, a variety of data on physical and natural resources, human resources, social practices and economic aspects etc. are required. Keeping in view the scope and content of plan and from overall development needs of a region, information needs for the planning could be broadly grouped into following data sets:

a) Natural resources data in terms of land use, cropping area, water bodies and drainage, soils, terrain characteristics, mineral resources etc

b) Demographic data - relating to population, sex ratio, age structure, urban and rural population, scheduled caste and scheduled tribe population, occupational structure migration etc.

c) Agro-economic data - comprising information about cropped and irrigated area, agricultural production, land holdings, live stock population etc.

d) Socio-economic activities relating to industrial, fishing activities, tourism development as well as beneficiary of various schemes and programmes of development.

e) Infrastructure data relating to availability and level of various facilities - utilities and services such as education, health, power, transport network, water supply, drainage etc.

2.3 Role of Earth Observation

Earth Observation data is a classic source of data on natural resources for a region and provides a record of the continuum of resource status because of its repetitive coverage. Remotely sensed data in the form of satellite imageries can be used to study and monitor land features, natural resources and dynamic aspects of human activities and towards preparation of thematic maps depicting various resource status - land use, cropping area, water bodies and drainage, soils, terrain characteristics, mineral resources. Thus, remote sensing data has to be an important element for the sustainable development activity. In a Geographical Information Systems (GIS) framework, integration or the synthesis of the spatial data, obtained from EO, and non-spatial information will have to be at the core of the sustainable development activities.

3.0 INDIA EO PROGRAMME - ACHIEVEMENTS

The EO programme in India follows an application driven approach and this has enabled the optimum utilisation of the remote sensing technology to address national priorities. With active user-participation, the programme has evolved to provide vital inputs to decision-making at central and state levels for sustainable development {2}.

3.1 Space and Ground Segment

The Indian Remote Sensing (IRS) satellites are the mainstay of NNRMS, providing operational remote sensing data services. Data from other satellites like Landsat, ERS-1, NOAA is also used to supplement the needs. The aerial remote sensing facilities are also effectively utilised for different types of aerial surveys. Presently, IRS-1C and IRS-1D, provide data from the following sensors:

* Panchromatic camera (PAN) which has a spatial resolution of 5.8 m, operates in Panchromatic region of the Electro-magnetic spectrum, with a swath of 70 km and can be steered up to + 26° across-track - thus enabling generation of stereoscopic imagery and improved revisit capability.

* Linear Imaging Self-Scanning - III (LISS-III) camera operating in four spectral bands - three in Visible/Near Infrared (VNIR) and one in Short Wave Infrared (SWIR) region. It has a spatial resolution of 23.5 m in VNIR bands and 70 m in SWIR band and a swath of 142 km and 148 km, respectively.

* Wide Field Sensor (WiFS), a coarse resolution camera with spatial resolution of 188.3 m and covering a wide swath of 810 km with 2 spectral bands in visible and NIR region.

Apart from the above, IRS-P3 satellite provides data from the following payloads:

* Modular Opto-electronic Scanner (MOS), designed and developed by DLR, Germany, is a 18 channel imaging spectrometer in visible/near-IR region and would provide an effective ground resolution of 500 m x 500 m and a swath of around 200 kms. The MOS payload is optimised for oceanographic applications.

* Wide Field Sensor (WiFS), similar to that of IRS-1C but with an additional Short Wave IR (SWIR) band and is used for the study of vegetation dynamics.

The National Remote Sensing Agency (NRSA), Hyderabad continued to acquire, process and disseminate data from India's IRS-1A, IRS-1B, IRS-1C, IRS-P2, IRS-P3 and IRS-1D, Landsat 5, European ERS-1/2 and US NOAA satellites. A variety of data products in the form of Black & White (B&W), False Colour Composite (FCC) and Computer Compatible Tapes (CCT), geocoded products, floppy and cartridge products and digitally mosaiced data. About 17,000 data products, including 14,000 from IRS, were supplied to the users during the current year.

3.2 Applications and Utilisation Segment

As a step towards establishing operational procedures for applications of remote sensing data for resources management, the Department of Space, along with user departments/agencies took up national-level projects in different resource management areas - oriented towards the goals of NNRMS. With active participation and funding support from User departments/agencies from both Central and State Governments, the technology, over the last two decades, has matured to cover diverse resource themes/areas such as forestry, wasteland mapping, agricultural crop acreage and yield estimation, drought monitoring and assessment, flood monitoring and damage assessment, landuse/land cover mapping, wasteland mapping, water resources management, groundwater targeting, marine resources survey, urban planning, mineral targeting and environmental impact assessment, sustainable development of land and water resources at rural watershed levels, etc.

