Citizens’ Charter Of Department Of Space

Department of Space (DOS) has the primary responsibility of promoting the development of space science, technology and applications towards achieving self-reliance and facilitating in all round development of the nation. With this basic objective, DOS has evolved the following programmes:

• Indian National Satellite (INSAT) programme for telecommunication, television broadcasting, meteorology, developmental education, societal applications such as telemedicine, tele-education, tele-advisories and similar such services

• Indian Remote Sensing (IRS) programme for management of natural resources and various developmental projects across the country using space based imagery

• Indigenous capability for design and development of satellite and associated technologies for communications, navigation, remote sensing and space sciences

• Design and development of launch vehicles for access to space and orbiting INSAT, IRS satellites and space science missions

• Research and development in space sciences and technologies as well as application programmes for national development

The Department of Space is committed to:

• Carrying out research and development in satellite and launch vehicle technology with a goal to achieve total self reliance

• Provide national space infrastructure for telecommunications and broadcasting needs of the country

• Provide satellite services required for weather forecasting, monitoring, etc.

• Provide satellite imagery required for the natural resources survey, management of natural disasters, public good services and monitoring of environment in the country

• Provide satellite imagery and specific products and services required for the application of space science and technology for developmental purposes through Central Government, State Governments, Quasi Governmental Organisations, Non-Government Organisations (NGOs) and the private sectors

• Undertake proof of concept demonstration of space applications

• Promote research in space sciences and development of applications programmes as per national needs

While implementing the above objectives, the Department of Space will:

• Provide the required satellite transponders and facilities to meet the communications, television broadcasting and security requirements of our country

• Provide adequate earth observation capability in spectral, spatial and temporal domains

• Provide launch services to meet national requirements and commercial needs

• Provide its products and services in a prompt and efficient manner to all the users/clients
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Highlights

The year 2014 has witnessed many momentous achievements of the Indian Space programme which, not only caught the attention of the country but the outside world as well. With the successful Mars Orbit Insertion of Mars Orbiter Spacecraft on September 24, 2014, India became the fourth Nation to successfully send a spacecraft to Mars and the first Nation in the world to do so in its first attempt. The successful launch of first experimental flight of India’s future heavy capacity launcher LVM3 (GSLV-MkIII) on December 18, 2014, which carried Crew Module Atmospheric Re-entry Experiment (CARE) as its payload, marked India’s progress towards self-reliance in launching four ton class of communication satellites into Geosynchronous Transfer Orbit. Besides this, launch of IRNSS-1B and IRNSS-1C - the 2nd and 3rd satellites of the Indian Regional Navigation Satellite System (IRNSS) by PSLV-C24 and PSLV-C26 respectively into the required sub-Geosynchronous Transfer Orbit (sub-GTO) were also achieved during the year. The French Earth Observation Satellite, SPOT-7 along with four smaller auxiliary satellites was also launched by the India’s workhorse launch vehicle, PSLV. The year also saw the launch of India’s latest communication satellite GSAT-16 carrying 48 communication transponders.

- IRNSS-1B, the second satellite of the seven satellites of IRNSS Constellation was successfully launched by PSLV-C24 into a sub GTO on April 04, 2014. It was the twenty sixth launch of PSLV as well as its twenty fifth consecutively successful mission. IRNSS constellation will enable introduction of satellite based position, timing and velocity services to a spectrum of users in the country and to the neighboring regions.

- PSLV-C23, the twenty seventh flight of PSLV was conducted on June 30, 2014, in which the vehicle placed the 715 kg French Earth Observation Satellite SPOT-7 together with four smaller auxiliary satellites (1 from Germany, 2 from Canada and 1 from Singapore) into the required polar Sun Synchronous Orbit of 655 km height.

- On September 24, 2014, India’s Mars Orbiter Spacecraft successfully entered into the scheduled elliptical orbit around planet Mars by firing its Liquid Apogee Motor and eight thrusters. Thus, India’s very first attempt to place a spacecraft in an orbit around Mars culminated with the success of this Mars Orbit Insertion Manoeuvre.

- IRNSS-1C, third of the seven satellites of the IRNSS Constellation, was successfully launched on board PSLV-C26 on October 16, 2014 into a sub Geosynchronous Transfer Orbit (sub GTO).

- GSAT-16, India’s latest communication satellite carrying 48 transponders was launched into a GTO by the European Ariane-5 VA221 from Kourou, French Guiana on December 07, 2014.

- The first experimental suborbital mission of India’s next generation launch vehicle LVM3, also known as GSLV MkIII, was successfully conducted on December 18, 2014 from Satish Dhawan Space Centre SHAR, Sriharikota. The vehicle carried the 3775 kg Crew Module Atmospheric Re-entry Experiment (CARE) to the intended height of 126 km, following which CARE successfully re-entered the earth’s atmosphere and landed safely over the Andaman Sea, about 20 minutes after launch.
By 2014 end, ISRO had a constellation of several commercial Communication satellites, exclusive Meteorological satellites, Earth Observation satellites, three Navigation Satellites and a spacecraft orbiting planet Mars.

Launch Vehicle Programme

During the year under review, ISRO’s workhorse Launch Vehicle PSLV, in its ‘XL” version, placed two Navigation Satellites IRNSS-1B and 1C in the required sub Geosynchronous Transfer Orbits by two separate flights - PSLV-C24 and PSLV-C26. Besides, the vehicle in its ‘Core Alone’ version placed five satellites from abroad including the 715 kg French Earth Observation Satellite SPOT-7 into the required sun Synchronous Orbit, further underscoring its reliability and versatility.

Activities pertaining to LVM3 (GSLV-MkIII) launch vehicle, capable of launching four ton satellites progressed well during the year and the vehicle’s first experimental suborbital flight (GSLV-Mk III-X) to flight test the liquid first stage as well as the two solid strap-ons and equipped with a passive C25 cryogenic upper stage, was successfully conducted on December 18, 2014. In that flight, LVM3 carried the 3775 kg Crew Module Atmospheric Re-entry Experiment (CARE) to a height of 126 km. Later CARE re-entered the Earth’s atmosphere and safely landed over the Bay of Bengal with the help of its parachutes about 20 minutes after its lift-off.

This apart, research and development activities in semi-cryogenic propulsion engine, air breathing propulsion and re-usable launch vehicle technology are also being pursued vigorously in an effort towards reducing the cost of access to space. Development of critical technologies for undertaking human spaceflight has also made further progress.

An important development pertaining to launch vehicle domain during the year was the formation of ISRO Propulsion Complex (IPRC) on February 01, 2014 by the elevation of Liquid Propulsion System Centre facilities at Mahendragiri. This was done by taking cognisance of the future growth of the space programme of the country and the concomitant expansion at Mahendragiri.

Satellite Programme

IRNSS-1B and 1C, the second and third satellites of the IRNSS Constellation, were successfully launched on board PSLV-C24 and PSLV-C26 on April 04, 2014 and October 16, 2014 respectively. IRNSS satellites employ the standard I-1K structure with a power handling capability of around 1660 W and a lift-off mass of about 1425 Kg. Like their predecessor IRNSS-1A, the IRNSS-1B and 1C carry a navigation payload as well as a C-band ranging payload. The satellites also carry Corner Cube Retro Reflectors for laser ranging. In Orbit Tests (IOT) of Navigation Payload, Ranging Payload and TT&C transponder of IRNSS-1B and 1C have been successfully completed and the satellites have been cleared for Navigation activities.
GSAT-16, India’s latest communication satellite carrying 48 communication transponders, launched on-board the European Ariane-5 on December 07, 2014 was successfully taken to its geostationary orbital slot by successively firing its Liquid Apogee Motor from MCF, Hassan.

The new satellites being built for meeting the country’s future requirements include IRNSS-1D, 1E, 1F and 1G of IRNSS constellation are planned to be launched on-board PSLV, GSAT-6 and GSAT-9 communication satellites to be launched by GSLV and GSAT-15 communication satellite planned to be launched by procured launch.

In the domain of earth observation satellites, it is planned to design, develop and build Cartosat-2C/2D/2E and Cartosat-3 in the Cartosat series of satellites, Resourcesat-2A in the Resourcesat series, Oceansat-3 and Scatsat-1 in the Oceansat series, and INSAT-3DR and GISAT in the INSAT series for meteorological applications during the 12th Five Year Plan.

Space Science Programme

Mars Orbiter Mission is India’s first interplanetary spacecraft mission as well as the first Indian spacecraft mission to planet Mars. With a lift-off mass of 1340 kg, the Mars Orbiter Spacecraft carries five payloads – Mars Colour Camera, Thermal infrared Imaging Spectrometer, Methane Sensor for Mars, Lyman Alpha Photometer and Mars Exospheric Neutral Composition Analyser. Mars Orbiter Mission primarily envisages to demonstrate the technologies for building, launching and navigating an unmanned spacecraft to Mars as well as to explore the planet by placing it in an orbit around that planet.

The spacecraft, which was launched by PSLV-C25 on November 05, 2013 from SDSC, Sriharikota into an elliptical earth parking orbit, was placed in ‘Mars Transfer Trajectory’ on December 01, 2013. During the year under review, the spacecraft was accurately navigated to Mars and on September 24, 2014 successfully entered into the planned elliptical orbit around planet Mars by firing its Main Liquid Engine together with eight thrusters for about 24 minutes. The mission is primarily a technological mission, which enabled ISRO to achieve critical mission operations with enhanced autonomy functions and stringent capabilities of propulsion and other spacecraft systems. All systems onboard the spacecraft are functioning normally in its orbit around Mars and it has already sent pictures of Mars disc showing many details.

The space science missions planned for future includes ASTROSAT, a multi-wavelength astronomical observatory in space, aimed at studying the distant celestial sources and scheduled to be launched using PSLV-XL in 2015-16. Chandrayaan-2, a follow-on mission to Chandrayaan-1 with an Orbiter, Lander and Rover, is to be launched onboard GSLV. Aditya-1, a scientific mission for solar studies carrying five scientific payloads including a Coronagraph, is planned to be placed in a halo orbit around the L1 Lagrangian point.
Space Applications and Disaster Management Support

Remote Sensing applications projects at National, State and Local levels are being carried out through well-established multi-pronged implementation architecture of National Natural Resources Management System (NNRMS) in the country. During the year, Indian Remote Sensing Satellite constellation helped in Agricultural Crops Inventory, Agricultural Drought, Forest Fire, Landslides, Earthquakes monitoring, Groundwater Prospects Mapping, Inventory; Monitoring of Glacial Lakes/Water Bodies, Sericulture Development and Satellite Aided Search and Rescue.

The hallmark of Indian space programme has been the application-oriented efforts and the benefits that have accrued to the country. The societal services offered by INSAT/GSAT satellites in the area of tele-education and telemedicine were continued during the year. Today, tele-education network has about 60,000 class rooms connected to various academic institutions and universities. ISRO Telemedicine network facilities cover 389 hospitals connecting 301 rural hospitals and 17 mobile vans to 66 super speciality hospitals for providing health care to citizens, especially in rural areas.

The Disaster Management Support (DMS) Programme of ISRO continues to provide space based information and services to the State and Central Government Departments to strengthen the disaster management activities. In 2014, flood monitoring was carried out for floods in 8 states and 112 flood maps were disseminated to the concerned State and Central officers in addition to making available to Users on the web through Bhuvan, DSC and NDEM web portals. In the case of unprecedented floods that devastated Jammu and Kashmir in September 2014, ISRO quickly established DMS satellite communication VSAT nodes with voice and data capabilities in Srinagar. Besides cumulative flood inundation maps and their progression as well as recession maps were prepared for Srinagar valley and the information was disseminated on daily basis during September 8 – 21, 2014. A Flood Early Warning System (FLEWS) is operational in Assam State by North Eastern Space Applications Centre (NE-SAC). A Flood Hazard Atlas for Odisha based on past flood incidents was prepared and handed over to Govt of Odisha for ground validations.

All the depressions and cyclones that originated in the Indian ocean region including Cyclone Hudhud which made a landfall at Visakhapatnam and Cyclone Nilofar which threatened Gujarat region during October 2014 were monitored and their track, intensity and landfall were predicted.

During 2014, NRSC has provided IRS satellites’ data for disasters occurred across the globe through International Charter “Space and Major Disasters”, “Sentinel Asia framework” and also through UNOOSA /UNESCAP. A total of 92 datasets for 26 events were provided during the year.

Space Commerce

Antrix Corporation, the commercial arm of the Department of Space, has been marketing the Indian space products and services in the global market. Under a commercial contract with Antrix, 40 international customer satellites have been successfully launched by PSLV. During the year, commercial launch contracts have been signed with customers from abroad for two dedicated satellite launches on PSLV, apart from the contract for three microsatellite launches.
Indian Space Industry

Involvement of Indian space industry continued during the year. In the past, it has made significant contribution towards the realisation of subsystems required for Indian space programme. Department of Space has associated more than 500 small, medium and large scale industries while implementing its various programmes. So far, Department of Space has transferred nearly 300 technologies to Indian industries for commercialisation and undertaken technical consultancies in various fields.

International Cooperation

International cooperation is an integral part of Indian space activities, and ISRO continues to lay importance on bilateral and multilateral relations with space agencies and space related bodies with the aim of taking up new scientific and technological challenges, defining international frameworks for exploitation and utilisation of outer space for peaceful purposes, refining space policies and building and strengthening existing ties between the countries. During the year, ISRO signed cooperative agreements with Brazil, China, EUMETSAT, Republic of Korea, Mexico and the United States including the implementing arrangement between ISRO and National Aeronautics and Space Administration (NASA) for cooperation on the NASA-ISRO Synthetic Aperture Radar (NISAR) mission for scientific studies of Earth.

Human Resources

The achievements of Indian space programme are the result of commitment, dedication and expertise of its personnel who continue to play a key role. Recognising the importance of talented and motivated personnel, the department has laid stress on recruitment, training and career progression features. Department of Space continues to strive for providing its personnel with facilities such as housing, medical, canteen and schooling for their children.

Indian Institute of Space Science and Technology

Towards capacity building in human resources and to meet the growing demands of the Indian Space Programme, the Indian Institute of Space Science and Technology (IIST), a deemed university, was established at Thiruvananthapuram in 2007. Towards the fulfillment of its primary objective of providing quality manpower to ISRO, 104 students of 2010 batch of B. Tech graduates were placed as Scientists/Engineers at various centres of ISRO.

Public Awareness on Space Programme

During the year, ISRO organised media visits to SDSC SHAR, Sriharikota and Mission Operations Complex (MOX), Bengaluru for the live coverage of PSLV and GSLV launches and Mars Orbit Insertion event of India’s Mars Orbiter Spacecraft. Besides, ISRO also organised many exhibitions at national and international conferences, important public congregations like cultural festivals, trade fairs and
events and also at academic institutions. Exhibitions and other outreach events were also organised in association with Non-Governmental Organisations in various places for keeping the public abreast of the Indian space programme.

**Right to Information – Ensuring Transparency**

Strict compliance to the requirements of Right To Information (RTI) Act 2005 is practiced in the department. Department of Space has implemented RTI Act 2005 by identifying the Central Public Information Officers, Assistant Public Information Officers and the Appellate Authority for stage one appeals. As required under the Act, Department of Space has published the requisite information on DOS website (http://dos.gov.in) and on ISRO website (http://www.isro.gov.in). During the period of January 2014 to December 2014, 832 applications were received and information was disseminated under the provisions of the RTI Act. 122 appeals were received by the First Appellate Authority and 18 appellants approached the Second Appellate Authority, namely, Central Information Commission.

**Conclusion**

Indian space programme during the year made outstanding progress in its quest towards mastering critical technologies and witnessed significant milestones in space exploration. Necessary infrastructure for casting large boosters, liquid propellant engines, heavy cryogenic boosters for advanced heavier launchers and missions in the area of remote sensing, communications and navigational satellites as well as space science have been established.

The continuing expansion of space applications programmes like tele-education and disaster management support and outreach through Direct-To-Home television, reiterates the increasing role played by the Indian space systems in providing direct benefits to the society. Thus, Indian Space Programme continues to pursue successful goals on all fronts in meeting the objective of achieving self-reliance in space technology and its applications for national development.
Organisation

Space activities in the country were initiated with the setting up of Indian National Committee for Space Research (INCOSPAR) in 1962. In the same year, work on Thumba Equatorial Rocket Launching Station (TERLS) near Thiruvananthapuram was also started. Indian Space Research Organisation (ISRO) was established in August 1969. The Government of India constituted the Space Commission and established the Department of Space (DOS) in June 1972 and brought ISRO under DOS in September 1972.

Space Commission formulates the policies and oversees the implementation of the Indian space programme to promote the development and application of space science and technology for the socio-economic benefit of the country. DOS implements these programmes through, mainly, ISRO, Physical Research Laboratory (PRL), National Atmospheric Research Laboratory (NARL), North Eastern-Space Applications Centre (NE-SAC) and Semi-Conductor Laboratory (SCL). Antrix Corporation, established in 1992 as a government owned company, markets the space products and services.

The establishment of space systems and their applications are coordinated by the national level committees, namely, INSAT Coordination Committee (ICC), Planning Committee on National Natural Resources Management System (PC-NNRMS) and Advisory Committee for Space Sciences (ADCOS).

DOS Secretariat and ISRO Headquarters are located at Antariksh Bhavan in Bengaluru. Programme offices at ISRO Headquarters coordinate the programmes like satellite communication and navigation, earth observation, launch vehicle, space science, disaster management support, sponsored research scheme, international cooperation, system reliability and quality, safety, publications and public relations, budget and economic analysis and human resources development. The major establishments of DOS and their area of activities are given in the following paragraphs:

Vikram Sarabhai Space Centre (VSSC)

Vikram Sarabhai Space Centre (VSSC) at Thiruvananthapuram is the lead centre for the design and development of launch vehicle technologies for the Indian Space Programme. The major programmes at VSSC include: Polar Satellite Launch Vehicle (PSLV), Geosynchronous Satellite Launch Vehicle (GSLV) and Rohini Sounding Rockets as well as the development of Geo-Synchronous Satellite Launch Vehicle.
(GSLV) - Mk III (LVM-III), reusable launch vehicles, advanced technology vehicles, air-breathing propulsion and critical technologies towards human spaceflight.

The Centre pursues active research and development and has developed core competence in various disciplines including aeronautics, avionics, materials, mechanisms, vehicle integration, chemicals, propulsion, space ordnance, structures, space physics and systems reliability. The Centre undertakes crucial responsibilities of design, manufacturing, analysis, development and testing related to the realisation of subsystems for the different missions. These are sustained by activities towards programme planning & evaluation, technology transfer, industry coordination, human resources development and safety. Planning, execution and maintenance of all civil works related to the Centre is also carried out. The Centre depends on administrative and auxiliary services for support.