3.2.1 Integrated Approaches for Support to Developmental activities

Realising the importance of adopting an integrated approach and recognising the mutual inter-dependencies of natural resources, the Department of Space at the behest of the Planning Commission and the Ministry of Rural Areas and Employment, initiated a major programme - Integrated Mission for Sustainable Development (IMSD). Under this mission, remote sensing based integrated land and water resources studies for 174 problem districts have been taken up. The IMSD approach involves integration of thematic information on various natural resources - land use/cover, types of wastelands, forest cover/types, surface water resources, drainage pattern, potential ground water zones, geomorphology (landforms), geology (rock types, structural details, mineral occurrence), soil types, etc. derived from satellite data and integrating them with other ancillary information, meteorological and socio-economic data in a Geographic Information System environment to arrive at locale-specific prescriptions for development. The locale-specific action plans include recommendations on water harvesting through farm ponds and check dams; soil conservation through terracing and contour bunding; afforestation, agro-forestry and agro-horticulture; fuel wood and fodder development; sand-dune stabilisation; mining and necessary conservation measures, etc.

3.3 Human Resources Development

Recognising the importance of human resources development for space related activities, regular training and education courses are conducted for professionals, students, teachers etc. The Indian Institute of Remote Sensing (IIRS) and other ISRO/DOS centres - Space Applications Centre, National remote Sensing Agency and Regional remote Sensing Service Centres provide regular courses in remote sensing. Apart from this, the State RS Centres, various central/state agencies like GSI, CGWB, AISLUS, NBSSLUP, SOI, IARI etc and academic institutes like IITs, Anna University, etc conduct regular training programmes in remote sensing. All these training facilities have helped in creation of a trained manpower base of about 3000 persons in the country.

Based on the strengths of India's space technology programme and the indigenously developed end-to-end capability, the United Nations has selected India to host the Centre for Space Science and Technology Education in Asia and the Pacific (CSSTE-AP). The Centre has been established in Dehradun and has started its regular education programmes - the first of which is on Remote Sensing and GIS.

Universities are actively involved in the EOS programme and take up research project/activities under the RESPOND scheme. Universities also have courses in RS which are at PG level or as papers in specific thematic courses.

4.0 FUTURE THRUSTS OF EO PROGRAMME

4.1 Assessment of Observation Needs for Sustainable Development

As mentioned earlier, the EO programme is primarily driven by the needs of the nation. Until now, a wide variety of applications have been operationalised and the benefits of satellite data have been widely felt. However, in the Indian context, the key areas {3} of applications that will require enhanced observation capability are:

a) **Management of natural resources to ensure sustainable increase in agricultural production.** Meeting the needs of food, fiber and shelter of the growing population is the country's prime concern. It is important to recognize that today's developmental prospects should not deprive the future generation its legitimate needs. As food is the most critical requirement of a human being, agricultural sustainability assumes the topmost priority in sustainable development.

   Increase in production is possible by bringing more areas under cultivation, by improving crop yields, by increasing cropping intensities and by integrated nutrient and pest management. Sustainable agriculture production would call for identification of problems at watershed level, adoption of proper soil and water conservation measures and optimal land-use planning at watershed level. Watershed characterization requires information on parameters like size, shape, topography, drainage, soils, landuse, landcover, climate and socio-economic data. Each of the applications mentioned above would require different sets of data from EO satellites.

b) **Study the state of the environment, its monitoring and assessment of the impact of developmental actions.** Development programmes have been and continue to be conceived, planned and executed, often causing detrimental effect on the environment. The rapid industrialization, urbanization and commercialization are responsible for increasing amounts of CO2 and other green house gases, air pollution and water and degrading lands. Deforestation trends have caused serious effects on global climate, soil erosion, water resources and food production. River valley projects, thermal power generation, mining, tourism etc., cause extensive damage to our ecosystem.

Impact analysis and assessment needs must be done to minimize adverse impacts. The study of impacts for an environmental impact analysis generally varies according to the type of project, development or action under evaluation. There are numerous bio-physical and socio-economic parameters which need to be measured and monitored as part of the analysis.

c) **Large-scale mapping**. The need for large-scale, high quality, thematic and topographic data has long been realized in various fields. In addition to the problem of producing maps of upto 1:10000 scale, there is a need for updating the existing information on topographic maps. Mapping and detection of changes in urban and cultural features are essential towards management of our settlements and planning of facilities. Similarly, the mapping of forests, landuse, geology etc at large scales are essential for the management of the resources at the local level. All developmental activities require elevation information at different scales. The generation of Digital Elevation Models (DEM) from satellite data will be a major application area.

d) **Exploration of marine resources and Oceanography**. India has a long coastline of about 7500 km including its island territories. Exploitation of its marine resources including living and non-living resources is a necessity to meet the food and fuel demands of the increasing population. Fisheries, aquaculture, seaweed harvesting etc., are some of the fields which need to be explored. An understanding of photosynthetic processes (primary production) is required to assess the marine biological resources of the globe, including pelagic and demersal fisheries, shellfish and even organic sedimentary deposits. Determining accurately the concentrations of photosynthetic pigments and the rates of photosynthetic carbon fixation in the surface euphotic layer lead to improved estimates of primary production in the ocean. Global information on geographical and seasonal variations in primary production will allow a more complete assessment of secondary production processes in the oceans.

e) **Inventory of non-renewable resources.** Unlike other surface phenomena, mineral resources are generally sub-surficial in nature. Occurrences of petroleum/mineral deposits are never haphazard. All the mineral/petroleum deposits follow certain mineralisation/structural patterns with various surficial indicators/guides which helps in their identification. Although many such guides exist in the conventional geological/geophysical method of prospecting, all of them cannot be followed in toto through airborne/space-borne remote sensing. Main limitation in usage of remote sensing for mineral/petroleum exploration is due to the fact that the mineral deposits are often relatively small targets located at considerable depths. The petroleum basins are in general highly deep-seated with limited surficial expressions. These limitations restrict the usage of remote sensing only to a reconnaissance level, providing input to further detailed ground-based geological/geophysical investigations.

f) **Process studies to study climatic change dynamics**. Climatic changes are affected by biological and geophysical processes. Oceans, forests and human activities, over the years have control over global climate. Earth's environment is the cumulative result of various biogeochemical interactions within the land-ocean-atmospheric system as well as energy-mass transfer between the earth and planetary space. A predictive knowledge about the environment require elaborate observation capabilities with adequate temporal and spatial resolution so that regional and global variations in geophysical, chemical and biological state of the earth system can be monitored. Various phenomena which influence the environment and thus have to be monitored include:

- Energy, mass exchange between space and Earth
- Energy, momentum and mass exchange between earth and atmosphere
- Biological activities on land and near surface water
- Atmospheric chemistry and atmospheric dynamics
- Precipitation, lightening etc.
- Ocean dynamics, sea surface temperature etc.
- Sea ice dynamics
- Surface geology, tectonic plate motion, tides, geologic faults etc.

g) **Operational meteorology and weather prediction**. Operational meteorology is concerned with forecasting the weather over all geographical scales and for periods ranging from upto a week to months. A number of measurements are required on a regular basis for operational meteorology. Temperature and humidity profiles, wind fields, cloud cover and temperature, cloud heights, liquid water content, precipitation, ocean topography etc., are some of the parameters that need to be measured not only for operational meteorology but also for climate monitoring and predictions.

4.2 Translation into EO Goals

The application thrust areas can be categorised into major areas of observation needs {4}, as follows:

a) **Cartographic applications where the need is for small-target detection and mapping of features in mixed-clusters**. The needs of mapping and feature detection require better elevation information and spatial scales of about 1:10,000+ would be essential. While resolutions of about 6 m (as provided by IRS-1C/1D) are adequate for updation of these thematic maps, information generation at this scale requires about 1-3 m resolution. Ideally, it is said that from information content point of view, a resolution of 1m would be essential to detect and map features at better than 1:25000 scale. Elevation differences of about 1m would also need to be mapped for cartographic and cadastral applications.

This segment would also be able to cater to the larger aerial photography market - which is a major share of the total EO market. As a result, many of the applications using aerial photographs can be done using this data and thus dependency on aerial surveys would reduce to a large extent.

b) **Crop and Vegetation applications**. With specific reference to crops and vegetation, the parameters of observation for agrometeorology, crop detection etc need to be encompassed with better spectral resolutions - specifically in the shortwave-infrared and ground resolution of about 10-20 m for different spatial bands. Another additional requirement apart from 10-20 multispectral is the pointability of the 5-10m multispectral sensor that would enhance the coverage and allow selective area addressing - which is crucial for the sample sites in the crop acreage and yield estimation applications. In conjunction, the WiFS ground resolution could be improved to around 100-150m with larger swath to assist in discriminability of vegetation types.

c) **Oceanographic applications**. Observation of physical oceanographic parameters like winds, sea surface temperature, waves, bathymetry, internal waves etc and biological parameters like phytoplankton etc., are essential towards the exploitation of the ocean resources. Targeting fish schools at deeper depths of the oceans is also important to help fishermen community increase their fish-catch, which has an important bearing on exports.

d) **Atmospheric applications**. Towards the study of land, air, ocean interaction (in the context of IGBP and other global initiatives) which are essential for monitoring global-changes - specifically of the ozone and other green-house effects, earth radiation-budgets, clouds, atmospheric constituents etc, observation of the atmosphere at coarser resolutions, high repetitivity and with instruments suited for atmospheric compositional analysis are essential. Synergy and simultaneity are the essential elements of a global system for these applications, and planning complementary/supplementary missions is the essential need.

TABLE - 1 shows the gap-areas and the observational needs to cover these areas.

5.0 DEFINITION OF FUTURE EO MISSIONS

Realising that these gap-areas and thrust applications need to be covered in the future IRS mission, a definition of the IRS Continuation missions has been made considering:

a) the application gap-areas and the need to leap frog in technology and applications, and be a front-ranked leader globally

b) state-of-art of technology in devices, optics, data handling, signal processing etc. towards catering to the application needs and their timely availability.

c) the opportunity of appropriately utilising the already approved developmental flights of PSLV and plan low-cost fast turn-around, application specific missions. As a result, all EO missions are planned for PSLV launch.