VSSC has extension Centres at Valiamala housing major facilities of mechanisms, vehicle integration and testing and at Vattiyoorkavu for the development of composites. The Ammonium Perchlorate Experimental Plant (APEP) has been set up by VSSC at Aluva near Kochi.

**ISRO Satellite Centre (ISAC)**

ISRO Satellite Centre (ISAC), Bengaluru, is the lead centre of ISRO for design, development, fabrication and testing of all Indian made satellites. As a sequel to its mandate of spacecraft realisation, the Centre is engaged in the development of cutting-edge technologies of relevance to its satellite building activities and setting up of infrastructure for design, development, fabrication and testing of spacecraft. Over the past four and a half decades, ISAC has developed intellectual capital in a wide spectrum of knowledge domains of spacecraft technology.

ISRO Satellite Integration and Test Establishment (ISITE) is equipped with the state-of-the-art clean room facilities for spacecraft integration and test facilities including a 6.5 Metre thermo vacuum chamber, 29 Ton vibration facility, Compact Antenna Test Facility and Acoustic Test Facility under one roof. Assembly, Integration and Testing of all Communication and Navigation Spacecraft is carried out at ISITE. A dedicated facility for the productionisation of standardised subsystems is also established at ISITE.

Since its inception in 1972, the centre has built 72 spacecraft varying from scientific/experimental satellites to the state-of-art operational satellites in the areas of Communication, Navigation, Remote sensing and Space Science.
Satish Dhawan Space Centre (SDSC) SHAR

SDSC SHAR at Sriharikota, with two launch pads, is the main launch centre of ISRO that carries out launch operations. The mandate for the centre is (i) to produce solid propellant boosters for the launch vehicle programmes of ISRO (ii) to provide the infrastructure for qualifying various subsystems and solid rocket motors and carrying out the necessary tests (iii) to provide launch base infrastructure and (iv) for assembly, integration and launching of satellites and launch vehicles.

The Centre is augmenting the infrastructure to meet the requirements of increased launch frequency of 5-6 launches per year. The present Vehicle Assembly Building (VAB) is being used for integration of PSLV/GSLV/GSLV Mk-III (LVM3) launch vehicles for launching from the Second Launch pad. Second Vehicle Assembly Building (SVAB), integrated with existing rail track leading to Second Launch Pad, is planned to augment the launch infrastructure and provide redundancy to existing critical infrastructure.

SDSC SHAR has a separate launch pad for launching the sounding rockets. The centre provides the necessary launch base infrastructure for sounding rockets of ISRO and for assembly, integration and launch of sounding rockets and payloads.

Liquid Propulsion Systems Centre (LPSC)

Liquid Propulsion Systems Centre (LPSC) is the centre of excellence in the area of Liquid and Cryogenic Propulsion for ISRO’s Launch Vehicle and Spacecraft programmes. The activities are spread across Valiamala / Thiruvananthapuram and Bengaluru centres.

LPSC Valiamala is the Headquarters and is responsible for R & D, system design / engineering, delivery of liquid and cryogenic propulsion systems, control components & modules and control power plants.

LPSC Bengaluru focuses on the design and development of satellite propulsion systems and production of transducers/sensors.

ISRO Propulsion Complex (IPRC)

ISRO Propulsion Complex (IPRC), Mahendragiri is equipped with the state-of-the-art-facilities necessary for realising the cutting edge propulsion technology products for Indian space research programme. Formerly, IPRC was known as LPSC, Mahendragiri and taking cognisance of the future growth of the space programme of the country and the concomitant expansion at Mahendragiri, it was elevated as IPRC with effect from February 01, 2014.

The activities carried out at IPRC, Mahendragiri are: assembly, integration and testing of earth storable propellant engines, cryogenic engines and stages for launch vehicles; high altitude testing of upper stage engines and spacecraft thrusters as well as testing of its sub systems; production and supply of Cryogenic propellants for Indian Cryogenic rocket programmes, etc.

IPRC is responsible for the supply of Storable Liquid Propellants for ISRO’s launch vehicles and
satellite programmes. IPRC delivers quality products to meet the zero defect demand of ISRO space programme ensuring high standards of safety and reliability. It also carries out Research & Development (R&D) and Technology Development Programmes (TDP) towards continual improvement of its contribution to Indian space programme.

**Space Applications Centre (SAC)**

Space Applications Centre (SAC) at Ahmedabad is a unique centre dealing with a wide variety of activities from payload developments to societal applications, thereby creating a synergy of technology, science and societal applications. The centre is responsible for the development, realisation and qualification of communication, navigation, earth observation and planetary payloads and related data processing and ground systems in the areas of communications, broadcasting, remote sensing, disaster monitoring/mitigation, etc. It is playing an important role in harnessing space technologies for a wide variety of applications for societal benefits.

In order to carry out the above tasks, SAC has highly sophisticated payload integration laboratories, electronic and mechanical fabrication facilities, environmental test facilities, systems reliability/assurance group, image processing and analysis facilities, project management support group and a well-stocked library. SAC has also put adequate emphasis on and practicing outsourcing and indigenous development of technology and vendors.

**Development and Educational Communication Unit (DECU)**

The Development and Educational Communication Unit (DECU) at Ahmedabad, is involved in defining, planning, implementing and conducting socio-economic research and evaluation of various societal applications. The visionary plan of DECU is to pursue the goals, on all fronts, in meeting the objectives of space-based societal applications for our nation’s overall development and to reach the unreached.

At present, the major programmes which support development, education and training are Telemedicine (TM), Tele-Education (TE) and other SATCOM Development and Applications, including Disaster Management System (DMS), Village Resource Centre (VRC) related activities, etc.

**ISRO Telemetry, Tracking and Command Network (ISTRAC)**

ISRO Telemetry, Tracking and Command Network (ISTRAC) is entrusted with the major responsibility to provide tracking support for all the satellite and launch vehicle missions of ISRO. The major objectives of the centre are: estimation of the preliminary orbits of satellites injected into space, carrying out mission
operations for all operational remote sensing and scientific satellites in normal phase, operation and maintenance of the ground segment for Indian Regional Navigation Satellite System and development of radars and associated systems for meteorological applications and launch vehicle tracking. In addition, ISTRAC has also been mandated to provide space operations support for Deep Space Missions of ISRO and to provide active support for Search & Rescue, Disaster Management and a host Space Communication Hub services for societal applications.

In order to realise these objectives, ISTRAC has established a network of ground stations at Bengaluru, Lucknow, Mauritius, Sriharikota (SHAR I & II), Port Blair, Thiruvananthapuram, Brunei, Biak (Indonesia) and Deep Space Network Stations DSN-32 and DSN-18 at Byalalu near Bengaluru. The Mission Operations Complex (MOX) has been established at Bengaluru for round-the-clock mission operations for all remote sensing and scientific satellites. All network stations of ISTRAC are connected to MOX through dedicated high-performance satellite/terrestrial communication links.

Towards the realisation of the ground segment of IRNSS, ISTRAC has established a network of stations to support IRNSS satellites consisting of ISRO Navigation Centre (INC) at Byalalu (40 km from Bengaluru), four CDMA Ranging stations at Hassan, Bhopal, Jodhpur and Shillong and twelve IRNSS Range and Integrity Monitoring Stations at Bengaluru, Hassan, Bhopal, Jodhpur, Shillong, Dehradun, Port Blair, Mahendragiri, Lucknow, Kolkata, Udaipur and Shadnagar and one IRNWT facility at Bengaluru.

**Master Control Facility (MCF)**

Master Control Facility (MCF) at Hassan in Karnataka and Bhopal in Madhya Pradesh monitors and controls all the Geostationary/Geosynchronous satellites of ISRO, namely, INSAT, GSAT, Kalpana and IRNSS series of satellites. MCF is responsible for Orbit Raising of satellites, In-orbit payload testing, and On-orbit operations all through the life of these satellites. MCF activities include round-the-clock Tracking, Telemetry & Commanding (TT&C) operations, and special operations like Eclipse management, Station-keeping manoeuvres and recovery actions in case of contingencies. MCF interacts with User Agencies for effective utilisation of the satellite payloads and to minimise the service disturbances during special operations.

MCF currently controls INSAT-3C, 3A, 4A, 4B, 4CR, INSAT-3D, Kalpana-1, GSAT-7, GSAT-8, GSAT-10, GSAT-12, GSAT-14, GSAT-16, IRNSS-1A, 1B and 1C. To carry out these operations effectively, MCF-Hassan is having an integrated facility consisting of nine Satellite Control Earth Stations.

MCF-Bhopal Facility is currently managing round-the-clock operations of two satellites in close coordination with MCF-Hassan. The Facility is configured with a 1 m Full Motion Antenna and four 7.2 m Limited Motion Antenna, a Satellite Control Centre and a Power Complex.

**ISRO Inertial Systems Unit (IISU)**

ISRO Inertial Systems Unit (IISU) at Thiruvananthapuram is responsible for the design and development
of Inertial Systems for both Launch Vehicles and spacecraft Programmes of ISRO. IISU also designs and develops Actuators and Mechanisms for spacecraft and allied applications.

The Unit has crossed major milestones of competence building phase, experimental phase and is presently engaged in the process of consolidation and productionisation of the sensors, systems, actuators and mechanisms for a variety of launch vehicle and spacecraft applications. IISU has also contributed to ISRO’s efforts to venture into the international space market by supplying Inertial Actuators and Solar Array Drive Mechanisms to prospective customers.

The experience and knowledge gained over the years are used for perfecting the present class of sensors and systems. Further, IISU has initiated technology development programmes in niche areas to adapt itself as a Centre of Excellence in Inertial Sensors and Systems. IISU strives to make the systems cost effective, reliable and realisable in tune with global trends.

Laboratory for Electro-Optic Systems (LEOS)

Laboratory for Electro-Optic Systems (LEOS), Bengaluru is responsible for design, development and production of Electro-Optic sensors and camera optics for remote sensing and meteorological payloads. The sensor system includes earth sensors, star trackers, sun sensors, magnetic sensors, fiber optic gyro, temperature sensors and processing electronics. Optics systems include both reflective mirror optics and refractive multi element optics for astronomical/scientific purposes, cartographic applications, remote sensing and meteorological payloads. Other special elements developed by LEOS include optical masks for sun sensors, black absorber coatings for star sensor optics, optical filters, narrow band filters, encoder and optical coatings. The technology development programmes of LEOS include development of miniature sensors, active pixel sensors, detectors, MEMS devices, high-resolution camera optics and optical coatings.

Sensor production building and Optics & MEMS building were inaugurated during the year. New facilities incorporated include installation of Ultra High Vacuum Chamber, Magneto-Rheological Finishing (MRF) facility, CNC Aspheric Grinder with Aspheric surface profilometer, MTF Test Bench Equipment.

National Remote Sensing Centre (NRSC)

NRSC at Hyderabad is responsible for remote sensing satellite data acquisition and processing, data dissemination, aerial remote sensing and decision support for disaster management. NRSC has a data reception station at Shadnagar near Hyderabad for acquiring data from Indian remote sensing satellites as well as others. The Centre is also engaged in executing remote sensing application projects in collaboration with the users. The Aerial Services & Digital Mapping (ASDM) Area provides end-to-end Aerial Remote Sensing services and value-added solutions for various large scale applications like aerial photography and digital mapping, infrastructure planning, scanner surveys, aeromagnetic surveys, large scale base map, topographic and cadastral level mapping, etc.
Regional Remote Sensing Centres (RRSCs) support various remote sensing tasks specific to their regions as well as at the national level. RRSCs are carrying out application projects encompassing all the fields of natural resources like agriculture and soils, water resources, forestry, oceanography, geology, environment and urban planning. Apart from executing application projects, RRSCs are involved in software development, customisation and packaging specific to user requirements and conducting regular training programmes for users in geospatial technology, particularly digital image processing and GIS applications.

**Indian Institute of Remote Sensing (IIRS)**

Indian Institute of Remote Sensing at Dehradun is a premier institute with the objective of capacity building in Remote Sensing and Geo-informatics and their applications through education and training programmes at postgraduate level. The Institute also hosts and provides support to the Centre for Space Science and Technology Education in Asia and the Pacific (CSSTE-AP), affiliated to the United Nations. The training and education programmes of the Institute are designed to meet the requirements of various target/user groups, i.e., for professionals at working, middle and supervisory levels, fresh graduates, researchers, academia, and decision makers. The duration of courses ranges from one week to two years.

The training and education programmes conducted by the Institute are broadly grouped into: Post-graduate Diploma courses, Certificate programmes and Awareness programmes. In addition, IIRS also conducts special programmes for International and National participants on request from different organisations. M.Tech. course of 24 months duration is being conducted in collaboration with Andhra University, Visakhapatnam; and M.Sc. course of 18 months duration being conducted in collaboration with the Faculty of Geo-information Science & Earth Observation (ITC) of the University of Twente (UT), The Netherlands.

**Physical Research Laboratory (PRL)**

Physical Research Laboratory (PRL) at Ahmedabad is an autonomous unit of DOS and a premier research institute engaged in basic research in the areas of Astronomy and Astrophysics, Solar Physics, Planetary Science and Exploration, Space and Atmospheric Sciences, Geosciences and Theoretical Physics.

PRL is actively participating in ISRO’s planetary exploration programme and has also developed capabilities for detecting exoplanets from its Mt. Abu Observatory. Studies
of Stellar and Solar astronomy are conducted from the Infra-red Observatory at Mt. Abu, and a lake site Solar Observatory in Udaipur, respectively. Another campus at Thaltej, Ahmedabad, hosts the planetary exploration (PLANEX) programme. Laboratory infrastructure has been established in this campus to develop instrumentation for future Space Science and Planetary missions and for initiating some of the proposed new research programmes. Significant progress has been made in the areas of planetary sciences and exploration. PRL is developing several payloads for the upcoming Chandrayaan-2 and proposed Aditya missions.

**National Atmospheric Research Laboratory (NARL)**

NARL at Gadanki near Tirupati, an autonomous society supported by DOS, is a centre for atmospheric research with the vision “Developing capability to predict the behaviour of the earth’s atmosphere through observations and modeling”. Towards realising this vision, NARL gives equal emphasis to technology development, observations, data archival, dissemination, assimilation and modeling.

NARL carries out its research activities under seven major groups, namely, Radar Application and Development Group, Ionospheric and Space Research Group, Atmospheric Structure and Dynamics Group, Cloud and Convective Systems Group, Aerosols, Radiation and Trace Gases Group, Weather and Climate Research Group and Computers and Data Management Group. Apart from these groups, there are also specific projects such as the LIDAR project and Advanced Space-borne Instrument Development project.

The facilities at NARL are available for National and International Scientists to conduct atmospheric research.

**North Eastern-Space Applications Centre (NE-SAC)**

NE-SAC, located at Shillong, is a joint initiative of DOS and North Eastern Council (NEC) to provide developmental support to the North Eastern Region (NER) using space science and technology. The centre has the mandate to develop high technology infrastructure support to enable NE states to adopt space technology inputs for their development. The centre has completed a number of applications projects sponsored by the user agencies in the region and taken up research and development projects under Earth Observation Applications Mission, ISRO Geo-sphere Biosphere Programme, Satellite Communications, Disaster Management Support and Space Science Programmes.
The Centres of Indian Space Programme

CHANDIGARH
- Semi-Conductor Laboratory

JODHPUR
- Western RRSC

UDAIPUR
- Solar Observatory

Mt. ABU
- Infrared Observatory

Ahmedabad
- Space Applications Centre
- Physical Research Laboratory
- Development and Educational Communication Unit

Mumbai
- ISRO Liaison Office

Bhopal
- Master Control Facility - B

Bengaluru
- Space Commission
- Department of Space and ISRO Headquarters
- INSAT Programme Office
- NNIRMS Secretariat
- ADCOS Secretariat
- Civil Engineering Programme Office
- Antrix Corporation
- ISRO Satellite Centre
- Laboratory for Electro-Optic Systems
- ISRO Telemetry, Tracking and Command Network
- Southern RRSC
- Liquid Propulsion Systems Centre

Hassan
- Master Control Facility

Byalalu
- Indian Deep Space Network
- Indian Space Science Data Centre
- ISRO Navigation Centre

New Delhi
- DOS Branch Secretariat
- ISRO Branch Office
- Delhi Earth Station

Dehradun
- Indian Institute of Remote Sensing
- Centre for Space Science and Technology Education in Asia-Pacific

Lucknow
- ISTRAC Ground Station
- ISRO Navigation Centre

Shillong
- North Eastern Space Applications Centre

Kolkata
- Eastern RRSC

Nagpur
- Central RRSC

Hyderabad
- National Remote Sensing Centre

Sriharikota
- Satish Dhawan Space Centre, SHAR

Tirupati
- National Atmospheric Research Laboratory

Aluva
- Ammonium Perchlorate Experimental Plant

Thiruvananthapuram
- Vikram Sarabhai Space Centre
- Liquid Propulsion Systems Centre
- ISRO Inertial Systems Unit
- Indian Institute of Space Science and Technology

Mahendragiri
- ISRO Propulsion Complex
## Budget Profile

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**Notes:**
- PRL: Physical Research Laboratory
- NARL: National Atmospheric Research Laboratory
- NE-SAC: North Eastern Space Applications Centre
- SCL: Semi-Conductor Laboratory
- IIST: Indian Institute of Space Science and Technology
- ISRO: Indian Space Research Organisation
- ANTRIX: Antrix Corporation Limited
- VSSC: Vikram Sarabhai Space Centre
- LPSC: Liquid Propulsion Systems Centre
- IPRC: ISRO Propulsion Complex
- SDSC: Sath Dhawan Space Centre
- ISAC: ISRO Satellite Centre
- SAC: Space Applications Centre
- NRSC: National Remote Sensing Centre
- IISU: ISRO Inertial Systems Unit
- DECU: Development and Educational Communication Unit
- MCF: Master Control Facility
- ISTRAC: ISRO Telemetry, Tracking and Command Network
- LEOS: Laboratory for Electro-optic Systems
- IIRS: Indian Institute of Remote Sensing
Antrix Corporation Limited

Antrix Corporation Limited, Bengaluru is a wholly owned Government of India Company under the administrative control of the Department of Space. Antrix Corporation Limited was incorporated in September 1992 as a private limited company owned by Government of India as a Marketing arm of ISRO for promotion and commercial exploitation of space products, technical consultancy services and transfer of technologies developed by ISRO. Another major objective is to facilitate development of space related industrial capabilities in India.