5.1 Sensor and Platform definitions for IRS-P4 (Oceansat-1)

IRS-P4 (OCEANSAT-1) will have payloads specifically tailored for the measurement of physical and biological oceanography parameters {5}. The IRS-P4 is slated for early-1998 launch by PSLV-C2.

5.1.1 Sensor characteristics of IRS-P4

The sesnor configuration for IRS-P4 are as follows:

* A 8-band **Ocean Colour Monitor (OCM)** with ~350m resolution in VNIR band and 500m resolution in SWIR band and having a swath of 1500 kms. The instrument will provide two days repetitivity. The shortwave band (1.6 um) has been added to use the experience that will be gained from MOS-C of IRS-P3 which will enhance the land applications.

  To provide better information on chlorophyll distribution near to the coast, 250m resolution is proposed for the OCM. This is expected to give better prediction capability of PFZ close to coast to help traditional fishermen. This will also help to use the data in a better way for a number of land applications (for example, snow melt run-off). However, in the case of SWIR the spatial resolution is kept at 500m due to limitations of the sensor devices in this band.

  High radiometric sensitivity and dynamic range will be required to measure the reflectance varying from 0.7 to 7% from the ocean surface. The bands 0.555-0.575, 0.655-0.675, 0.845-0.885 and 1.55-1.7 micrometer will have a dynamic range covering 100% solar reflectance, thus making it suitable for land (including snow and cloud) studies also.

* **Multi-frequency Scanning Micorwave Radiometer (MSMR):** To complement the biological ocean parameters measured by OCM with some of the physical oceanographical parameters such as Sea Surface Temperature (SST), wind speed and atmospheric water vapour, etc., a Multi Frequency Scanning Microwave Radiometer (MSMR) has also been chosen for this mission. Besides complementing OCM with physical oceanographic variables, MSMR will also provide important data during monsoon period which otherwise is not available on regular basis due to cloud cover from other operational VNIR sensors. The MSMR will also be configured to provide 1500 kms swath so as to have ground coverage identical to OCM. The unique combination of optical and microwave sensors, monitoring the same swath concurrently will enable oceanographic applications such as study of surface currents and measure scales ETTIS and GYRES and modelling the mixed layer, not possible with other satellite systems.

  As the microwave emission characteristics are different at different frequency and polarisation, a multi-frequency dual polarised radiometer system is a must to retrieve the required geophysical parameters. The frequency and polarisation combination for MSMR have been arrived at by taking to consideration various applications such as atmospheric water vapour, SST, precipitation over oceans, ocean surface winds, cloud liquid water, snow/ice coverage, etc. Considering the sensitivity of various geophysical parameters at different frequency bands, following frequency/polarisation combination has been found most optimum :

- 6.6 GHz(V&H)
- 10.6 (GHz) (V&H)
- 18 GHz (V&H) and
- 21 GHz (H)

The system has been configured with conical scanning mechanism so that the data is corrected at a constant incident angle of 50 deg. Over the total swath. Various receivers are configured using Dicke configuration with two point onboard calibration using hot termination and cold sky horn antenna.

TABLE - 2 shows the specifications of IRS-P4 payloads.

5.1.2 IRS-P4 Spacecraft main bus

The spacecraft mainframe configuration is derived from the experience of developing IRS-P2/P3/1C/1D. The mainframe changes will be those pertaining to interface changes for payload accommodation. Besides to facilitate global data coverage of scanning microwave radiometer data, solid state recorder of 128 Mbits capacity is included in the mainframe to store atleast 3 continuous orbits of data. Also the mainframe has satellite positioning system to have better orbit determination accuracy leading to improved location accuracy.

5.2 Sensor and Platform details of IRS-P5 (Cartosat-1)

IRS-P5 (CARTOSAT-1) will have a cutting-edge technology in terms of sensor systems and will provide state-of-art capabilities. The satellite will have only a PAN camera with 1-2.5 m resolution and ~12-30 km swath and Fore-Aft stereo capability. The 1-2.5 m resolution data will cater to the specific needs of cartographers and terrain modelling applications. The 1-2.5m stereo data could be modelled for obtaining terrain height information and it would be possible to map elevation differences of about 2-5m that will considerably improve the contour information for environmental manage- ment and implementation activities. This satellite will provide cadastral level information upto 1:5000 scale for thematic applications {6}.

5.2.1 Payloads Configuration for IRS-P5

In IRS-P5 spacecraft, the two Panchromatic cameras are mounted such that one looking fore at +26 deg with respect to NADRIR and the other looking aft at –10 deg with respect to NADIR along the track direction. To meet the required resolution and swath within the constraints of spacecraft size and weight, the optical system is designed with three mirror off-axis reflective telescope with an off-axis concave hyperboloidal primary mirror, a convex spherical secondary mirror and an off-axis concave ellipisoidal tertiary mirror. In order to meet the 2.5m, resolution and the swath of 30 km, 12K-8 Port, 7 micron linear CCD detectors have been selected. The payload electronics shall be using high speed ECL devices to meet the data rate requirement of 210 MBPS for minimum of 6 bit quantisation levels. The overall size of one PAN camera will be about 1500 x 850 x 1000 mm^3 and shall weight about 200 kgs.