As the commercial and marketing arm of ISRO, Antrix is engaged in providing Space products and services to international customers worldwide. With fully equipped state-of-the-art facilities, Antrix provides end-to-end solution for many of the space products, ranging from supply of hardware and software including simple subsystems to a complex spacecraft, for varied applications covering communications, earth observation and scientific missions; space related services including remote sensing data service, Transponder lease service; Launch services through India’s operational launch vehicle PSLV; Mission support services; and a host of consultancy and training services.

Semi-Conductor Laboratory (SCL)

Semi-Conductor Laboratory (SCL) at Chandigarh, an Autonomous Body under the Department of Space, is engaged in Research & Development in the area of Microelectronics. Activities at SCL are focused on Design, Development, Assembly & Testing of CMOS and MEMS Devices for various strategic applications. SCL is also engaged in Manufacture & Supply of ASICs for Locomotives of Indian Railways, Hi-Rel Board Fabrication, Component Screening for ISRO units, Indigenisation of Electronic Boards for Indian Air Force and Production of Radiosonde for Atmospheric Studies.

Upgradation activities have been completed on 8” CMOS Wafer Fabrication Line with the establishment of 0.18µm CMOS Technology. The support infrastructure comprising of Clean Rooms, High Purity Systems, Utilities Plants and Distribution Network are in operation on 24X7 basis. The 8” Wafer Fab
Line is ready for the start of trial production. Qualification activities for both Process and Device Reliability are in progress.

**Indian Institute of Space Science and Technology (IIST)**

IIST, Asia’s first Space University, was established at Thiruvananthapuram during 2007 with the objective of offering high quality education in space science and technology to meet the demands of Indian Space Programme. The institute offers Bachelor’s Degree in Space Technology with specialisation in Avionics and Aerospace Engineering and Integrated Masters Programme in Applied Sciences with special emphasis on space related subjects. Research in IIST is built on the foundations of various academic programmes run by the Departments of Aerospace Engineering, Avionics, Chemistry, Physics, Mathematics as well as Earth and Space Sciences. IIST has started several Post Graduate programmes that have been received a resounding response; 91 students were admitted under 13 M.Tech. and 1 MS programmes. Research programmes of the institute focus on various areas of Science, Engineering and Humanities and currently has 70 research scholars. The IIST has a faculty strength of 85.

IIST has set up three Centres of Excellence in (i) Advanced Propulsion and Laser Diagnostics (APLD) Laboratory (ii) Virtual Reality Lab (iii) Centre for Advanced Research in Nanoscience and Technology. Towards the fulfillment of its primary objective of providing quality manpower to ISRO, 104 students of 2010 batch of B. Tech graduates were placed as Scientists/Engineers at various centres of ISRO.
Communication and Navigation Satellite System

Communication Satellite

Indian National Satellite (INSAT) system, established in 1983, is the largest domestic communication satellite system in the Asia Pacific Region with several communication satellites in operation including the commercial communication satellites like INSAT-3A, INSAT-3C, INSAT-4A, INSAT-4B, INSAT-4CR, GSAT-8, GSAT-10, GSAT-12, GSAT-14 and GSAT-16. The overall coordination and management of INSAT system rests with INSAT Coordination Committee.

SATELLITES IN SERVICE

INSAT-3A

INSAT-3A is a multipurpose satellite launched in April 2003. INSAT-3A payloads include Normal C-band transponders with expanded coverage from Middle East to South East Asia, Extended C-band transponders providing India coverage and Ku-band transponders providing India coverage.

The satellite also carries a Satellite Aided Search and Rescue (SAS&R) payload having a global receive coverage with 406 MHz uplink and C-band downlink with India coverage for relay of signals from distress beacons in sea, air or land. The meteorological payloads of INSAT-3A are described in the chapter on "Earth Observation System".

INSAT-3C

Launched in January 2002, INSAT-3C payloads include Normal C-band transponders, Extended C-band transponders, S-band transponders to provide BSS services and an MSS payload. All the transponders provide coverage over India. The satellite is continuing to provide satisfactory service.

INSAT-4 Series

INSAT-4A

Launched in December 2005 by the European Ariane launch vehicle, INSAT-4A carries Ku-band transponders employing 140 Watt Travelling Wave Tube Amplifiers (TWTAs) with footprint covering Indian mainland and C-band transponders with expanded radiation patterns encompassing Indian geographical boundary and area beyond India.
INSAT-4B

Configured with payloads identical to that of INSAT-4A, INSAT-4B was launched onboard the European Ariane-5 launch vehicle on March 12, 2007. INSAT-4B carries Ku-band and C-band transponders. Two Transmit/Receive dual grid offset fed shaped beam reflectors of 2.2 m diameter for Ku-band and 2 m diameter for C-band are used. INSAT-4B has augmented the high power transponder capacity over India in Ku-band and over a wider region in C-band. Due to a power anomaly, the satellite is operating at lower power.

INSAT-4CR

INSAT-4CR was launched by GSLV from Sriharikota in 2007. INSAT-4CR with high power Ku-band transponders is the third satellite in INSAT-4 series. INSAT-4CR is designed to provide Video Picture Transmission (VPT), Digital Satellite News Gathering (DSNG), Very Small Aperture Terminals (VSATs) and other data communication services.

GSAT-8

GSAT-8 is a communication satellite configured around 3000 Kg class (I-3K) bus with a lift-off mass of 3093 kg and 6 kW power generation capacity with a mission life of more than 12 years. The satellite was launched in May 2011 and carries Ku-band transponders covering Indian mainland and Andaman and Nicobar Islands as well as a two channel GAGAN (GPS Aided GEO Augmented Navigation) payload operating in L1 and L5 bands. The GAGAN payload provides Satellite Based Augmentation System (SBAS), through which the accuracy of the positioning information obtained from the GPS satellites is improved by a network of ground based receivers and made available to the users in the country through geostationary satellites.

GSAT-12

GSAT-12 satellite is configured around 1000 Kg class (I-1K) bus with Extended C-band Solid State Power Amplifier (SSPA) based commercial transponders. The satellite was successfully launched onboard PSLV-C17 on July 15, 2011 with a lift-off mass of 1410 kg. The satellite is designed for a mission life of 8 years.

GSAT-10

GSAT-10, India’s advanced communication satellite, was successfully launched by Ariane-5 from Kourou, French Guyana on September 29, 2012. Weighing 3400 kg at lift-off, GSAT-10 payload includes communication transponders in normal C-band, lower Extended C-band and Ku-band as well as a GAGAN payload operating in L1 and L5 bands. GSAT-10 is the second satellite to carry GAGAN payload after GSAT-8. GSAT-10 also carries a Ku-band beacon to help in accurately pointing ground antennas towards the satellite.
GSAT-14

GSAT-14 satellite is envisaged to enhance Extended C-band and Ku-band communication transponder capacity. It also carries two Ka-band Beacons. Designed with a mission life of around 12 years, it employs the standard I-2K structure with the power handling capability of around 2600 W and a lift-off mass of 1982 kg. GSAT-14 was successfully launched on January 05, 2014 onboard GSLV-D5 Mission, the second development flight of GSLV with indigenous Cryogenic stage.

GSAT-16

GSAT-16 is a communication satellite configured around I-3K Extended bus with a lift off mass of 3150 kg and 6500 W power generation capacity with a mission life of more than 12 years. The spacecraft’s payload includes Transponders in Ku-band, C-band and Extended C-band. The satellite was launched by Ariane-5 from Kourou, French Guyana on December 06, 2014. GSAT-16 is aimed at further augmenting communication services in the country.

SATELLITES UNDER DEVELOPMENT

GSAT-6 and GSAT-6A

GSAT-6 is a high power S-band communication satellite. The satellite is configured around I-2K bus with a lift-off mass of 2200 kg. It is configured with CxS and SxC transponders. This spacecraft will also provide a platform for developing technologies such as demonstration of large unfurlable antenna in satellites, handheld ground terminals and network management techniques that could be useful in future satellite based mobile communication applications. GSAT-6 is planned to be launched by GSLV.

All electrical and mechanical packages of the satellite are delivered to Assembly Integration and Testing (AIT) and disassembled Mode IST was carried out in three phases.

GSAT-6A will be a follow-on satellite planned to be launched by the end of 12th Five Year Plan.

GSAT-15

GSAT-15 is a communication satellite of 3150 kg lift-off mass and 6500 W power generation capacity. It is designed for a mission life of more than 12 years. The payload includes Ku-band transponders and a two channel GAGAN payload. The satellite will be launched onboard a procured launcher.

The disassembled mode Integrated Spacecraft Test (IST) is in progress and the readiness of the spacecraft is planned in third Quarter of 2015.
GSAT-9

GSAT-9 is configured to augment the growing need of Ku-band transponders. The satellite employs the standard I-2K structure with the power handling capability of around 3000 W, with a lift off mass of 2195 kg. It is designed for a mission life-of more than 12 years.

The subsystem fabrication activities are in progress. Integration of payload systems is completed. The satellite is planned to be launched onboard GSLV-MK II.

GSAT-11

GSAT-11 is an advanced communication satellite employing a new class of bus weighing 4000-6000 Kg. The payload includes Ka x Ku-band Forward Link Transponders and Ku x Ka-band Return Link Transponders. Subsystem fabrication activities are in various stages of completion. A detailed qualification programme is in an advanced stage of completion.

GSAT-18

GSAT-18 is a communication satellite configured around I-3K extended bus with a lift off mass of 3425 kg and 6 KW power generation capacity. The satellite’s transponders include Ku, Normal C and Extended C-band transponders The proposal is under process for approval of the Government.

GSAT-17

GSAT-17 is a communication satellite configured around I-3K extended bus with a lift off mass of 3425 kg and 6 KW power generation capacity. The satellite’s commercial transponders include Ku, Normal C and Extended C-band transponders. The satellite also carries CxS and SxC transponders as well as DRT and SAR transponders The proposal is under process for approval of the Government.

GSAT-19

GSAT-19 is planned as the payload for the first developmental flight of the indigenous GSLV-MK-III-D1 Launcher. GSAT-19 satellite will act as a test bed for development of advanced spacecraft technologies and bus subsystem experiments like New modular I-6K Structure, Electrical propulsion System, Active thermal control using deployable thermal radiators, Motorised deployment of solar panels, miniaturised IRU, indigenous Li-ion battery, 2 KW BDR, indigenous C-Band TWTA, etc., for future I-6K Bus.

Configuration finalisation is in progress.
Satellite Navigation Programme

Satellite Navigation (SATNAV) has been identified as one of the important programmes of the department that includes GPS Aided Geo Augmented Navigation - GAGAN as well as Indian Regional Navigation Satellite System (IRNSS).

GPS Aided Geo Augmented Navigation (GAGAN)

GAGAN is a Satellite Based Augmentation System project, which is jointly being implemented by Indian Space Research Organisation and Airport Authorities of India. The main objectives of GAGAN are to provide Satellite-based Navigation services with accuracy and integrity required for civil aviation applications and to provide better Air Traffic Management over Indian Airspace. The system will be interoperable with other international SBAS systems and provides seamless navigation across regional boundaries.

The GAGAN architecture consists of 3 segments, namely, ground segment, space segment and user segment.

The space segment consists of satellites carrying the GAGAN payloads. Currently, the GAGAN signal is being broadcast through two Geostationary Earth Orbit (GEO) satellites GSAT-8 and GSAT-10 covering whole Indian Flight Information Region (FIR) and beyond. An on-orbit spare GAGAN transponder will be flown on GSAT-15.

The ground segment consists of several Indian Reference stations (INRES), Indian Master Control Centres (INMCC) and Indian Land Uplink stations (INLUS).

The Directorate General of Civil Aviation (DGCA), India has certified the GAGAN system - to RNP0.1 (Required Navigation Performance, 0.1 Nautical Mile) service level on December 30, 2013. It was later commissioned on February 14, 2014. The availability of GAGAN Signal in space will bridge the gap between European Union’s EGNOS and Japan’s MSAS coverage areas, thereby offering seamless navigation to the aviation industry. An MOU was signed between ISRO and AAI in January 2014 for a period of 7 years. The GAGAN System is poised to APV1/1.5 level of certification by the middle of 2015 to offer precision approach services over the Indian land mass.

Indian Regional Navigation Satellite System (IRNSS)

IRNSS is an independent regional navigation satellite system being developed by India. It is designed to provide accurate position information service to users in India as well as the region extending up to 1500 km from its boundary, which is its primary service area. IRNSS will provide two types of services, namely, Standard Positioning Service (SPS) and Restricted Service (RS) and is expected to provide a position accuracy of better than 20 m in the primary service area.
The IRNSS system mainly consists of Ground Segment, Space Segment and User Segment. The space segment consists of seven satellites with three in geostationary orbit and four in inclined geosynchronous orbit. The navigation payload transmits signals in L5 and S-band. The ranging payload consists of a C-band transponder, which facilitates accurate determination of the range of the satellite.

IRNSS satellite employ the standard I-1K structure with a power handling capability of around 1660W and a lift-off mass of around 1425 Kg and is designed for a mission life of around 10 years. All satellites in the constellation have identical configuration.

IRNSS-1A
The first of the 7 satellites of the IRNSS Constellation, IRNSS-1A, was successfully launched onboard PSLV-C22 on July 01, 2013 and is functioning satisfactorily.

IRNSS-1B
The satellite was launched successfully on April 4, 2014 by PSLV-C24. IRNSS-1B is functioning satisfactorily.

IRNSS-1C
The satellite was successfully launched onboard PSLV-C26 on October 16, 2014. Orbit raising operations and In-Orbit Testing were successfully completed and Spacecraft performance is satisfactory.

IRNSS-1D
The satellite is in its advance stage of realisation and is expected to be launched during the first quarter of 2015.

The remaining satellites are in various stages of realisation. The complete IRNSS constellation is planned to be realised by 2015-16.

Ground Segment: Ground Segment is responsible for the Establishment, operation and maintenance of the IRNSS network of stations and associated facilities to support the IRNSS constellation. The Ground segment comprises of Spacecraft Control Facility, Navigation Centre, Range and Integrity Monitoring Stations, Network Timing Facility, CDMA Ranging Stations, Laser Ranging Service and Data Communication Network.

IRNSS Navigation Centre (INC)
At the IRNSS Navigation Centre-1 (INC-1), Byalalu, Bengaluru, installation of computers and servers has been completed and the navigation software has been installed. Real-time Navigation operations
started at INC from August 1, 2013 and validation of navigation payload is in progress. Civil works for establishing the backup IRNSS Navigation Centre at Lucknow (INC-2) is in progress.

IRNSS Range and Integrity Monitoring Stations (IRIMS)

Twelve IRIMS established under Phase-1& Phase-2 are functioning nominally and performing one-way ranging and transmitting the data in real time to INC-1.

IRNSS CDMA Ranging Stations (IRCDR)

The IRCDR stations are functioning nominally and two-way CDMA ranging is being carried out from all the four IRCDR stations viz., at Bhopal, Hassan and Jodhpur and Shillong.

IRNSS Spacecraft Control Facility (IRSCF)

With respect to ground infrastructure pertaining to Telecommand and telemetry, one 11 m antenna and four 7.2 m antennas are planned as part of Satellite Control Facility at Hassan for the purpose of controlling four IRNSS satellites of the constellation. All these stations have been established. An exclusive Satellite Control Centre for IRNSS is under construction at Hassan. IRSCF at Hassan Supported the Launch and Early Orbit Phase (LEOP) and In Orbit Test (IOT) phases of IRNSS-1A, IRNSS-1B and IRNSS-1C. At Bhopal, a backup Satellite Control Facility is being established with one 11 m antenna and three 7.2 m antennas for the control of three IRNSS satellites.

IRNSS Network Timing Facility (IRNWT)

All interfaces of IRNWT with navigation software are working smoothly and Timescales are maintained within 20ns (2δ) with respect to UTC. Data exchange related to timescales is being regularly being carried out with National Physical Laboratory (NPL), India and traceability of IRNWT with UTC is maintained through NPL. Procurement process for the establishment of a backup timing facility at INC-2 Lucknow is under progress.

IRNSS Data Communication Network (IRDCN)

Terrestrial communication links between INC and IRCDR stations and Phase -1IRIMs have been functioning nominally. VSAT links are also expected to be activated after receiving the necessary regulatory clearances.

IRNSS Laser Ranging Service (IRLRS)

IRNSS Laser Ranging Service is being provided by 10 international laser ranging stations under International Laser Ranging Service (ILRS) network. Two special laser ranging campaigns were supported by ILRS for IRNSS-1A and IRNSS-1B missions.
Navigation Signal Performance Analysis

Navigation signal performance analysis being performed using Payload Test Receivers (PTR) developed by space Application centre (SAC) of ISRO. This was used during IRNSS-1A IOT at Hassan. IRNSS signals are received and analysed at SAC using Payload Test Receiver (PTR).

User Segment

For design and manufacturing of user receivers, following steps have been taken:

• In house design and development
• In house design and development through contract with industry
• Design and production by industry
• In addition, the Signal-In-Space Interface Control Document (SIS-ICD) of SPS has been made available to the public through registration to facilitate production of user receiver by interested industries.
Earth Observations System

Indian Remote Sensing (IRS) satellite system was commissioned with the launch of IRS-1A in the year 1988. Currently, ten remote sensing satellites are operational in orbit (Resourcesat-2, Cartosat-1, Cartosat-2, Cartosat-2A, Cartosat-2B, RISAT-1, RISAT-2, Oceansat-2, Megha-Tropiques and SARAL). Though Cartosat-1, Cartosat-2, Cartosat-2A, RISAT-2 and Oceansat-2 satellites have completed their designed mission life in orbit, these satellites continue to provide imaging services for the remote sensing user community. Various instruments onboard these satellites provide data in varied spatial, spectral and temporal resolutions to cater to different user requirements in the country. The INSAT series of satellites, with meteorological payloads operating from geostationary orbit, provide data for generating various parameters, namely, cloud motion vectors, cloud top temperature, water vapour content, vertical profiles of temperature and humidity, facilitating weather forecasting, genesis of cyclones and their track prediction, etc. Currently, INSAT-3A, KALPANA-1 and INSAT-3D are providing meteorological data to the user community.

Earth Observation Satellites in Service

Cartosat-1 was launched into a 617 km polar Sun synchronous orbit on May 5, 2005 onboard PSLV-C6. Two panchromatic cameras, PAN (Fore) and PAN (Aft) are providing high quality images with 2.5 m spatial resolution and a swath of 30 km. The cameras are mounted with a tilt of +26 deg and -5 deg along track with respect to nadir that provides stereo pairs for the generation of Digital Elevation Model (DEM). Data from Cartosat-1 are being used for cartographic applications, DEM generation and other high-resolution geospatial applications. The satellite has completed nearly 10 years in orbit and is currently providing limited imaging services.