5.2.2 Spacecraft Platform

The spacecraft mainframe elements will be similar to that of IRS-1C/1D. The structure consists of main platform (MPL) and Payload Platform (PPL). The PPL is attached to MPL through a strut support structure and a CFRP cylinder. The PPL houses the payloads, conical sensor heads, payload data storage, star sensors, gyro package and payload electronics packages. MPL houses the mainframe elements and data transmission systems. The power system will be similar to IRS-P4 except that IRS-P5 will have 40 Nos. of Solar Panels on either side to meet the EOL power requirement of 1100 watts for the global operational requirements of the payloads.

The Attitude and Orbit Control System configuration of IRS-P5 is basically same as that of IRS-1C/1D i.e. 3 axis body stabilised. The stringent pointing accuracy requirements of 0.05 deg and stability requirements of 5×10^5 deg/sec are planned to be achieved by using Star Sensors in loop, better algorithms and magnetic bearing reaction wheels, and using MIL-1750 processor with ASICs and HMCS and operating with 32 msec major cycle time. The RCS will have single surface tension type fuel tank of size 879 mm (OD) mounted within the main central cylinder. There will be 16 Nos. of 1N thrusters and 4 Nos of 11N thrusters to meet the attitude and orbit control requirements.

The Data Handling and Transmission System shall be suing 2:1 Data Compression to compress the payload data rate of 210 MBPS to 105 MBPS and transmit in 2-X Band carriers after QPSK modulation. The TWTAs shall have two out of three redundancy with an output power of 40 watts each.

The overall Spacecraft size shall be of 2.7 mters dia and a height of about 2.9 meters. The total mass of the Spacecraft shll be about 1500 kgs including the payload and the fuel for 5 years of operation.

5.3 Sensor and Platform details of IRS-P6 (Resourcesat-1)

IRS-P6 (RESOURCESAT) will be the state-of-art satellite mainly for agricultural applications and vegetation applications and will have a 3-band multispectral LISS-4 camera with a spatial resolution of better than 6m and a swath of around 25 km with across-track steerability for selective area monitoring. An improved version of LISS-3 - LISS-3' with 4 bands (red, green, near-IR and SWIR), all at 23 meters resolution and 140 km swath will also provide the much essential continuity to LISS-3. These payloads will provide enhanced data for vegetation applications and will allow multiple-crop discrimination; species level discrimination and so on. Together with an enhanced wide-field sensor, WiFS' with 80 m resolution and 1400 km swath, the payloads will aid greatly for crop and vegetation applications and integrated land and water applications. The data will also be useful for high accuracy resource management applications, where the emphasis is on multi crop studies for type mapping, vegetation species identification and utilities mapping {7}.

5.3.1 Payload Configuration

The LISS-III' payload is similar to LISS-III camera payload of IRS-1C/1D. This payload will have 3 visible and near infrared (VNIR) bands covering 0.52-0.59 (Band-2), 0.62-0.65 (Band-3), 0.77-0.86 (Band-4) micron bands; and a SWIR band covering 1.55-1.7 micron (Band-5). The first three bands will have a spatial resolution of 23.5 meters with a swath of 140 kms. The spatial resolution and swath combination of band-5 (SWIR) is also planned to be around 23.5 meters and about 140 kms respectively. The lens modules, detectors and electronics are identical to that of IRS-1C/1D except for the SWIR band wherein the optics design and the detector are modified to suit the required resolution.

LISS-IV is a multi-spectral camera having three bands which are same bands 2,3,4 of LISS-III with a spatial resolution better than 10m and a swath of about 23.6 kms alongwith steering capability of ±26° across track. The electro-optic module for LISS-IV is identical to that of PAN camera of IRS-1C/1D.

The AWiFS camera is also a solid state push-broom sensor operating in three spectral bands which are identical to B3, B4, B5 of LISS-III camera. AwiFS is a wide angle medium resolution camera providing a ground resolution of around 100m and a swath of around 700 kms. This wide swath coverage enable AWiFS camera to provide a repetivity cycle of 5 days for any given location on the ground.

TABLE – 3 shows specifications of IRS-P6 Payload.

5.3.2 Spacecraft Platform

The spacecraft mainframe elements will be similar to that of IRS-1C/1D. The structure consists of main platform (MPL) and Payload Platform (PPL). The PPL is attached to MPL through a strut support structure and a CFRP cylinder. The PPL houses the payloads, conical sensor heads, payload data storage, star sensors, gyro package and payload electronics packages. MPL houses the mainframe elements and data transmission systems.

The power system will be similar to IRS-P4 and shall meet the EOL power requirements of 1000 watts for the global operational requirements of the payloads. The AOCS configuration of IRS-P6 is basically same as that of IRS-1C/1D, i.e. 3 axis-body stabilised. The pointing requirements of 0.15 deg and stability requirements of better than 3 x 10-4 deg/sec are planned to be achieved by using Star Sensors in loop, better algorithms and magnetic bearing reaction wheels and using MIL-1750 processor with ASICs and HMCS and operating with 32 msec major cycle time.