Cartosat-2, launched on January 10, 2007 onboard PSLV-C7, carries a single panchromatic camera with the capability to provide better than 1 m spatial resolution imagery of 9.6 km swath. It was placed in a Sun synchronous polar orbit at a nominal altitude of 630 km with a re-visit of 4-5 days. The satellite can be steered along and across the track of up to ± 45 deg to facilitate frequent imaging of any specific area. The satellite has completed 8 years in orbit and still providing imaging services.

Cartosat-2A, launched on April 28, 2008 by PSLV-C9, is an advanced remote sensing satellite with similar capabilities of Cartosat-2. Cartosat-2B was launched onboard PSLV-C15 on July 12, 2010 as a follow on mission of Cartosat-2A and is configured to provide multi-scene imaging capabilities during a pass.

Oceansat-2, a follow on mission to Oceansat-1, was launched on September 23, 2009 onboard PSLV-C14 into a polar Sun synchronous orbit at an altitude of 720 km, with an equatorial crossing time of 12:00 noon. Oceansat-2 carries three sensors onboard, namely, Ocean Colour Monitor (OCM),
Ku-band pencil beam Scatterometer and a Radio Occultation Sounder for Atmospheric studies (ROSA). The eight band Ocean Colour Monitor provides data at 360 m spatial resolution of 1420 km swath with two-day repetitivity. The data is used to generate Local Area Coverage (LAC) product of 360 m resolution (2 days coverage cycle) and Global Area Coverage (GAC) product of 1 km resolution (8 days coverage cycle). The Ku-band pencil beam Scatterometer has provided data for deriving the global wind velocity (magnitude and direction) over ocean surface, which was used as an input for weather forecasting, monitoring of cyclones & their trajectory and ocean state forecasting. After serving the user community for about 4 years, the payload has developed a few mechanical anomalies and stopped functioning since March 2014. ROSA Payload, designed and developed by Italy, was flown in Oceansat-2 to study temperature and humidity profile of the atmosphere.

**RISAT-2**, with X-band Synthetic Aperture Radar (SAR) was realised in association with Israel aerospace industries and launched onboard PSLV-C12 on April 20, 2009. The satellite enables imaging of the surface features during both day and night under all weather conditions. RISAT-2 has enhanced the country’s capability in the disaster management support activities. The satellite has completed more than 5 years in orbit.

**Resourcesat-2** is a follow on mission to Resourcesat-1 to provide data continuity to Indian and global user community. It was launched by PSLV-C16 into an 817 km Sun synchronous orbit on April 20, 2011. As in Resourcesat-1, it has three optical remote sensing payloads, namely, LISS-3, LISS-4 and AWIFS with enhanced multispectral swath from 23 km to 70 km for LISS-4 and improved radiometric resolution from 7 bits to 10 bits for LISS-3 and LISS-4 and 10 bits to 12 bits for AWIFS. It also carried an additional payload, known as AIS (Automatic Identification System) from COMDEV, Canada as an experimental payload for ship surveillance in Very High Frequency (VHF) band to derive position, speed and other information of ships.

**Megha-Tropiques** (Megha means cloud in Sanskrit and Tropiques means tropics in French) is a joint ISRO-CNES satellite mission for better understanding of the life cycle of convective systems and their role in the associated Energy Moisture Budget in the tropical regions. The satellite was launched by PSLV-C18 on October 12, 2011 into an 867 km orbit at an inclination of 20 deg with respect to the equatorial plane. The four scientific instruments carried by the satellite are - (i) Microwave Analysis and Detection of Rain and Atmospheric Structures (MADRAS), an imaging radiometer developed jointly by CNES and ISRO (ii) SAPHIR, a six channel humidity sounder (iii) SCARAB, a four channel scanner for radiation budget measurement and (iv) GPS-ROS, a GPS radio occultation system to provide vertical profiles of temperature and humidity of the Earth’s atmosphere. All the payloads, except MADRAS, are performing satisfactorily and are providing useful scientific data for research and analysis. MADRAS sensor is not functioning now. However, the first 16 months data provided by MADRAS has been calibrated and archived for scientific studies and hosted through Meteorological and Oceanographic Satellite Data Archival Centre (MOSDAC) portal.
(RISAT-1) Radar Imaging Satellite-1 is the first indigenous microwave remote sensing satellite designed and developed by ISRO. The satellite was successfully launched by PSLV-C19 into a Sun synchronous orbit at an altitude of 536 km on April 26, 2012. The satellite carries a Synthetic Aperture Radar (SAR) Payload operating in C-band (5.35 GHz). The satellite enables imaging of the surface features during both day and night under all weather conditions. The payload operates in various modes, namely, Fine Resolution Stripmap (FRS-1), Fine Resolution Stripmap (FRS-2), Medium Resolution ScanSAR (MRS) and Coarse Resolution ScanSAR (CRS). RISAT-1 data is being extensively used for applications in agriculture, particularly for paddy monitoring in kharif season and management of natural disasters like floods and cyclones.

The Satellite with ARGOS and ALTIKA (SARAL) was successfully launched into a Sun synchronous orbit at an altitude of 785 km, on February 25, 2013, onboard India’s Polar Satellite Launch Vehicle, PSLV-C20. SARAL is an oceanographic satellite jointly developed by Indian Space Research Organisation (ISRO) and the French Space Agency, CNES. SARAL payloads are accommodated in the Indian Mini Satellite-2 bus. The Ka-band altimeter, ALTIKA, provided by CNES, operates at 35.75 Giga Hertz (GHz) for ocean applications. A dual frequency microwave radiometer (23.8 and 37 GHz) is embedded in the altimeter to correct tropospheric effects on the altimeter measurement. Doppler Orbitography and Radio-positioning Integrated by Satellite (DORIS) onboard enables precise determination of the orbit. The LASER Retro-reflector Array (LRA) helps to calibrate precise Orbit Determination System and the Altimeter System several times throughout the mission. SARAL ARGOS Data Collection System is a joint contribution of ISRO and CNES to the development and operational implementation of the global ARGOS data collection system for a variety of data from ocean buoys and transmits the same to the ARGOS Ground Segment for subsequent processing and distribution. SARAL provides data products to the user communities for applications in marine meteorology and sea state forecasting; operational oceanography; seasonal forecasting; climate monitoring; earth system and climate research.

Meteorological Satellites in Service

INSAT-3D, an advanced meteorological (weather) satellite, was launched on July 26, 2013 onboard Ariane-5 VA-214 from Kourou, French Guiana. INSAT-3D, positioned at the orbital slot of 82 deg East longitude in the geostationary orbit, adds a new dimension to weather monitoring through its Atmospheric Sounding System, which provides vertical profiles of temperature (40 levels from surface to ~ 70 km), humidity (21 levels from surface to ~ 15 km) and integrated ozone from surface to top of the atmosphere.

Payloads onboard INSAT-3D are:

- **Imager:** It is an improved multi-spectral Imager (optical radiometer) capable of generating the images of the Earth in six wavelength bands significant for meteorological observations, namely, visible (0.55-0.75 µm), shortwave infrared (1.55-1.70 µm), middle infrared (3.8-4.0 µm), water vapour (6.5-7.1 µm) and two bands in thermal infrared (10.2-11.3 µm and 11.5-12.5 µm) regions. The
significant improvements in imaging system over that of KALPANA-1 and INSAT-3A enables night time imaging of low clouds/fog, estimation of Sea Surface Temperature (SST) with better accuracy and acquisition of high spatial resolution images in the visible and thermal infrared bands

- **Sounder:** It is the first geostationary sounder system over Indian Ocean region. It has 19 channels, with 18 narrow spectral channels in shortwave infrared, middle infrared and long wave infrared regions and one channel in the visible region. It provides information on the vertical profiles of temperature, humidity and integrated ozone. These profiles are available for a selected region over Indian landmass every one hour and for the entire Indian Ocean region every six hours.

- **Data Relay Transponder (DRT):** It is used for receiving meteorological, hydrological and oceanographic data from remote, uninhabited locations over the coverage area from Data Collection Platforms (DCPs) like Automatic Weather Station (AWS), Automatic Rain Gauge (ARG) and Agro Met Stations (AMS).

- **Satellite Aided Search and Rescue (SAS & R) Transponder:** The payload picks up and relays the alert signals originating from the distress beacons of maritime, aviation and land based users to the Indian Mission Control Centre (INMCC), located at Bengaluru.

**INSAT-3A**, which was launched on April 10, 2003, carries a Very High Resolution Radiometer (VHRR) with imaging capability in the visible (0.55-0.75 µm), thermal infrared (10.5-12.5 µm) and water vapour (5.7-7.1 µm) channels, providing 2 km, 8 km and 8 km spatial resolutions respectively. It is positioned at 93.5 deg east longitude. The satellite also carries a Charge Coupled Device (CCD) camera providing 1 km spatial resolution, in the visible (0.63-0.69 µm), near infrared (0.77-0.86 µm) and shortwave infrared (1.55-1.70 µm) bands.

**KALPANA-1** is an exclusive meteorological satellite launched by PSLV-C4 on September 12, 2002. It is positioned at 74 deg east longitude. The satellite carries VHRR and DRT payloads to provide meteorological services. Although the satellite has completed its design life of seven years, it continues to provide satisfactory service.

**FUTURE EARTH OBSERVATION MISSIONS**

India’s future Earth Observation Programme will ensure the continuity of the thematic series of satellites, namely, Resourcesat, Cartosat, Oceansat and RISAT for land, water and ocean applications. Also, INSAT system would continue to provide support in the area of meteorology and atmosphere related studies. It is also envisaged to realise a Geo Imaging Satellite (GISAT) in geostationary orbit to enable near real time imaging. The overall aim is to maintain the continuity of services and carryout enhancements in technological capabilities with respect to sensors and payloads in order to meet the operational applications. In this regard, it is planned to design, develop and launch Cartosat-2C/2D/2E and Cartosat-3 in the Cartosat series of satellites, Resourcesat-2A in the Resourcesat series, Oceansat-3 and Scatsat-1 in the Oceansat series, and INSAT-3DR in the INSAT series for meteorological applications in the 12th Five Year Plan. A brief description of these future missions is given hereunder:
Cartosat-2C/2D/2E: Cartosat-2C mission is a follow on mission in Cartosat series with the primary mission objective of providing high resolution scene specific spot imageries. It carries Panchromatic (0.65 m resolution) and Multispectral (2.0 m resolution) cameras operating in Time Delay Integration (TDI) mode. The Spacecraft configuration is similar to Cartosat-2B with a lift-off mass of around 710 Kg with a mission life of 5 years. The spacecraft is planned to be launched by PSLV into a nominal altitude of 500 Km. Cartosat-2D/2E are high resolution remote sensing follow on satellites in the Cartographic series and the configuration of these satellites are similar to Cartosat-2C. The readiness of the first satellite in this series is planned during end of 2015 and the other two during end of 2016 and 2017 respectively.

Resourcesat-2A: It is a follow on mission to Resourcesat-2, and intended to provide continuity of data to the users. The configuration is similar to Resourcesat-2 having three-tier imaging capability, with a unique combination of payloads consisting of three solid-state cameras, namely, a high resolution Linear Imaging Self Scanning Sensor – LISS-IV, a medium resolution Linear Imaging Self Scanning Sensor – LISS-III and an Advanced Wide Field Sensor (AWiFS). The spacecraft mass is around 1200 kg with a mission life of 5 years. The satellite will be placed in Sun Synchronous Polar Orbit (SSPO) of 817 Km altitude with an inclination of 98.69 deg. The spacecraft is scheduled for launch during 2016 onboard PSLV.

SCATSAT-1: It is a continuity mission for Oceansat-2 Scatterometer to provide continuity of data required for weather forecasting services, generate wind vector products for weather forecasting, cyclone detection and tracking services to the users. The spacecraft carries Ku-band Scatterometer similar to the payload flown onboard Oceansat-2. The spacecraft is built around standard IMS-2 Bus and the mass of the spacecraft is 370 Kg. The spacecraft will be put in SSPO orbit of 720 km altitude with an inclination of 98.27 deg by PSLV. The mission life of the satellite is 5 Years.

Cartosat-3: It is an advanced agile satellite to obtain imageries with spatial resolutions of 0.25 m in Panchromatic, 1 m in 4 band multispectral and 12 m in Hyper Spectral for advanced Cartographic Applications with an operational life of 5 years. It carries Advanced High resolution Panchromatic
Camera (AHRPAN), Advanced High resolution Multispectral Camera (AHRMX) and Advanced High Resolution Hyper Spectral Imager (AHRHySI) operating in Time Delay Integration (TDI) mode. Many new technologies/elements are being developed like highly agile structural platform, Payload platform, Data handling & Transmission systems, Advanced Onboard Computer and New Power Electronics, Dual Gimbal Antenna, etc. A series of three satellites are being planned with similar configuration for cartographic applications.

**GISAT-1:** It is a Geo Imaging Satellite operating from geostationary orbit to provide high temporal resolution. The GISAT-1 payload is derived from the in-orbit proven Cartosat-2 imager, which can provide a spatial resolution in the range of 50 m to 1.5 km, depending on the spectral band (VNIR, SWIR, TIR) being used. The spacecraft platform is a modified version of I–1K bus, with power handling capability of around 2037 W during Equinox with a lift-off mass of 2100 kg. The readiness of the satellite is planned during first quarter of 2017. The spacecraft is planned to be positioned at 93.5 deg East longitude in the geostationary orbit of 36,000 km height to provide near real time images of large areas of the country, under cloud free conditions, at frequent intervals. That is, selected sector-wise image every 5 minutes and entire Indian landmass image every 30 minutes at 50 m spatial resolution. The potential applications are quick monitoring of disasters, natural hazards and calamities, episodic events and any short term event along with the meteorological applications.

**INSAT-3DR:** This is a follow-on advanced meteorological satellite planned to be positioned at 74 deg East longitude in the geostationary orbit configured with an Imaging System and an Atmospheric Sounder. It carries two meteorological payloads namely, 6 channel Imager & 19 channel Sounder. In addition to this, it also carries a Data Relay Transponder (DRT) and Satellite Aided Search and Rescue (SAS&R) payload to provide continuity to INSAT SAS&R services. The satellite is designed for enhanced meteorological observations, monitoring of land and ocean surfaces, generating vertical profile of the atmosphere in terms of temperature and humidity for weather forecasting and disaster warning.

**GROUND SEGMENT**

ISRO Telemetry, Tracking and Command Network (ISTRAC) provides tracking support for all operational remote sensing and scientific satellites. ISTRAC also provides active support for Search & Rescue, Disaster Management Support and hosts space communication hub services for societal applications. ISTRAC has established a network of ground stations at Bengaluru, Lucknow, Mauritius, Sriharikota, Port Blair, Thiruvananthapuram, Brunei and Biak in Indonesia to provide TTC support for ISRO’s space missions. At present, ISTRAC provides TTC and spacecraft health monitoring and control services for 11 satellites in orbit, namely, RISAT-1, Megha-Tropiques, Resourcesat-2, Cartosat-1, Cartosat-2, Cartosat-2A, Cartosat-2B, Oceansat-2, RISAT-2, SARAL and Mars Orbiter Mission spacecraft.

**SATELLITE DATA ACQUISITION, PRODUCTS AND SERVICES**

The National Remote Sensing Centre (NRSC), Hyderabad is the nodal agency for satellite remote sensing data acquisition, archival, processing and dissemination in the country. NRSC Shadnagar ground
station receives data from ten Indian remote-sensing satellites and two foreign satellites at Integrated Multi-mission Ground Segment for Earth Observation Satellites (IMGEOS) with station efficiency exceeding 99%. About 7714 satellite passes were acquired and archived during April-October, 2014.

With the implementation of IMGEOS, processing capability has increased to 1000 products/day and data product delivery time is reduced to within an hour for emergency needs and 24 hours for normal needs (Standard products). NRSC is also operating a ground station (Svalbard, Norway) near North Pole through KSAT since 2007, for acquiring global data from IRS satellites.

NRSC has established and operationalised Antarctica Ground Station (AGEOS), at Bharati Station of NCAOR, for IRS data reception facilitating Global coverage. Currently, data reception for Resourcesat-2, RISAT-1 and Cartosat-1 are operational at AGEOS. About 2,300 payload passes (Resourcesat-1: 1700, RISAT-1: 130, Cartosat-1: 470) were acquired and archived during April-October, 2014. Also, Telemetry downlink and Tele-command uplink are operational for TTC passes. INTELSAT-904 Satellite link between Bharati, Antarctica – NRSC, Shadnagar & NCAOR, Goa is being utilised to transfer about 102 GB/day Payload data dumped at Antarctica Station to NRSC, Shadnagar in about 7 hours at 36 Mbps throughput.

**International Ground Stations (IGS):** Euromap - Germany IGS was augmented for Resourcesat-2 data archival and processing. Also, INPE-Brazil IGS was upgraded for Resourcesat-2 data reception and processing at National Institute for Space Research (INPE), Cuiaba, Brazil. Towards serving RISAT-1 data to global clients, Real time Direct Data Ingest system, Ancillary data processing system and DPGS for RISAT-1 data reception and processing were installed and operationalised at Kongsberg Satellite Services (KSAT), Norway during Aug 2014. IRS data downlinks were enabled for 5 ground stations (2 stations for Cartosat-1, 1 station for Resourcesat-2, 2 stations for Oceansat-2 including INCOIS and Mauritius) and cumulative duration of data download from all the stations is 188 h 38 min.

In summary, Indian Remote Sensing Satellite data is acquired at (i) Shadnagar (ii) Svalbard & Tromso (iii) Other Indian Ground Stations at INCOIS & DEAL (iv) International Ground Stations and (v) Antarctica. The station work flow manager system was upgraded for automatically routing the data from Tromso, Svalbard & Antarctica into IMGEOS chain for data processing and product generation.

About 120 Terabytes of satellite data was archived during the year 2013-14 for the passes acquired from Shadnagar data reception facility (73069 GB), AGEOS (23794 GB) and Svalbard facility (25983 GB).

**Legacy Satellite Data Porting on to IMGEOS Archival facility:** Older missions’ data archived on traditional/ legacy media DLTs/DVDs/CDs (pre-IMGEOS scenario) is being ported onto IMGEOS for improving the Turn-Around-Time (TAT) of data products. Data porting for Carosat-1 was completed by April 2014 and also Resourcesat-1 except for Svalbard acquired data.
3D-Visualisation System: A 3D visualisation system has been established at NRSC, Shadnagar. (shown in the Figure below). The facility is equipped with software for streaming 2D & 3D satellite data and interactive visualisation of multiple layers. 3D visualisation based data analysis applications are being developed for Disaster Management services with real-time quick look display in full-swath, rendering 2D and 3D satellite data for visualisation and surfing, expert analysis for areas of interest, searching critical points, etc.,

Development of 2.7 m antenna Terminal: The 2.7 m antenna terminal in axially displaced ellipse configuration was realised and evaluated antenna G/T (24.2 db at 50 deg elevation was achieved). A compact X-band down converter developed for single conversion to Intermediate Frequency (IF) was developed towards the realisation of the system. The system was shifted to Shadnagar for establishment at the Antenna Control Point identified at IMGEOS. Program tracking for the terminal was implemented and testing was completed with simulated trajectory, meeting the lag error specification of ± 0.20 limit. Civil works were initiated and antenna establishment, integration with servo systems and testing for acquisition of satellite passes is planned to be completed shortly.

Satellite Data Processing: IRS data is being processed for generating standard, value added and precision products. Besides, high resolution IRS data products are corrected for terrain using CartoDEM as reference. Oceansat-2 data product generation chain, which was in standalone mode, was integrated into IMGEOS during 2014. 63,215 data products were generated for various IRS sensors from April-October, 2014. The satellite data reception, processing and product generation chains were established for Metop A/B & Suomi-NPP missions reception and processing.
Microwave satellite data processing is operational for the ongoing microwave based satellite remote sensing missions of RISAT-1, RISAT-2, SARAL and ERS-1/2. All the satellite passes of RISAT-1 were processed as part of evaluating the processing chain for its robustness and data anomalies/issues, if any, are analyzed and reported to mission for corrective measures. About 37,000 products were generated during April-November, 2014 for user needs, data quality evaluation, information products generation and internal analysis of processing chain.

RISAT-1 data products were generated for Disaster Management Support Programme (DMSP) during (a) Floods in Jammu & Kashmir, Odisha, Mumbai, Assam, Udalgiri, Rishikesh, (b) Land Slides (Nepal, Pune), (c) Earth Quakes (Pakistan) and (d) Hudhud cyclone. Data products were also generated for Agricultural applications, especially FASAL. Also, International charter requests (Brazil floods, Sinaburg Volcano, China floods, Vietnam floods etc.,) were serviced by providing data products to users in specified TAT (i.e., within 1 hour for emergency products). RISAT-1 MRS data of Jammu and Kashmir is shown below.

RISAT-1 MRS Data of 12-Sep-2014 covering J&K

Operational Geophysical Records (OGDRs) are being generated in Near Real Time at Shadnagar using data received from EUMETSAT (Payload Telemetry (PLTM) and Dynamic Auxiliary Data). 3818 OGDRs were generated during the period (April-October, 2014) and about 12,400 IGDRs were retrieved from AVISO server and disseminated to users. The Significant Wave Height (SWH) extracted from the recent Hudhud cyclone data acquired on October 10, 2014 from SARAL ALTIKA IGDR product in cyclone region is shown in the next page.
SWH extracted from OGDRs for all 501 orbits (1002 passes-full cycle) of Cycle-17

Satellite Data Dissemination: NRSC, Hyderabad, as the national agency, acquires and disseminates all the satellite data within India. As per the Remote Sensing Data Policy (RSDP 2011), all satellite remote sensing data of resolutions up to 1 m is distributed on a non-discriminatory basis and on “as requested basis”; and all data of better than 1 m resolution is screened and cleared by the appropriate agency prior to distribution. During 2013-14, Financial Year (FY) 1,10,575 satellite data products were disseminated to users through data supply chain. During April-October, 2014 period, 42,402 data products are disseminated.

Web downloads: LISS-III, AWiFS satellite data and CartoDEM data sets through Bhuvan web portal and OCM & Scatterometer data (archived/ reprocessed data for 2010-2014 period) through Oceansat-2 Web portal are being served as free downloads to users. OCM GAC data is made available for eight day cycles. During 2013-14, FY about 3,15,300 Products were downloaded by users using the facility. During April-October, 2014 period, about 1,04,375 products were downloaded.

Customer Relationship Management (CRM): Beta version of CRM phase-I software developed under IMGEOS for continual improvement of operational efficiency, productivity, customer satisfaction, etc., was operationalised from January 2014. The system enables NRSC Data Centre to consolidate the communications from the users, provide continuity of interaction with the users and monitor product generation chain with a particular emphasis on user needs and perception.
Improvements in Browse Quality Indicators: Scene based data loss information (derived from raw data) was implemented for Resourcesat-2. Also, cloud segmentation in Resourcesat-2 multi-spectral data using an empirical method based on spectral characteristics of land features was developed and operationalised. Auto-cloud cover estimation in high resolution panchromatic satellite imagery using ‘Spectral characteristics and context information based cloud feature extraction’ algorithm was implemented and is ready for operational use.

User Order Processing System (UOPS): New version of UOPS was developed using Rich Internet Application (RIA) technologies and interactive map server for integrated satellite data ordering services, enhanced user-friendly data browsing, selection and ordering features. The system provides resolution based data searching, replacing sensor based method, thereby allowing data ordering from multiple sensors seamlessly to cover users Area of Interest (AOI). It also provides user information, data order status, pricing, etc., for the delivery of effective services. The system is also scalable for new satellite-sensors.

Bhuvan Services:
Bhuvan (http://bhuvan.nrsc.gov.in) is ISRO’s Geoportal providing visualisation services and Earth observation data to users in public domain. The portal also provides various services for remote sensing user community. The portal has witnessed about 9.5 lakh unique visitors in the last five years of its services. It has about 51,000 registered users and has served more than 2.8 lakhs downloads from NRSC Open EO Data Archive (NOEDA). During 2014, Bhuvan had 26 new releases of applications and services, like Bhuvan visualisation services, NRSC Open EO Data Archive (NOEDA) Services, Thematic Services, Disaster information services, Bhuvan - NICES Portal.

Timely satellite data products demanded by Accelerated Irrigation Benefit Program (AIBP) to monitor major and medium national irrigation projects were released under “Web-enabled Bhuvan Products for AIBP (CWC) from Cartosat Missions".
New applications in Bhuvan for Geo-Governance: State-wise portals are being developed on Bhuvan for Geo-Governance by providing all available Information on Administrative layers, Agriculture & Soil, Disaster specific datasets, Geology & Mines, Land use/Land cover, Urban, Socio-economic details etc. Currently it is available for 11 states. Portal for mapping infrastructure, vehicle tracking and incident reporting was implemented to assist Government of Andhra Pradesh in General elections of 2014. Towards this, information on about 68,000 polling stations data was uploaded on Bhuvan.

MOSDAC Services:
An Android Application for viewing 3 hourly weather forecasts on Android based hand held devices has been released on MOSDAC. Metadata has been published for complete one year INSAT-3D products (archived on MOSDAC) as per ISO 19115 standards and the same are now available at global CEOS catalogue test server. Area of Interest (AOI) based data ordering of Megha Tropiques and SARAL data has been released on MOSDAC. MADRAS Sensor data (October 2011 to December 2013) flown onboard Megha-Tropiques mission is being released after reprocessing. Website giving intense rain details from INSAT-3D Hydro - Estimator (HE) product, with identified met-sub-divisions at regular half hourly intervals has been linked and released on MOSDAC. Cyclogenesis alerts with track forecasting and intensity prediction for cyclones, namely Nanauk, Hudhud, Nilofer have been released. Validation results have also been hosted. NOWCASTING results related to heavy rain and or cloud burst over Himachal Pradesh and Uttarakhand at half hourly interval is being hosted on a regular basis with value addition in terms of interactive display of relevant layers such as DEM, rivers, roads, taluka, district, etc using GEOSERVER. Near Real Time data services has been provided to Operational Agencies, namely, NASA-GPM (Megha-Tropiques-SAPHIR), NCMRWF (EUMETCAST), PRWONAM (KALPANA1, WRF Forecast, NOWCAST, etc), launch Campaign for SHAR (48 hr model forecast, 30 Min forecast, next 15 days cyclone prediction, enhanced cloud images etc.), KALPANA-1 data to IMD, Delhi.

NRDB Services:
Natural Resources Database (NRDB) is a systematic archive of thematic layers generated under various National Natural Resources Management System (NNRMS) programme, which includes wasteland, Natural Resource Census (NRC), wetland, desertification, National GIS, etc.,. Around 1300 raster images have been processed using the automated procedure to generate 54 snow cover layers covering Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Sikkim and Arunachal Pradesh for all nine months (2011-2012 and 2012-2013). The same have been hosted on NNRMS/NRDB Portal. The NRDB layers are made available to users as Web Map Service (WMS). The metadata of the NRDB content has been shared with National Spatial Data Infrastructure (NSDI).

Geophysical and Special Products:
As in the 2013, a major thrust has also been given for the development of geophysical and information products in 2014. Some of the important products are:
Water and Snow Information products, RISAT-1 (MRS) data based Water fraction information of India, Oceansat-2 Chlorophyl products, Snow Freeze/Melt trends from Oceansat-2 SCAT data, Full India Surface Water Mapping with OCM LAC, Snow Albedo from Resourcesat-2 AWIFS and Monthly Cloud Histogram product for Clear Sky Radation (CSR) analysis, etc.,

AWIFS Data & Snow Albedo map (2013) over Himalayas

Some of the Information Products developed for User projects includes Full India 4-cycle Monthly AWIFS NDVI products, Water balance based geo-spatial hydrological products and Stereo Imaging of Antarctica Sites.

2-Cycles of Full India NDVI from Resourcesat-2 AWIFS & its Composite products
AERIAL SERVICES & DIGITAL MAPPING AREA

The Aerial Services & Digital Mapping (AS&DM) of National Remote Sensing Centre, Hyderabad is a unique national facility that has end-to-end capability and state-of-the-art infrastructure in the domain of Aerial Remote Sensing data acquisition and processing for Large Scale Mapping, sensor validation, disaster studies, urban planning, etc. Till October 2014, Aircraft utilisation was to the tune of 148 hours. Some of the important activities carried out are:

- Aerial LiDAR & DC survey covering 600 km², over Hudhud cyclone affected areas around Visakhapatnam city under Disaster Management Support Programme. Aerial survey was carried out during October 13-17, 2014 covering Visakhapatnam (600 sq.km) acquiring about 4350 images (Figure shown below). The data was processed and images were delivered for damage assessment/planning relief measures to Government of Andhra Pradesh.

- Aerial LiDAR & DC survey, pre-processing & field leveling for Brahmaputra Basin Phase-II covering 15400 km² under Disaster Management Support Programme.

- Part of Lohit district in Arunachal Pradesh covering 700 km² using Hyper-spectral Sensor
• Betul site, Madhya Pradesh covering 100 km² as part of National Carbon Project
• Two sites (Nagpur and Savner) covering 200 km² each as part of GCPL Phase-III project

LiDAR-DC Surveys: Airborne LiDAR data was acquired for Mahanadi, Ganga, Godavari and Brahmaputra river basins under Disaster Management Support Programme. Till date, data acquisition to the tune of 61898 km² was completed. Data acquisition over West Bengal (6500 km²) is in progress. Data processing was completed for Godavari basin covering 5140 km². DTM generation and Geospatial database generation are in progress for Mahanadi Basin (6800 km²) and data pre-processing tasks are in progress for Brahmaputra Basin (15,400 km²).

National Carbon Project (NCP) - Betul Site: The project was intended for estimating above ground biomass of a tropical forest in India using LiDAR canopy volume profiles. During the current year, LiDAR and GPS data for Betul tower site was acquired and processed for accurate geo-referencing of LiDAR data. Digital Surface Model (DSM), Digital Terrain Model (DTM) and Canopy Height Model (CHM) have been extracted from LiDAR point cloud for deriving tree structural parameters.

GCPL Phase-III (NNRMS): The study was taken up to densify the Ground Control Points (GCPs) for future Cartosat missions as well as to improve the overall planimetric accuracy. Airborne large format digital data is used to generate high precision ortho data for six test sites (Nagpur, Savner, Ranchi, Alwar, Bhind, Pune) for calibrating the satellite platform. The total task covers 8500 GCPs (including 1100 PSPs) with accuracy better than 50 cm and their collection in two modes - using GAGAN SBAS/ Commercial DGPS services in first mode and pre-signalised points (PSPs) with monumentation in the second mode. So far, GCP collection including database generation was completed for 2530 / 7400 points covering South India. In the second mode, pre-signalised GCPs are being collected with monumentation. About 480/1100 pre-signalised points were monumented till now. Field data collection for 3000 GCPs and 500 PSPs over North India would be completed by February 2015. Also, collection of about 500 GCPs and 40 PSPs in J&K and NE states is planned during March 2015.

High Resolution Topographic Mapping for A&N Islands was initiated last year to generate topography data at 1:10,000 scale for entire A&N islands (8250 km²) and at 1:5000 for 3 main islands (Portblair, Havlock and Neil islands). In the first phase, Cartosat-1 data was used to generate DEMs, ortho-images and maps. DEM of Car Nicobar Island is shown in the Figure in the next page. In the second phase, cloudy areas were addressed using the corresponding microwave data for generation of the products. The three main islands were mapped on 1:5000 scale using high resolution data. The topographic database was generated and delivered to Decision Support Centre for Disaster Management Support.
Towards establishment of Tsunami warning centres, geospatial database of Indian coast (covering Paradeep to Cochin) is being generated for INCOIS. A new value added product, ‘Generation of 3D building models’ was also introduced to assess the heights of buildings that can help in vertical evacuation during disasters like Tsunami. The heights were generated for about 20,00,000 buildings in the east coast (Paradeep-Cochin stretch) using the automated tool developed for extracting the heights from DSM & DTM generated from LiDAR point cloud and building foot prints obtained from the ortho-images.
Space Applications

Satellite Communication Applications

A fleet of commercial communication satellites, namely, INSAT-3A, INSAT-3C, INSAT-4A, INSAT-4B, INSAT-4CR, GSAT-8, GSAT-10, GSAT-12, GSAT-14 and GSAT-16 are operating over India with communication transponders in C-band, Extended C-band, Ku-band and S-band. These transponders support the services like television, telecommunication, radio networking, strategic communication and societal applications. The prominent users of the transponders are BSNL, Doordarshan, All India Radio, strategic govt. users, public sector units, private VSAT operators, DTH and TV operators, banking and financial institutions, etc.

Under societal applications, ISRO has supported programmes like Telemedicine, Tele-education, Village Resource Centre (VRC) and Disaster Management Support (DMS) Programmes which are solely national development oriented with an aim to address specific requirements at different strata of the society.

In order to meet additional transponder requirements from various users, about 96 transponders in C and Ku-band are leased from international satellite operators, through Antrix Corporation Limited on a back-to-back arrangement with users and satellite operators. Thus, satellite communication is playing a major role in the socio-economic development of the country.

Television

INSAT has been a major catalyst for the expansion of television coverage in India. Satellite television now covers 100% area and 100% population. The terrestrial coverage is over 81 percent of the Indian land mass and over 92 percent of the population. Doordarshan is a major user of INSAT satellites for providing television services over the country.

Doordarshan is presently operating 33 satellite channels and has a vast network of 67 Studios and 1416 Transmitters of varying power. In addition, Doordarshan is providing free-to-air Direct-to-Home (DTH) service. Growth of Doordarshan network is shown below

<table>
<thead>
<tr>
<th>Table: 33 Satellite channels of Doordarshan</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>All India Channels (5)</strong></td>
</tr>
<tr>
<td>DD National, DD News, DD Sports, DD Bharati and DD Urdu</td>
</tr>
<tr>
<td><strong>Regional Channels (16)</strong></td>
</tr>
<tr>
<td>DD Malyalam, DD Chandana, DD Yadagiri, DD Podhigai, DD Sahyadri, DD Girnar, DD Odiya, DD Kashir, DD North East, DD Bangla, DD Punjabi, DD Rajasthan, DD Bihar, DD UP, DD MP and DD Saptagiri</td>
</tr>
<tr>
<td><strong>State Networks (11)</strong></td>
</tr>
<tr>
<td>Himachal Pradesh, Jharkhand, Chhattisgarh, Haryana, Uttarakhand, Tripura, Mizoram, Meghalaya, Manipur, Arunachal Pradesh and Nagaland</td>
</tr>
<tr>
<td><strong>International Channel (1)</strong></td>
</tr>
<tr>
<td>DD India</td>
</tr>
</tbody>
</table>
Doordarshan launched its free-to-air DTH service “DD Free Dish (Earlier DD Direct+)” in December, 2004 with a bouquet of 33 TV channels. This service was started with the primary objective of providing TV coverage to the areas hitherto uncovered by terrestrial transmitters. Capacity of DTH Platform was subsequently augmented to 59 TV channels. DTH signals can be received anywhere in the country (except Andaman & Nicobar Islands) with the help of small sized dish receive units. For A&N Islands, DTH service in C-band with a bouquet of 10 channels was started with effect from September, 2009.

The DTH platform has been expanded by adding one more transponder and increasing the capacity. The upgraded DD DTH platform will be having 64 SD channels in MPEG 2 DVB-S and 41 SD & 1 HD channel in MPEG 4 DVB-S2.

DTH services are becoming popular with the introduction of premium services like HDTV services, On-demand movie services, etc. High power Ku-band transponders are used to support DTH television service with smallest dish antenna all over India.

About 80 Ku-band transponders from INSAT/GSAT and Leased satellites are catering to DTH television services. Doordarshan is presently using a total of 19.25 Transponders (12.25 C-band & 7 Ku-band) of 36 MHz each on INSAT System. It is estimated that (TRAI Report - November 2014) there are about 67.57 Million registered DTH subscribers and 38.24 active DTH subscribers.

**Satellite News Gathering and Events Broadcasting**

Satellite News Gathering using INSAT system enables coverage of on-the-spot real-time news and important events at different locations for transmission to a Central Station. These live coverages are rebroadcast over respective television channels. Doordarshan alone has 14 C-band and 18 Ku-band Digital Outdoor-Broadcast Digital Satellite News Gathering terminals operating through INSAT satellites.

**Radio Networking**

Radio Networking (RN) through INSAT provides a reliable high-fidelity programme channels for National as well as Regional Networking. Around 415 All India Radio (AIR) stations have been equipped with receive terminals. AIR is utilising one C-band transponder of INSAT-3C for uplinking RN carriers across the country. AIR has 21 radio channels on DTH platform in Ku-band being uplinked with TV carriers from Todapur, New Delhi on INSAT-4B.