The RCS is similar to that of IRS-1D and will have single surface tension type fuel tank of size 879 mm (OD) mounted within the main central cylinder. There will be 16 Nos of 1N thrusters and 4 Nos. of 11N thrusters to meet the orbit control requirements.

The Data Handling and Transmission System shall also be similar to IRS-1C/1D except some modifications and changes in the data formatter. The TWTAs shall have two out of three redundancy with an output power of 40 watts each.

It is planned to provide 50-60 GB memory capacity solid state recorder onboard IRS-P5 to store about 10 minutes of LISS-IV data or 15 minute LISS-III and AWiFS data for the global operation of the payloads.

The overall Spacecraft size will be of 2.1meters dia and a height of about 2.1 meters. The total mass of the Spacecraft shall be about 1200 kgs including the payloads and the fuel for 5 years of operation.

5.4 Sensor and Platform details of IRS-P7 (Atmos-1/Climatsat-1/Oceansat-2)

IRS-P7 (ATMOS-1/OCEANSAT-2/ CLIMATSAT-1) an integrated mission which will cater to global observations of climate, ocean and the atmosphere {8}. The satellite will have:

* instruments to cater to the needs of oceanographic applications and will have microwave instruments - mainly a Ku-band Altimeter, Ku-band Scatterometer, Microwave Radiometer and a Thermal Infrared Radiometer. Observation of oceanographic parameters like winds, sea surface temperature, waves, bathymetry, internal waves etc would be possible using the data from these instruments. These parameters are essential towards the exploitation of the resources of India's Exclusive Economic Zone.

* instruments for atmospheric chemistry applications and mainly for Global change applications, specifically for atmospheric constituents study, pollution study and monitoring the ozone and greenhouse effects. This would be possible with instruments for atmospheric applications - ATMOS which will have spectrometers, sounders and different radiometers.

* instruments to observe climate and meteorological parameters. The instruments for this have to be firmed up but will include microwave sounders, radiometers, rain radars etc.

5.5 Beyond 2005

Beyond 2005, the thrust will be to have missions having all weather applications, with multi frequency and multi polarisation microwave payloads - both Synthetic Aperture Radar and other Passive instruments. These data sets could also be useful for soil moisture estimation applications and oceanography studies. The development of this satellite is planned to be initiated in the 9th Plan period itself.

Apart from these the development of Hyperspectral Imaging Sensors, Spectrometers, Synthetic Aperture Radar (SAR) etc will also be taken up leading into future EO missions.

The profile of RS missions addresses the concept of continuity, operational missions and the advanced missions upto 2005. **FIGURE - 1** shows the profile of Earth Observation systems for the decade 1995-2005. The impact on utilisation accruing from these proposed missions has also been assessed and is enclosed as **FIGURE - 2.**

6.0 CONCLUSIONS

The Indian Remote Sensing Satellite, IRS-1A, IRS-1B, IRS-1C, IRS-P2, IRS-P3 and IRS-1Dhave provided India with an unique opportunity to use remote sensing data for monitoring and management of our natural resources and environment. India, today has five RS satellites in orbit and in a combined manner one can get RS data once in 7 days.

The trend is to move to better resolutions - spatially to observe local-details and map more details; spectrally to discriminate more features and temporally to observe more frequently. The second generation IRS satellites take cognisance of state-of-the-art technology development scenario in the world and the user requirements during 1990s. The better spatial and enhanced spectral resolutions, more frequent re-visit and stereo viewing capabilities will no doubt throw open many new thrust areas in applications. Application-specific missions for Cartography, Environment, Oceanography etc in the immediate future are also being planned and these will also provide high-quality data for specific applications. Now that the IRS is catering to the global market, the continuity of existing services and enhancing the scope of the applications is a prime consideration so as to be able to provide cost-effective solution for environment management and sustainable development.

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TABLE - 1: APPLICATION REQUIREMENTS FOR OBSERVATION

Theme	Pay-load	Observation characteristics
Cartography	PAN	About 1m resolution for 1:10,000 and better scales of mapping and about 3 m height resolution; Stereo in Fore-Aft; Swath of about 30 Km.
	XS	About 5 m in three bands.
Agriculture	WiFS	About 100-150 m resolution with SWIR band also; 750-900 km swath; 2-3 days repeat.
	XS	About 5 m resolution in three optical bands and SWIR at about 20-25 m resolution; Possibility of Sample-segment viewing
	Spectrometer	Resolutions of about 50 m and about 64 bands in Optical/IR
Agrometeorology		Microwave Sounders, Radiometers and Thermal sensors with Spectrometric observations.
Soils/Crops/Terrain	SAR	Multi-parameter SAR with about 10-20 m resolution for land and water resources assessment
Ocean	Scatt/Alt/OCM	As has been defined for OCEANSAT mission
Atmosphere	Spectrometer	Broad resolution; 64-128 bands in UV/optical and IR