**Telecommunications**

INSAT satellites have been traditionally supporting telecommunication applications for providing voice and data communications. Satellite links are the primary means of connectivity to remote and far flung regions of the country and they are the backup links for large number of terrestrial connectivities.
The satellite networks of modern age embrace, to a large extent, Very Small Aperture Terminals (VSATs) to cater to the traffic and application requirements of varied users. The VSAT networks are designed to support all kinds of applications supporting video, voice and data, with a wide range of data rates from few kilobits per second (kbps) to 8 megabits per seconds (mbps). A VSAT network comprises of a central hub and hundreds of terminals which are further interfaced to computers and other peripheral devices. The hub acts as a gateway with interface to external connectivity and several application servers. Rapid technological advancements and reduction in the cost of user equipment are increasing the popularity of VSAT network. A VSAT network works out to be a cheaper option while establishing a network to cover a wide geographical area, state wide or nationwide. VSAT networks operate in C, Extended C and Ku-bands.

1355 Satellite Earth Stations of different size are operating in satellite network of BSNL, Government users, Closed user group, commercial users and broadcasters and are being utilised for telecommunications / broadcasting applications. As per provisional estimates, about 2,33,841 VSATs (excluding NICNET and VSAT micro terminals) are being used in star / mesh connectivity of various size and capabilities. Telecom services are being provided by BSNL to remote and inland through satellite media in C band and Ku band from main earth stations as backhaul point to point connections. BSNL is also providing GSM connectivity, ATM/Banking connectivity through 16300 IPSTAR VSATs as well as one by two voice channel connectivity to remote areas through 5824 DSPTs (Digital Satellite Phone Terminal).

Captive satellite based networks for NTPC, GAIL, Oil and Natural Gas Corporation Ltd., National Fertilizer Ltd., Coal India Ltd., ERNET, Karnataka Power Transmission Corporation Ltd., IOCL, BPCL, Jai Prakash Industries Ltd., Indian Railway Project Management Unit, ICAR, POLNET and Infotel Satcom are operational in INSAT system. The networks of Bombay Stock Exchange in Extended C Band are operational on INSAT system. A number of other captive government networks like Indian Coast Guard, Ministry of Defence, Cabinet Secretariat, DRDO etc are also working with INSAT satellites.

**Telemedicine Programme**

ISRO Telemedicine pilot project was started in the year 2001 as part of proof-of-concept demonstration programme, linking Apollo Hospital at Chennai with the Apollo Rural Hospital at Aragonda village in the Chittor district of Andhra Pradesh. The Telemedicine technology involved the ICT based system consisting of customised medical software integrated with the computer hardware along with medical diagnostic instruments connected to the commercial VSAT at each location. The Telemedicine software consisted essentially of store-and-forward modules for Tele-radiology, Tele-cardiology and Tele-pathology purposes along with the video-conferencing facility. The medical record/history of the patient are sent to specialist doctors, who would study and provide diagnosis and treatment during videoconference with the patients. The tele-consultation process is facilitated by a doctor at Patient-end.

The Telemedicine programme has been connecting remote/rural/medical college hospitals and Mobile Units through the Indian satellites to major specialty hospitals in cities and towns. ISRO Telemedicine network today covers various states/regions including Jammu & Kashmir, Ladakh, Andaman & Nicobar
Islands, Lakshadweep Islands, North-Eastern states and other mainland states. Many tribal districts of Kerala, Karnataka, Chhattisgarh, Punjab, West Bengal, Odisha, Andhra Pradesh, Maharashtra, Jharkhand, Rajasthan, etc., are also covered under Telemedicine programme.

While DOS/ISRO provides Telemedicine systems software, hardware and communication equipment as well as satellite bandwidth, state governments and the speciality hospitals have to allocate funds for their part of infrastructure, manpower and facility support. In this regard, technology development, standards and cost effective systems have been evolved in association with various state governments, NGOs, specialty hospitals and industry.

Telemedicine programme has been implemented in association with state governments, specialty hospitals and trust hospitals through MOU. So far, 389 hospitals have been provided with the Telemedicine facility across the country. Out of 389 hospitals, 301 are rural/district/medical college hospitals (remote hospitals), 17 are Mobile Telemedicine units, 66 are Speciality Hospitals and 5 Monitoring nodes. In December 2014, about 150 Telemedicine Centres are operational and others have developed technical problems due to maintenance and operational aspects. ISRO is working with users to resolve these issues.

Development and Educational Communication Unit (DECU), a unit of ISRO located in Ahmedabad implements the network operations and interact with state governments and specialty hospitals in overseeing the utilisation of the network.

The Continuing Medical Education (CME) facility was introduced in the Telemedicine (TM) networks in 2013. A Learning Management System (LMS) server was installed at the ISTRAC Telemedicine hub, Bengaluru, to accommodate 150 institutions/nodes. This facility will help hospitals and medical institutions to share their experiences and best practices with each other.

Three CME lectures have been conducted on the network during November and December 2014. It is planned to hold one session every month from the DECU studios by inviting the medical professionals. The CME facility is configured, in such a way that any telemedicine node on this network can be made a Lecture Originating Node.

During the Jammu & Kashmir floods, a Satcom link was established between Telemedicine terminal at DECU and patient node at Sher-i-Kashmir Institute of Medical Science (SKIMS), Srinagar, for supporting the disaster relief activities. The Telemedicine nodes that were damaged due to the cyclone Phailin in Odisha are repaired and functionalised. An operational training was coordinated for the node coordinators of Chhattisgarh TM nodes.

It is proposed to upgrade the existing telemedicine network with latest technology during the next financial year. DOS is working with Ministry of Health and Family Welfare to evolving a mechanism for use of technology for addressing healthcare needs.
Tele-education (EDUSAT) Programme

‘EDUSAT’, India’s first thematic satellite dedicated exclusively for educational services, was used extensively to cater to a wide range of interactive educational delivery modes like one-way TV broadcast, video interactivity, computer aided teaching, web-based tools, etc. EDUSAT had manifold objectives - to supplement the curriculum-based teaching, imparting effective teacher training, providing access to quality resource persons and new technologies, thus finally resulting in taking education to every nook and corner of India. EDUSAT provided connectivity to schools, colleges and higher levels of education and also supported non-formal education including development communication.

EDUSAT Programme was implemented in three phases: pilot, semi-operational and operational phases. Pilot projects were conducted during 2004 in Karnataka, Maharashtra and Madhya Pradesh with 300 terminals. The experiences of pilot projects were adopted in semi-operational phase. During semi-operational phase, almost all the states and major national agencies were covered under EDUSAT programme.

The networks implemented under EDUSAT programme comprise two types of terminals, namely, Satellite Interactive Terminals (SITs) and Receive Only Terminals (ROTs). As on December 2014, a total of 83 networks were implemented connecting to about 60,051 schools and colleges (around 4,790 SITs and around 55,261 ROTs) covering 26 States and 3 Union Territories of the country.

The operations and maintenance of tele-education networks in North East states are now decentralised and being handled through North Eastern-Space Application Centre, Shillong. Technical support is provided to the users by establishing a Technical Support and Training Centre (TSTC) for their close monitoring and timely support provided so that the downtime is minimised and utilisation is increased.

Use of GSM based interactivity as audio return channel to tele-education studios is explored. This would enable use of Receive Only Terminals (ROTs) more effectively.

During the year, a new Ku-band Hub was commissioned at Aizwal in Mizoram. The migration of Integrated Disease Surveillance Project (IDSP) network has been completed. Currently, IIT-B tele-education network is being migrated to GSAT-12 and Nagaland tele-education network to INSAT-4CR.

In coordination with users 27 tele-education hubs were enabled for rebroadcast of Hon’ble Prime Minister’s address on September 05, 2014 and Mars Orbit Insertion of Mars Orbiter spacecraft on September 24, 2014. These programmes were received by around 45,000 ROTs and 2000 SITs.

Mobile Satellite Services

S-band Mobile Satellite Service (S-MSS) is being provided using INSAT-3C satellite. Two classes of services, namely, Type-C and Type-D are identified for MSS. The MSS Service provides the communication to the portable and moving devices.
- **INSAT Reporting (Type-C) Service**

  It is a low bit rate one-way reporting service with portable and hand-held terminals using shared channels. This unique one-way messaging from a remote location to user-headquarters operates with the Delhi Earth Station (DES) of DOS as the hub. This is an experimental service. Short messages from user terminals are relayed through the satellite to the hub and are automatically forwarded to the respective user headquarters via Fax or data links. This reporting service is provided using small hand-held terminals. Most of the terminals are attached with GPS receivers for transmitting their position information.

- **INSAT Type-D Service**

  It is a low bit rate two-way communication service with small portable satellite terminal supported through INSAT System. It is planned to support voice and FAX services. The terminal is useful for voice communication, especially during disasters when other means of communication breakdown. It can be used from any location in India for emergency communication. Transmit and receive frequencies of the terminal are in S-band and it is mainly used by the government users. The portable terminal is connected to the EPABX at the central hub station through satellite channel and hence could be considered as an extension of EPABX and call could be made between any satellite terminals and local phones on EPABX. The central hub station is located at Delhi Earth Station, New Delhi.

  The terminals are being realised with the participation of Indian industries, using ISRO developed technology.

**Satellite Meteorology**

The meteorological satellite data of INSAT is processed and disseminated by INSAT Meteorological Data Processing System (IMDPS) of India Meteorological Department (IMD) which was installed by M/s Antrix Corporation through an MOU with India Meteorological Department. At present, Kalpana-1(VHRR, DRT), INSAT-3A (VHRR,CCD,DRT) and INSAT-3D(Imager, Sounder, DRT) satellites carrying meteorological payloads are supporting weather forecasting services. INSAT-3D IMDPS was dedicated to the nation in January 2014. The system is capable to receive and process the data of all three existing geostationary meteorological satellites.

The products derived from the satellite data include: Cloud images in the Visible, Short wave Infra-red, Mid Infra-red, Thermal Infra-red, Water Vapour Channels and special enhanced images, Atmospheric Motion Vectors (IR Wind, Water Vapour Winds, MIR and Visible Winds), Sea Surface Temperature, Outgoing Long-wave radiation, Quantitative Precipitation Estimates, Night time Fog, Smoke, Fire, Snow Cover, Aerosol Optical Depth, Upper Tropospheric Humidity, NDVI, Temperature & Humidity profiles, Total ozone, Total/Layer Precipitable Water Vapour and Stability Indices. All these images and products are disseminated on a realtime basis through dedicated IMD website. Satellite observed radiances are now being assimilated in NWP models so as to improve their forecast ability. Satellite images are used in monitoring cyclones. Intensity and position of cyclones is given to forecasters in real time.
using Dvorak technique. Satellite data and images are also used in monitoring various other significant weather phenomena such as Fog and thunderstorms.

IMD has installed 675 Automatic Weather Stations (AWS) and other agencies have installed about 1200 AWS all over the country. IMD has also installed 1220 Automatic Rain Gauge (ARG) Stations. AWS and ARG services are operational by using the Data Relay Transponders (DRT) of INSAT-3A and INSAT-3D having global receive coverage with a 400 MHz uplink and 4504 MHz downlink frequencies with a data-rate of 4.8 kbps for relay of Meteorological, Hydrological, Agro-Meteorological and Oceanographic data from unattended stations. The data collection is mostly carried out in Time Division Multiple Access (TDMA) mode to enhance the output.

For quick dissemination of warnings against impending disaster from approaching cyclones, all channels of communications are used e.g. website, SMS, FAX, telephone and satellite. IMD’s Area Cyclone Warning Centres generate special warning bulletins and transmit them every hour in local languages to the affected areas. During recent past, in case of Hudhud cyclone, warning was disseminated to all stakeholders which resulted in minimum loss to human life. IMD is now upgrading all these existing network of CWDS/DCWDS by the ISRO developed DTH modified type CWDS. An MOU has been signed among ISRO, IMD and Doordarshan for replacement of the existing network of CWDS by new DTH modified type CWDS designed by ISRO. The implementation of DTH based DWDS project is under progress and 178 systems have been successfully installed till date. It is stated that satellite technology is of great use in meteorology and plays a very significant role in the improvement of weather forecasting and dissemination. In fact, the improvement in weather forecasting is mainly attributed to increasing use of satellite data.

**Satellite Aided Search and Rescue (SAS&R)**

India is a member of the international COSPAS-SARSAT programme for providing distress alert and position location service through LEOSAR (Low Earth Orbit Search And Rescue) satellite system. Under this programme, India has established two Local User Terminals (LUTs), one at Lucknow and the other at Bengaluru. The Indian Mission Control Centre (INMCC) is located at ISTRAC, Bengaluru. The system is operational from the past 24 years.

INSAT-3A, located at 93.5 deg East and INSAT-3D located at 82 deg East, are equipped with a 406 MHz Search and Rescue payload. INSAT-3D, the advanced metrological satellite was launched on July 26, 2013. INSAT-3D SAR payload and corresponding ground processing system test result were submitted to Cospas-Sarsat, which got approved in October 2014 and the system has been declared commissioned.

The SAR payload on INSAT-3A and INSAT-3D pick up and relay alert signals originating from the distress beacons of maritime, aviation and land users. Indian LUTs provide coverage to a large part of the Indian Ocean region rendering distress alert services to Bangladesh, Bhutan, Maldives, Nepal, Seychelles, Sri Lanka and Tanzania. The operations of INMCC/LUT are funded by the participating agencies, namely, Coast Guard, Airports Authority of India (AAI), and Directorate General of Shipping and Services.
INSAT GEOSAR Local User Terminal (GEO LUT) is established at ISTRAC, Bengaluru and integrated with INMCC. The distress alert messages concerning the Indian service area, detected at INMCC, are passed on to Maritime Rescue Coordination Centres (MRCCs) of Indian Coast Guard (Mumbai, Chennai, Port Blair), and Rescue Coordination Centres (RCCs) of AAI (Mumbai, Kolkata, Delhi, Chennai). The search and rescue activities are carried out by Coast Guard, Navy and Air Force. INMCC is linked to the RCCs, MRCCs, SPOCs (Search and Rescue Points of Contact) and other International MCCs (Mission Control Centres) through Aeronautical Fixed Telecommunication Network (AFTN) and through FTP (File Transfer Protocol) links. The Indian LUTs and MCC provide round the clock service and maintain the database of all 406 MHz registered beacons carried on-board Indian ships and aircraft.

Development of indigenous search and rescue beacons has been completed, and is now under qualification phase through international agencies.

During the year 2014, INMCC provided search and rescue support to 9 distress incidents in Indian service area through Indian system and contributed to saving of 32 human lives.

During 2014, about 802 new radio beacons were added in Indian database (most of them for maritime applications). Till date, there are about 854 registered user agencies (Maritime & Aviation) in India with an Indian beacon population of 13,854 in INMCC database.

INMCC also extended support for recovery of Crew Module Atmospheric Re-entry Experiment (CARE) which was launched onboard LVM3 test mission on December 18, 2014. The CARE module carried a SAR beacon.

**Standard Time and Frequency Signal Dissemination Services**

A Standard Time and Frequency Signal (STFS) Dissemination Service using INSAT system is provided by National Physical Laboratory. This service is available round-the-clock in a broadcast mode and is receivable on a set up consisting of receive antenna, a front-end converter, an FM demodulator and a microprocessor controlled signal decoder. The service consists of a train of 5 KHz bursts signal, which is frequency modulated on the carrier. The timing service has a precision of better than one microsecond and accuracy of better than 20 microseconds.

**Applications of GPS AIDED GEO AUGMENTED NAVIGATION (GAGAN)**

The implementation of GAGAN has numerous benefits to the aviation sector in terms of fuel saving, saving in equipment cost, flight safety, increased air space capacity, efficiency, enhancement of reliability, reduction in work load for operators, coverage of oceanic area for air traffic control, high position accuracy, etc. The quantum of benefits in the aviation sector would depend on the level of utilisation of such benefits.
Some of the benefits GAGAN is expected to bring for Civil Aviation sector are:

- Safety benefits—Vertical guidance improves safety, especially in adverse weather conditions
- Reduction of circling approaches
- Environmental benefits—Approach with Vertical Guidance procedures will help facilitate better energy and descent profile management during the final approach
- Global seamless navigation for all phases of flight including arrival, departure, oceanic and en route
- Allow direct routings, multiple approaches resulting in considerable fuel savings to airlines and provide for capacity enhancement of airports and airspace

In addition to aviation sector, GAGAN is expected to bring benefits to other sectors like:

- Navigation and Safety Enhancement in Railways, Roadways, Ships, Spacecraft
- Geographic Data Collection
- Scientific Research for Atmospheric Studies
- Geodynamics
- Natural Resource and Land Management
- Location based services, Mobile, Tourism, etc.

Applications of IRNSS

IRNSS will provide two types of services, namely, Standard Positioning Service (SPS) which is provided to all the users and Restricted Service (RS), which is an encrypted service provided only to the authorised users. The IRNSS System is expected to provide a position accuracy of better than 20 m in the primary service area.

Some applications of IRNSS are:

- Terrestrial, Aerial and Marine Navigation
- Disaster Management
- Vehicle tracking and fleet management
- Integration with mobile phones
- Precise Timing
- Mapping and Geodetic data capture
- Terrestrial navigation aid for hikers and travelers
- Visual and voice navigation for drivers
Disaster Management Support (DMS) Programme

The Disaster Management Support (DMS) Programme of ISRO continues to provide space based information and services to the State and Central Government Departments to strengthen the disaster management activities. The DMS-Decision Support Centre (DMS-DSC) established at National Remote Sensing Centre (NRSC) is actively engaged in monitoring natural disasters such as flood, cyclone, agricultural drought, landslides, earthquakes and forest fires. Information generated from aerospace systems are disseminated to the concerned in near real time for aiding in assessment, management and decision making.

**Floods:** In 2014, flood monitoring was carried out for floods in 8 states and 112 flood maps were disseminated to the concerned State and Central officers in addition to making available to Users on the web through Bhuvan, DSC and NDEM web portals. In the case of unprecedented floods in Jammu & Kashmir, cumulative flood inundation maps and their progression & recession maps were prepared for four locations in Srinagar valley, viz., Hari Nivas (make shift seat of J&K government), Civil Secretariat Srinagar, Raj Bhavan and Air Force Station, Srinagar and the information was disseminated on daily basis during September 08-21, 2014. A Flood Early Warning System (FLEWS) is operational in Assam State by North Eastern Space Applications Centre (NESAC). A Flood Hazard Atlas for Odisha based on past flood incidents was prepared and handed over to Govt of Odisha for ground validations.