TABLE - 2 : SPECIFICATIONS OF IRS-P4 PAYLOADS

A] OCEAN COLOUR MONITOR

	IFOV (Meters)	~ 350m
	Swath (Kms)	1500
	Instrument Bands	Wavelength (nm)
	1	402-422
	2	433-453
	3	490-510
	4	500-520
	5	555-575
	6	655-675
	7	745-785
	8	845-885
4	MTF	>0.2 AT Nyquist Freq.
5.	Digitisation	12 bits
6.	Data Reate (MbPS)	17.35
7.	Along Track Steering	+20, 0, -20 degrees
8.	Payload Weight	75 kilograms
9.	Payload Power	1 Electro-Poptics Module
10.	No. of Packages	4 Electronics Packages

B] MULTI-FREQUENCY SCANNING MICROWAVE RADIOMETER

	Frequency (GHz)	6.6, 10.6, 18, 21
2.	Altitude (Km)	743
3.	Antenna Dia (cm)	86
4.	Polarisation	V&H, V&H, V&H, H
5.	3 dB Beam Width (deg)	4.2, 2.6, 1.6, 1.4 for respective frequencies
6.	Spatial Resolution (deg (k)	120, 75, 45, 40 for respective frequencies
7.	Swath (Km)	1500
8.	Temperature Resolution (deg. K)	<1.0
9.	Dynamic Temperature Range (deg.k)	10.330
10.	Data Rate	5
11.	DC Power (W)	76
12.	DC Power (W)	76

TABLE – 3 : SPECIFICATIONS OF IRS-P6 PAYLOAD

Sensor	Spectral Bands	Spatial Resolution (m)	Swath (Km)	Radiometric Resolution/Quantisation
LISS-III	B2 : 0.52-0.59 B3 : 0.62-0.68 B4 : 0.77-0.86	23.5	140	7 Bit
	SWIR : 1.55-1.70	23.5	140	7 Bit
LISS-IV	B2 : 0.52-0.59 B3 : 0.62-0.68 B4 : 0.77-0.86	<10	23.5	6-10 Bit
AWiFS	B3 : 0.62-0.68 B4 : 0.77-0.86 B5 : 1.55-1.70	<100	~700	7 Bit

FIGURE - 1 PROFILE OF EARTH OBSERVATION SYSTEMS FOR THE DECADE 1995-2005

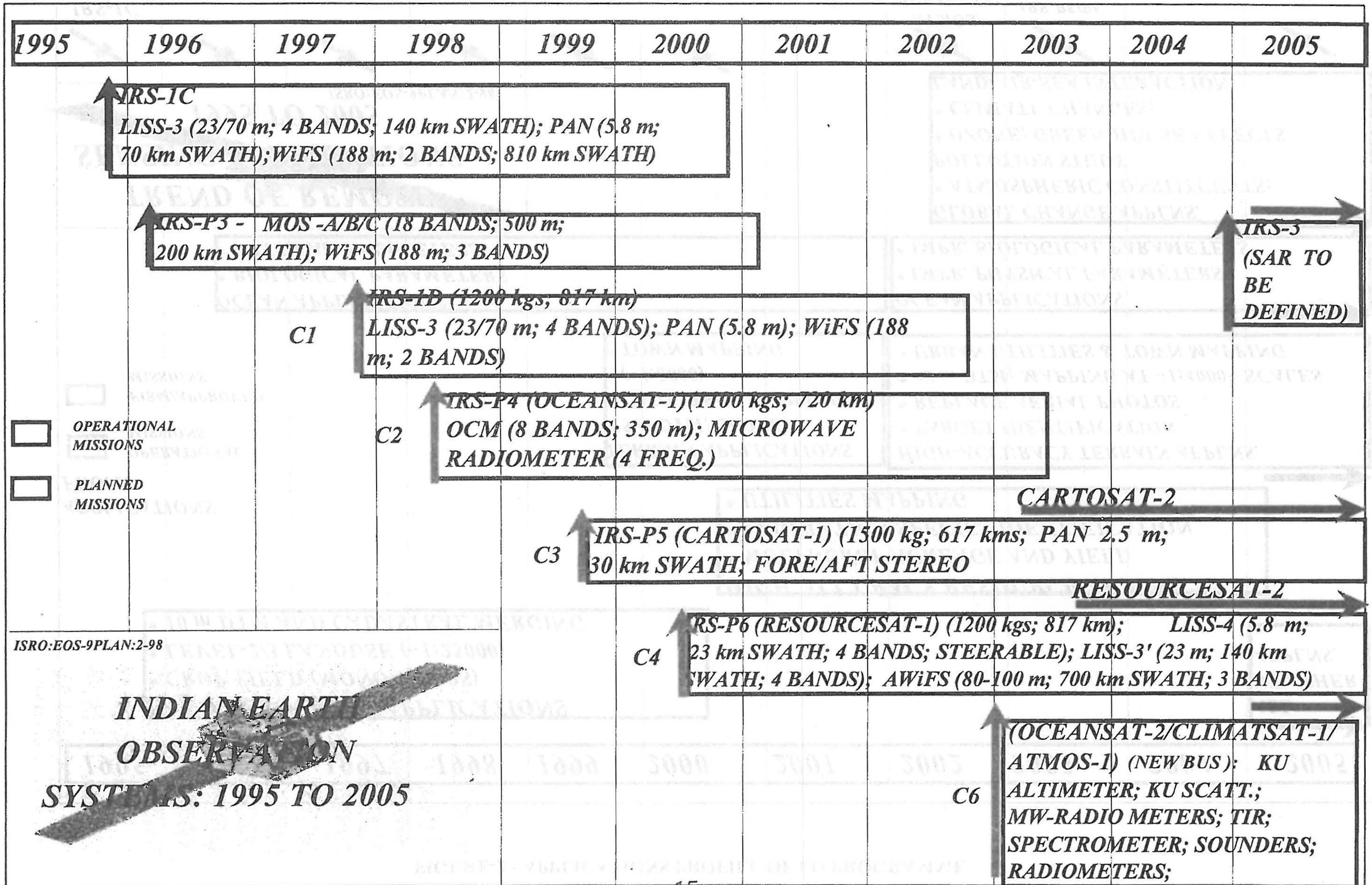

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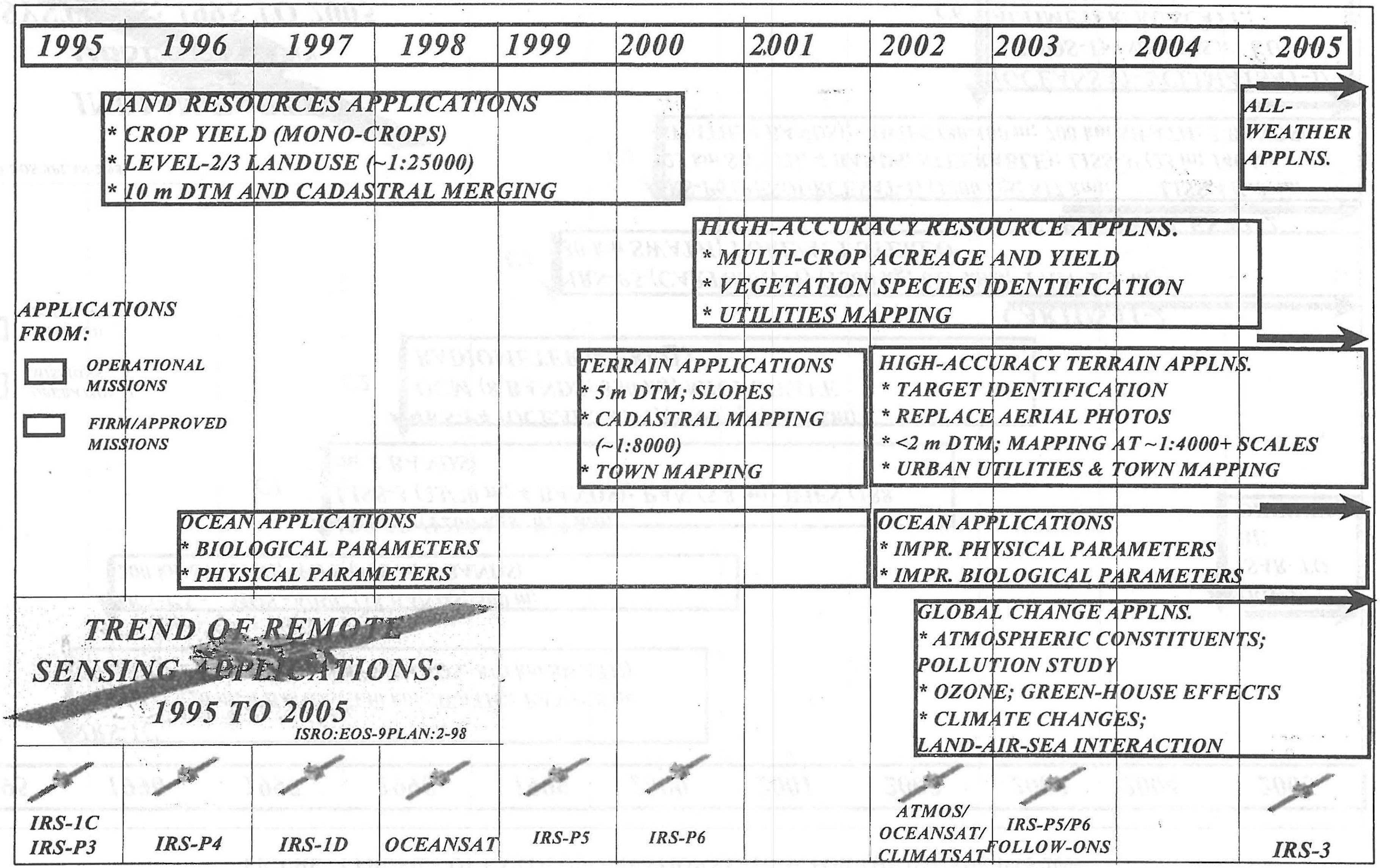
FIGURE-2 : APPLICATIONS PROFILE OF EO PROGRAMME



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