**Cyclones:** All the depressions and cyclones originated in the Indian ocean region were monitored and the track, intensity and landfall were predicted. This includes Cyclone Hudhud which made a landfall at Visakhapatnam and Cyclone Nilofar which threatened Gujarat region during October 2014. All the information was regularly updated on the MOSDAC website (http://www.mosdac.gov.in) as part of information dissemination. The very severe Cyclonic Storm ‘Hudhud’ over Bay of Bengal made landfall at Andhra Pradesh coast on October 12, 2014 causing heavy damage to Vishakhapatnam city. District-wise inundation statistics were generated and disseminated within 8 hours of acquisition of data. Assessment of damage to infrastructure like roads, railways etc was also taken up using the high resolution data (Cartosat / World View / Quickbird / Pleiades). Further, integrating Bhuvan and an android based application helped collecting more than 25,000 damage details from public which helped the district authorities to attend to the problems.
Agricultural Drought: NRSC is providing continuous technical support to Mahalanobis National Crop Forecasting Centre (MNCFC), MoA/GoI for Agricultural drought assessment. During 2014, modules related to Shortwave Angle Slope Index (SASI) computation, Soil moisture estimation through water balance methodology and generation of crop sown area products were added to the NADAMS Analysis Software operationalised at MNCFC in 2013.

Forest Fire: The Indian Forest Fire Response and Assessment System (INFFRAS) provides (3-4 times a day) near real time (within 30 minutes from acquisition) in season MODIS based fire alerts during February–June every year. In the 2014 fire season, 26,163 fire alerts were generated.

Landslides: A massive landslide blocked Sun Koshi River in Northern Nepal on August 02, 2014 leading to formation of a lake. The landslide and the consequent debris that dammed lake were monitored continuously using temporal LISS-IV images for change detection in the landslide zone. Further, the landslide was also characterised using LISS-IV multispectral data.

Severe floods that hit Jammu & Kashmir during first week of September, 2014 also triggered a number of landslides especially south of the Pir-Panjal range. An event based inventory of 1074 landslides in the South of Pir-Panjal Range from Resourcesat-2 LISS-IV Mx image was made using a semi-automatic detection method and manual mapping. The inventory was rapidly disseminated through Bhuvan to aid in relief measures.

National Database for Emergency Management (NDEM): NDEM is a GIS repository of data to support disaster/emergency management support, in real/near real time. Under Phase-1,
NDEM v1.0 was made operational and services to the authorised users have been enabled from Shadnagar through DMS secured network (DMS-VPN). Version 2.0 of the portal development is completed. Populating the content and procurement of computer infrastructure are in progress. Database is being organised in-house at multiple scales and offered as WMS service. DSS tools for Emergency Management are being developed. NDEM-Public portal was launched on ISRO-Bhuvan site for enabling access to unrestricted products and services. A Crisis Management Portal is also being developed under NDEM-Public for managing emergency situations.

Aerial survey for large-scale mapping: Airborne LiDAR data was acquired for Mahanadi, Ganga, Godavari and Brahmaputra river basins. Till date, data acquisition to the tune of 61,898 sq km has been completed. Data acquisition over West Bengal (6,500 sq km) is in progress. Data processing was completed for Godavari basin covering 5,140 sq km. DTM generation and Geospatial database generation are in progress for Mahanadi Basin (6,800 sq km) and data pre-processing tasks are in progress for Brahmaputra Basin (15,500 sq km). Aerial survey was carried out during October 13 - 17, 2014 covering Visakhapatnam (600 sq.km) acquiring about 4,350 images to identify the damages due to Hudhud cyclone. The data was processed and images were delivered for damage assessment planning relief measures to Govt. of Andhra Pradesh.

Communication Support: The satellite based satellite communication network, by interconnecting the National Emergency Operations Centre (NEOC) at MHA, the PMO, and the State Emergency Operations Centres (SEOCs) for Ministry of Home Affairs is being maintained. ISRO extended the SATCOM Support for Jammu & Kashmir Disaster support Management. Four nodes were installed at Hari Nivas (Make shift seat of government), Raj Bhavan, Civil secretariat and Air force station. Each node supports video conference, five telephone connections (2 fixed and 3 Wi-Fi phone) and internet access.

Establishment of Doppler Weather Radars: Under Disaster management Support two Doppler Weather Radars are being established at Thiruvananthapuram and Cherapunji. The Radars are undergoing final tests and will be operationalised soon.

Satellite Aided Search and Rescue: The Satellite Aided Search and Rescue (SASAR) Programme has been providing operational services to the users in India and seven neighboring countries for the last 21 years with the aid of GEO and LEO ground systems. The Satellite Aided Search and Rescue system which provides services to 7 neighboring countries. In 2014, 9 incidents involving 32 lives are reported.

International cooperation in DMS: During 2014, NRSC has provided IRS data for disasters happened across the globe through International Charter “Space and Major Disasters”, Sentinel Asia framework and also through UNOOSA/UNESCAP. A total of 92 datasets for 26 events were provided.
Remote Sensing Applications

Remote Sensing application projects at National, State and Local levels are being carried out through well established multi-pronged implementation architecture of National Natural Resources Management System (NNRMS) in the country. Major ISRO Centres, namely, National Remote Sensing Centre (NRSC), Hyderabad and Space Application Centre (SAC), Ahmedabad spearhead all such applications development and implementation initiatives from ISRO/DOS. State Remote Sensing Application Centres play a key role in implementation and reaching out to the grassroots for effective utilisation of the technology. User Ministries of State and Central Government departments and other institutions play a major role in utilising remote sensing technology in their own departments. In addition, Private sector, Non-Governmental Organisations and Academia also utilise this technology in different developmental sectors of the country. Some of the major application projects carried out during the year 2014-15 are highlighted below:

Natural Resources Census (NRC)

- **National Land Use / Land Cover Mapping (1:250,000 scale):** Mapping for the 10th cycle (2013-14) has been completed and statistics were generated. The net sown area estimate was 148.5 Mha as against 148.20 Mha of the 9th cycle (2012-13). Work is in progress for 11th cycle. The LULC data of the first 9 cycles were hosted on Bhuvan web portal. This data was used to derive value added products on spatial distribution of crop-occurrence and fallows.

- **National Land Use / Land Cover Mapping (1:50,000 scale):** The 2nd cycle of National level LULC mapping at 1: 50,000 scale aims to generate land use/ land cover change database depicting areas of change in 2005-06 data base/ reference compared with 2011-12 data. Interpretation was completed for all 597 districts in the country. Generation of change matrix (2005-06 & 2011-12) and analysis is also completed.

- **Nationwide Geomorphology and Lineament Mapping (NGLM):** The project aims to create a baseline geospatial database on geomorphology and lineaments for the entire country using LISS-III data (2005-06) at 1:50000 for subsequent monitoring. Mapping was completed with a three level, genesis-based classification system for geomorphological mapping using three seasons LISS-III data (2005-06). Seamless state mosaic database for geomorphology and lineament is made available in Bhuvan and Sample map is shown in the next page.
Crop Acreage and Production Estimation: During the current year, First Estimate (F1) of sugarcane was carried out at Mahalanobis National Crop Forecast Centre (MNCFC) as part of operationalisation and SAC was involved in giving training, ground truth and digital analysis. Early assessment of cotton crop using multi-date RISAT-1 MRS data for the States of Punjab, Haryana, Gujarat, Maharashtra and Karnataka States were made. Rabi Sorghum acreage estimation using Resourcesat-2 AWIFS data for 2013-14 for Maharashtra and Karnataka States was carried out. The techniques development for crop discrimination and area estimation of finger millet, sorghum, maize, groundnut and pearl millet was attempted using multi-date MRS and one Radarsat-2 polarimetric data over selected study sites. Rice (Kharif-13, Rabi - 4 States) and Wheat crop (six states) yield models based on RISAT and AWIFS were provided to MNCFC for final forecast (F3) in 2013-14. INSAT CCD based Rabi crop progression was operationalised at MNCFC.

Indian Forest Cover Change Alert System (InFCCAS): A remote sensing based technique was developed for automatic detection of forest cover loss of an area greater than 2 hectare for rapid sub-annual monitoring. The forest pixels are identified on Resourcesat-2 AWIFS data. The study is being carried out for eight 2 deg x 2 deg State tiles (35 tiles of Andhra Pradesh, Chhattisgarh, Goa, Himachal Pradesh, Karnataka, Madhya Pradesh, Maharashtra and Telangana). Results have indicated forest cover loss in 6,674 locations in 2011-12 and 4,742 locations in 2012-13.

Monitoring of Biosphere Reserves in India: Towards conserving the prioritised forest landscapes a study was initiated in 2012 to monitor the Nilgiri, Agasthyamala, Similipal and Rann of Kuchchh.
biosphere reserves. Land use/land cover changes with special emphasis on vegetation types and canopy density are being monitored at five year intervals on 1:50,000 scale using IRS data. Analysis is in progress to compare this information with the field collected phytosociological data to understand the changes and its diversity. The study indicated that Great Rann of Kuchchh was severely affected by invasion of *Prosopis juliflora* (weed).

**Snowmelt Runoff Forecasting in Himalayan River Basins:** A snow melt runoff model was developed for forecasting both seasonal and short term (16 daily basis) discharge during summer months (April-May-June). It is a spatially distributed model based on energy balance approach with snowmelt, glacier melt, run-off due to rainfall and base flow components as inputs. The model was operationalised for all the five Himalayan river basins (Chenab, Beas, Sutlej, Yamuna and Ganga) in 2013. The forecast deviation was within the acceptable limit except for the month of June 2013. Based on the feedback, the model was fine tuned and forecasts were issued for April-June, 2014.

**Inventory and Monitoring of Glacial Lakes/Water Bodies:** Inventory of the glacial lakes and water bodies in the Himalayan River basins using 2009 data has indicated the presence of 503 glacial lakes and 1525 water bodies. All large lakes and water bodies (> 50 ha in size) were monitored during June to October for 2010-2014. Monitoring was done for 438 out of 477 water bodies that were inventoried using satellite data of 2009. Of these, 178 water bodies have shown decrease in water spread and 88 water bodies have shown increase. In addition, 170 water bodies have not changed significantly (+/- 5%) and 2 water bodies have dried up. Results are portrayed in the Table below:

<table>
<thead>
<tr>
<th>Month</th>
<th>No. of Glacial lakes/Water bodies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Monitored</td>
</tr>
<tr>
<td>June 2014</td>
<td>344*</td>
</tr>
<tr>
<td>July 2014</td>
<td>220**</td>
</tr>
<tr>
<td>August 2014</td>
<td>213***</td>
</tr>
<tr>
<td>September 2014</td>
<td>300*</td>
</tr>
<tr>
<td>October 2014</td>
<td>425*</td>
</tr>
<tr>
<td>June-October, 2014</td>
<td>438**</td>
</tr>
</tbody>
</table>

Note: * 1 GL & 2 WB is dry; ** 2 WB is dry; *** 3 WB is dry

Monthly status of Water spread during June – October 2014

**India-Water Resource Information System (India-WRIS):** The India-WRIS WebGIS is a ‘Single Window solution’ for comprehensive, authoritative and consistent data & information on India’s water resources in a standardised national GIS framework for planning, development and management.
of water resources. India-WRIS WebGIS Version 4.0 was released on March 28, 2014. The portal contains 12 major information systems, 35 sub information systems, 95 spatial layers and large number of attributes (> 700) with 5-100 years data of the country. The database has been updated further, based on the feedback received from CWC and States. The River network for the entire the country has been digitised on 1:50,000 scale using LISS-IV and Cartosat-1 merged product. The length of the river network is 42,86,044.55 Km. Stream ordering up to 11th order has been done at sub-basin wise, and integrated at basin level as well as at country level. Delineation along with codification was completed. Mapping of water bodies (7,98,909) for the entire country was completed. The total area covered by water bodies is 48,379.89 Sq Km.

12 Main Information Systems of India-WRIS

Rajiv Gandhi National Drinking Water Mission (RGNDWM): The project aims at generating ground water resources database of the entire country for Ministry of Rural Development. Mapping work under Phase IV for 13 states and 5 UTs & Islands was completed by July 2014. During Phases I, II & III, Groundwater prospects was completed in 19 States (2 States in part). In Phase-IV, groundwater quality is also being mapped for entire country using ground water quality data of Ministry of Drinking Water and Sanitation (MoDWS), and State line departments. Ground Water Quality mapping (GWP) is in progress and planned to be completed by March 2015.

National Urban Information System (NUIS): Subsequent to the preparation of thematic geospatial database at 1:10,000 scale for 152 towns (as basic spatial input for Master Plan preparation), a web based geospatial framework and software tools ‘NUIS-Bhuvan’ has been developed for the
preparation of Master Plans by the Urban Local Bodies (ULBs) and workshops were conducted. State and Central government officials were trained on Bhuvan for effective use of remote sensing satellite data, NUIS database, its updation and analysis framework.

Space-based Information Support for Decentralised Planning (SIS-DP): The project aims to enable Decentralised Planning at Panchayat level through web based spatial information system. The spatial datasets comprise of ortho-rectified satellite imagery, thematic and field data, resource maps, cadastral maps, administrative boundaries, infrastructure layers, climate and socioeconomic data along with user friendly tools. Cartosat-1 and LISS-IV ortho-products were generated for 36 States/Union Territories and were made available through Bhuvan portal for geo-visualisation. Thematic mapping (land cover, settlements, infrastructure, drainage and water bodies) on 1:10,000 scale was completed for 350 out of 650 districts of the country and the data was hosted on Bhuvan-Panchayats portal. Bhuvan-Panchayats portal version - 2.0 and Mobile app for Panchayath Raj Institutions (PRI) asset data collection was released in November 2014.

Polar Science Applications: Sea ice advisory was provided for route planning during Antarctic Expedition. Climate change studies were carried out based on the impact of surface melting on rift propagation. Ice margin disintegration around Indian Antarctic stations was also monitored.

Monitoring of Snow and Glaciers of the Himalayas (Phase-II): It is a joint initiative of Ministry of Environment, Forests & Climate Change and Dept of Space. The project aims at monitoring
of snow and glaciers in the Himalayas. Basin wise snow cover monitoring at 5 and 10 day interval for time frame 2008-14, using AWiFS data for Indian Himalayan region, has been carried out for 35 sub-basins. Snow cover products and snow cover Atlases prepared in this project have been archived at NRDB portal for dissemination. The outputs include 5 and 10 daily sub-basin wise snow cover maps, statistics and depletion curves. The data is used to analyze the snow accumulation and ablation patterns in different parts of Himalayan region and as input to snow melt forecast models. Around 2300 glaciers for time frame 2010-2013 have been monitored using multi-date satellite data and the analysis shows that 87 % of the glaciers are showing no change, 12% are retreating and 1% glaciers have advanced.

**Desertification Status Mapping of India – 2nd Cycle:** The project is being carried out at the behest of Ministry of Environment, Forests & Climate Change. Multi-temporal AWiFS satellite data of two time frames (2012-13 & 2002-03) covering entire India were procured for preparation of Desertification status maps at 1:500,000 scale as well as carrying out change detection. 21 collaborating agencies are associated with this project towards carrying out the mapping at various parts of the country. Preparation of Desertification status maps for all the States has been completed. The quality checks are in progress. Further, multi-temporal LISS-III satellite data of two time frames (2012-13 & 2002-03) of 78 selected districts are being analyzed for preparation of Desertification status maps at 1:50,000 scale and change detection.

**Shoreline Change Mapping of the Indian Coast (CWC funded):** The project aims to carry out inventory of coastal erosion and status of coastal protection measures taken up by states along the entire Indian coast using multi-date satellite imagery, in-situ data and GIS techniques. The project has been completed and inventory of the coastal erosion at 1:25,000 scale for entire Indian coast using multi-date satellite data is available in GIS environment. Shoreline change atlas of the Indian Coast were submitted to Ministry of Water resources and released during the Workshop on Implementation of Coastal Management Information System (CMIS) on May 13, 2014.

**R&D PROJECTS / STUDIES**

**Inventory of Coffee Plantation:** A pilot study has been taken up to generate spatial database on coffee plantation using geo-spatial techniques in traditional coffee growing area in Southern States, namely, Chikmagalur, Belur, Mudigere and Virajpet talukas in Karnataka; Yercaud taluka in Tamil Nadu and Vayitthiri taluka in Kerala. High resolution Resourcesat-1 LISS-IV (5.0 m) and Cartosat-1 (2.5 m) data was used in the study for delineation of coffee plantations supplemented with in-season ground truth information. The inventory in all the six areas was completed and area statistics were computed. Validation of results in comparison to village level (revenue estimates) statistics furnished by Coffee Board is in progress. It is proposed to extend the study to generate nationwide digital database on coffee plantations.
Inventory of Horticultural Fruit and Plantation Crops: Pilot studies were taken up to scale up and develop national missions for horticulture and plantation crops. The major fruit and plantation crops under diverse agro-climatic regions taken up for the studies include Plantation crops (coffee, tea & rubber), Fruit crops (mango, banana, citrus & grapes) and Nut crops (coconut, areca nut & cashew nut). Both textural and contextual information was used in the feature extraction model in addition to spectral and NDVI information for classification of horticultural crops using object oriented techniques.

Geo-environmental study of Jharia Coalfield (JCF): A study was carried out using time series differential interferometric (D-InSAR) observations during 2007-2010 for detection of land subsidence affected areas and the associated disturbed sub-surface strata using GPR. The D-InSAR observations reveal land subsidence affected areas and ground deformation due to coal fires and underground mining activities. The geo-environmental hazard map of the Jharia coalfield was generated. 2-D GPR profile of Sijua area revealed severely affected area due to coal fire disrupted subsurface strata, void development and underground extension of surface cracks.

Agricultural drought vulnerability: A quantitative approach was developed for measuring crop-generic agricultural drought vulnerability at sub-district level. Agricultural drought vulnerability model was
implemented in Andhra Pradesh, Telangana and Haryana. Analysis of data on soils, irrigation support, cropping pattern, farm holdings and time series rainfall, rainy days and NDVI at sub-district level, resulted in the generation of different contributing indicators. Agricultural drought vulnerability index has effectively captured the variability in agricultural drought vulnerability within each district.

**Regional Tide Modeling:** Sea level is an essential climatic variable (ECV), which is being measured precisely through satellite altimeters. Several oceanic processes contribute to variability of sea level with tide being the major contributor. As tide is periodic and highly predictable, its contribution can be removed from the altimetry measurement for further investigation of sea level variability. A regional tidal model for the Indian coastal ocean based on Princeton Ocean Model (POM) is developed and correction of ALTIKA data for deriving information on variability of sea level is in progress.

**Net Primary Productivity (NPP) over India:** The Carnegie-Ames-Stanford approach terrestrial ecosystem model along with climatic parameters and NDVI was used for simulation of NPP and Net
Ecosystem Production (NEP). The study revealed that amplitudes of annual cycle of MODIS NDVI are comparable with respective semi-annual cycles of AVHRR NDVI. But the amplitude values of MODIS NDVI are significantly larger (30% over estimates of NPP annual budget) over India.

**Atmospheric CO$_2$ retrieval and monitoring:** Under national network for monitoring of atmospheric CO$_2$, two new stations were established at Nagpur and Ponmudi to the existing six stations for in-situ observations of atmospheric CO$_2$.

**Monitoring & Assessment of Ecosystem Processes in North-Western Himalaya:** For sustainable environmental development, making disaster resilient society and improved livelihood in the North Western Himalayan (NWH) region, an interdisciplinary research project in collaboration with research organisations/ institutes located in NWH is taken up as major focused research activity during 12$^{th}$ FYP. The project aims to study various aspects of ecosystem processes in the NWH using recent advances of Earth Observation techniques and allied spatial technologies supported by extensive field investigation and field instrumentation. The research focus is on geodynamics and seismicity, vulnerability assessment of mountain ecosystems, sustainable mountain agriculture, climate change impacts on productivity of food and plantation crops, assessing soil erosion and nutrient loss and its impact on soil quality and crop productivity, water resources status and availability, and study of extreme rainfall events and rainfall retrieval.

**NATIONAL INFORMATION SYSTEM FOR CLIMATE & ENVIRONMENT STUDIES (NICES):**

One of the objectives of NICES programme is to build the geospatial information base on environment and climate variables using EO data and ground based measurements. A few of them are already hosted on Bhuvan Portal. The products that are being generated under NICES include:

- Two day global composite wind field for the period January 2000-February 2014.
• Ekman currents, Geostrophic currents and total currents for the period March 2013 to February 2014.
• Daily surface soil moisture from EO data for India at 25 km resolution.
• Himalayan snow melt and freeze detection and monitoring from EO daily data for three years covering from 2011 to 2013 at 2.25 km resolution
• Mesoscale model compatible annual Land Use / Land Cover (LU/LC) from IRS-AWIFS data for nine years from 2004 to 2013.
• Daily total columnar, stratospheric and tropospheric ozone at 1° x 1° resolution for four years from 2010 to 2013.
• Seasonal GPS Radio Occultation profiles of temperature, humidity and refractivity for the Indian region at 1 km vertical resolution and 1 deg x 1 deg spatial grid using COSMIC data from 2007 to 2012.

An atmospheric observatory was established at NRSC, Shadnagar. Advanced instruments procured and installed include Fourier Transform Infrared Spectrometer (FTIR) to measure the Sun spectra in the Middle infrared Region (MIR) (16-2µm) and a Greenhouse Gas Analyzer (GGA) to measure dry mixing ratios of GHGs (CH₄, CO₂, H₂O). The Fast Repetition Rate Fluorometer (FRRF) was procured for measuring Gross Primary Productivity during sea truth with a cosine PAR sensor, pressure sensor, Actinic light chamber and dark chamber.

**Capacity Building:**

Indian Institute of Remote Sensing (IIRS) is a premier institute with the primary aim to build capacity in Remote Sensing and Geo-informatics and their applications through education and training programmes at postgraduate level. The Institute also hosts and provides support to the Centre for Space Science and Technology Education in Asia and The Pacific (CSSTE-AP), affiliated to the United Nations, to conduct remote sensing and GIS training & education programmes at Post Graduate level. The training and education programmes of the Institute are designed to meet the requirements of various target/ user groups, i.e., for professionals at working, middle and supervisory levels, fresh graduates, researchers, academia and decision makers. The duration of courses range from one-week to two-years. The education programmes conducted by the Institute include: (1) M.Tech. course of 24 months duration being conducted in collaboration with Andhra University, Visakhapatnam and (2) M.Sc. course of 18 months duration being conducted in collaboration with the faculty of Geo-information Science & Earth Observation (ITC) of the University of Twente (UT), The Netherlands. In addition to the regular training and education programmes, the Institute also conducts ‘Distance Learning Programme’ since 2007, which is unique in the country complementing the education programmes of the Indian universities.

The Institute has trained 9479 professionals (till September, 2014), including 942 professionals from abroad representing 94 countries from the Asia, Africa and South America. A total of 363 students have graduated in the M.Sc./M.Tech courses conducted by the Institute since 2002. Special tailor-made/ on-demand courses are conducted at the request of the national and international user departments in the last few years. Demand for such tailor-made courses has increased significantly.
In addition, IIRS has also trained 1400 professionals including 681 in short and 719 in long-term courses from various countries in the Asia-Pacific Region in its endeavour of providing technical support to CSSTE-AP for all its RS and GIS training and education programmes.

Further, 15834 graduate and post-graduate students from 217 universities spread across the country have also benefited through the distance learning programmes being offered by the Institute since 2007. In the present ongoing programme, the number of universities registered is 217 with more than 3300 participants.

IIRS launched e-learning programme in the field of RS, GIS & GPS in October 2014 for mid-career professionals, researchers, academia, fresh graduates and user department professionals from different States and Central Government Departments/Ministries. This comprehensive online programme is flexible for anytime, anywhere learning free of cost keeping in mind the demands of geographically dispersed audience and their requirements. In the first batch more than 1000 participants have registered.

Brief details of the courses in current year are given hereunder with the number of participants in brackets:

- **Regular courses** benefiting 290 participants from India and abroad (including 25 foreign participants) namely PGD (18), NNRMS (61), ITEC(24), M.Tech (28), M.Sc (06), Decision Maker (32), Special-courses (121).

- **CSSTE-AP** conducted various courses at IIRS, SAC and PRL, namely, PG Course in RS & GIS (21), RS-Short Courses (41), International Training Course on SAS-PG (PRL) (12), PG Course in SATMET (17), International Training Course on Small Satellite Missions (19).

- **Special/ Tailor-made courses** are being designed and conducted for Indian Air Force (15), IIRS/ ISRO (18), Indian Statistical Service Officers (16), Central Water Commission (25), National Institute of Veterinary Epidemiology and Disease Informatics (13), Ministry of Environment and Forests (34), School Students of Uttarakhand (23).

In addition, NRSC, Hyderabad and SAC, Ahmedabad also conduct training programmes as per the requirements of the user community. During 2014-15, NRSC has trained 239 persons by organising eleven courses (three Special, three Regular, three customised and two In-house). The technical support and training in various disciplines like remote sensing, photogrammetry, microwave remote sensing and Geo-informatics for various Central/State line departments, academic institutions as well as R&D institutions are being carried out regularly.

**ISRO GEOSPHERE BIOSPHERE PROGRAMME (IGBP)**

The thrust of ISRO Geo-sphere Biosphere Programme (IGBP) has been mainly on measuring, modeling and monitoring the human factor in the biological, chemical and physical processes of the Earth system, thereby understanding the regional factors influencing climate change. IGBP programme has made significant contributions in the areas of Aerosol Optical Depth (AOD), aerosol radiative forcing, boundary layer characterisation, understanding the carbon cycle, both in the atmosphere and the ocean, etc.
The first-ever regional synthesis of long-term primary data on AOD, obtained from the ARFINET stations, has revealed an increasing trend with a significant seasonal variability. The trend is statistically significant and consistent, especially at locations where the measurements have been made since 1980s, and the rate of increase appears to increase in the recent decade. Trivandrum (TVM) and Visakhapatnam (VSK) had the longest database, spanning more than 20 years. Over most of the stations, AOD shows an increasing trend. Seasonally, the rate of increase is consistently high during the dry months (December to March) over the entire region whereas the trends are rather weak during the pre-monsoon (April to May) and summer monsoon (June to September) seasons.

Spatial distribution of ARFINET observatories across India is shown in the figure. The colored posts represent stations over which the data are long enough and trends are significant; the colour is a measure of the trend following the colour bar on the right. The triangles show Aerosol Robotic Network (AERONET) stations. The AOD trend at the station with the longest record (TVM, shown at the bottom) depicts a steady increase since 1986.

Under the National Carbon Project (NCP), seven sub-projects were taken up aimed at creation of remote sensing based spatial repository of terrestrial and oceanic Net Carbon balance estimates over India, its periodic assessment through an observational network and provide support to Ministry of Environment & Forests (GoI) communications to UNFCCC on carbon balance. They include Vegetation Carbon Pool, Soil Carbon Pool, Soil Vegetation Atmospheric Fluxes, Carbon Cycle Modeling and Simulation, Coastal Carbon Dynamics, Hydro-geochemistry of Cauvery Basin and Atmospheric CO₂ Retrieval and Monitoring.

The Vegetation Carbon Pool (VCP) aims to assess terrestrial phytomass and terrestrial carbon methods for upscaling the field collected stand level flux data to regional levels and to revisit forest stand
characterisation. An integrated Terrestrial and Aerial LiDAR survey was undertaken at Betul. Point clouds from five terrestrial scans were merged to create a Gap filled canopy height model. Individual trees in the point cloud were identified and located using Height scaled canopy openness index (HSCOI) and marker controlled watershed segmentation approach. Individual tree identification through 3D Point cloud segmentation is in progress.

Under the Soil Carbon pool & Dynamics, collection and analysis of samples on CO₂ emissions across various land covers from field is in progress. Methodology is being finalised for measurement of soil respiration using CO₂ sensors and Soil CO₂ efflux was determined from 30 cm depth under different soil types and land use.

As part of Energy and Mass Exchange in Vegetative Systems project, techniques and models have been developed and validated for quantification of evapotranspiration and primary productivity using Indian GEO-LEO satellite sensors for generation of a few decades climatology data over India.

Under the Land Use and Land Cover (LULC) Modeling and Impact of Human Dimensions in Indian River Basins, Basin-wise LULC maps on 1:250,000 scale and driver datasets (physical and socio-economic) were prepared at decadal interval for all the 14 river basins in the country. An indigenous model using open source tools is developed for modeling LULC dynamics & model tested and validated in six river basins. Hydrological modeling tool has been developed for analyzing the hydrological processes using a physically-based, macro-scale VIC (Variable Infiltration Capacity) model which ran successfully in six river basins; Hydrological simulation has been carried out for Ganga, Mahanadi and Narmada basin for 1985, 1995 and 2005 and impact of LULC change on hydrological regime has been studied.

As part of monsoon reconstruction using an annually resolved stalagmite from Kotumsar cave, India, a high resolution analysis of a stalagmite sample that grew between ~5000 and 4000 year BP, was taken up. This sample shows annual laminations of ~1mm thickness. Sub-sampling for stable isotope analysis was carried out using micro-mill with a spatial resolution of ~200 micrometer to resolve seasonal changes. The monsoon variability is reconstructed using δ18O and δ13C measured on Delta V-plus isotope ratio mass spectrometer and the values in the reconstructed time series are identified as mega-drought events.
Space Transportation System

The Indian Space Programme, over the last five decades, has made rapid strides in launch vehicle technology to achieve self-reliance in space transportation system with the operationalisation of Polar Satellite Launch Vehicle (PSLV) and Geosynchronous Satellite Launch Vehicle (GSLV). The culminated efforts in the development of launch vehicle technology has paved the way from the modest beginning with the launch of a sounding rocket to design, planning and execution of interplanetary missions.

Major Accomplishments

Polar Satellite Launch Vehicle

Polar Satellite Launch Vehicle (PSLV), the Indian operational launcher, completed its twenty-eighth flight during the year. It was the twenty-seventh consecutively successful mission, further proving the reliability and versatility of this medium lift vehicle developed by ISRO. PSLV has emerged as a versatile launch vehicle to carry out Sun Synchronous Polar Orbit (SSPO), Geosynchronous Transfer Orbit (GTO) and low inclination Low Earth Orbit (LEO) missions.

During the year, PSLV-C24 in the ‘XL’ configuration successfully launched IRNSS-1B satellite, the second satellite in the Indian Regional Navigation Satellite System (IRNSS), on April 04, 2014 from the First Launch Pad (FLP) at Satish Dhawan Space Centre, Sriharikota. The spacecraft weighing 1432 Kg was precisely injected into the intended orbit of 283 x 20,630 km with an inclination of 29 deg.

Later, PSLV-C23 in the ‘core alone’ configuration successfully launched SPOT-7, a French earth observation satellite along with four co-passenger satellites namely, AISAT of Germany, NLS 7.1 & 7.2 of Canada and VELOX-1 of Singapore, from the First Launch Pad at Satish Dhawan Space Centre, Sriharikota on June 30, 2014. These five satellites were launched under commercial agreements between ANTRIX and the respective international agencies.
PSLV-C26 in the ‘XL’ configuration successfully launched IRNSS-1C, the third satellite in the Indian Regional Navigation Satellite System (IRNSS) from the First Launch Pad of Satish Dhawan Space Centre, Sriharikota on October 16, 2014. This was the twenty-seventh consecutively successful mission of PSLV.

The next PSLV flight, PSLV-C27, in ‘XL’ configuration, will launch IRNSS-1D satellite, the fourth satellite in the Indian Regional Navigation Satellite System (IRNSS), which is targeted for launch in the first quarter of 2015.

**Geosynchronous Satellite Launch Vehicle (GSLV)**

GSLV is a three-stage vehicle employing solid, liquid and cryogenic propulsion modules for its stages and is capable of launching 2 ton class of communication satellites into Geosynchronous Transfer Orbit (GTO).

The next flight of GSLV, GSLV-D6, will be the third developmental flight with indigenous Cryogenic engine and stage to demonstrate the robustness and reliability of the vehicle. The realisation of subsystems/stages for the next flight is in advanced stage. The solid booster (S139) motor with all pyro-elements and one of the liquid propellant strap-on (L40 stage) are ready. The remaining three liquid propellant strap-ons and liquid propellant second stage (GS2) of the vehicle are under realisation. Flight Acceptance tests of cryogenic engine and the steering engines have been successfully completed and assembled with Liquid Oxygen propellant stage tank. Assembly and integration of Cryogenic flight stage is in progress.

The launch of GSLV-D6 carrying GSAT-6 communication satellite is targeted during the third quarter of 2015.

**Geosynchronous Satellite Launch Vehicle Mark III (GSLV-Mk III)**

GSLV-Mk III is the next generation launch vehicle of ISRO capable of launching 4 ton class of satellite to Geosynchronous Transfer orbit (GTO). The vehicle is also known as LVM3.

GSLV-Mk III is a three stage launch vehicle with three propulsion stages and has a lift-off weight of 640 tonnes and a height of 43.4 m. The GSLV-Mk III vehicle configuration is two Solid strap-on boosters Stages (S200), Liquid core Stage (L110) and Cryogenic Stage (C25). The spacecraft is accommodated in a 5 metre diameter composite payload fairing of 110 m³ volume.

The solid strap-on booster stage S200 and the liquid L110 stage underwent development tests on ground and the stages were realised for flight testing. The Cryogenic stage is under advanced stage of development. Design and development of Cryogenic Engine (CE-20) subsystem elements including Gas Generator, Liquid Oxygen (LOX) and Liquid Hydrogen (LH2) Turbo Pumps and Thrust Chamber have been completed.
Many major development and qualification tests were successfully conducted during the year, which include structural qualification test of 5 metre diameter Carbon Fibre Reinforced Polymer heat shield, functional test of L110 nozzle closure system, functional separation test of heat shield, actuation trial of S200 Flex Nozzle Control system, integrated tests including vibration and acoustic tests for Strap-on Nose Cone (SNC) avionics assembly functional tests of L110 Separation system, payload separation system and S200 forward and aft link separation system. Towards Cryogenic Engine Subsystem development, hot tests of Engine thrust chamber and Integrated Turbo Pump were carried out successfully. Cryogenic Engine has been integrated and interfaced with test facility. Combined liquid oxygen and liquid hydrogen chill down and flow trial successfully completed. Cryogenic engine is ready for commencement of the integrated system level hot tests.

To validate and characterise the LVM3 vehicle during the atmospheric phase of flight and to demonstrate the in-flight performance of propulsion systems (S200 and L110 stages) together with other vehicle systems, a sub-orbital experimental flight of LVM3 vehicle (designated as LVM3-X or GSLV Mk-III X) was conducted on December 18, 2014 from Satish Dhawan Space Centre, Sriharikota. In this maiden flight, LVM3 carried the 3775 kg Crew Module Atmospheric Re-entry Experiment (CARE) into a height of 126 km. Following this, CARE re-entered the Earth’s atmosphere and after its successful survival during the re-entry phase, landed near its scheduled landing spot in the Andaman Sea with the help of its parachutes and safely recovered.

Semi-cryogenic Project

The semi-cryogenic Project envisages the design and development of a 2000 kN semi-cryogenic engine for a future heavy-lift Unified Launch Vehicle (ULV) and Reusable Launch Vehicle (RLV). The semi-cryogenic engine uses a combination of Liquid Oxygen (LOX) and ISROSENE (propellant-grade kerosene), which are eco-friendly and cost-effective propellants.

The major development during the year includes single element Preburner test to characterize pre-burner injector elements and single element thrust chamber hot test to characterise thrust chamber injector elements. The tests demonstrated the ignition with hypergolic igniter and flame holding at very high mixture ratios and the stage combustion cycle respectively. Fabrication of semi-cryogenic engine sub-assemblies, namely, the Thrust Chamber, Mixing Head, Main Turbo pump, Booster turbo pumps, Preburner and Heat Exchanger have been initiated through industries. The first hardware, namely, the Low Pressure Oxidiser Turbo pump has been realised.

Assembly and testing of 14 types of control components out of 21 types have been completed. Assembly and testing of 7 types of control components are in progress.

Realisation of Semi Cryo Cold Flow Test facility (SCFT) consisting of Fluid system, Power absorption system, drive system, vacuum drying system and instrumentation system is in progress. Augmentation of Thrust Chamber Test Facility is being carried out for Semi Cryo subscale engine test. A Request for proposal has been prepared for realisation of Integrated Engine Test facility.
Reusable Launch Vehicle – Technology Demonstrator (RLV-TD)

A winged Reusable Launch Vehicle Technology Demonstrator (RLV-TD) has been configured to act as a flying test bed to evaluate various technologies, namely, hypersonic flight, autonomous landing, powered cruise flight and hypersonic flight using air breathing propulsion towards realising a Two Stage to Orbit (TSTO) fully Reusable Launch Vehicle.

Major highlights of RLV-TD development during the year include 3D heat flux and shear stress distribution over Technology Demonstrator Vehicle (TDV) studies and the Reaction Control System (RCS) jet-on/off studies carried out through Computational Fluid Dynamics simulations. Aero elastic tests were conducted at National Aerospace Laboratories and Indian Institute of Science to establish the margins.

Onboard software was validated in simulation test-bed. Flight models of 12 avionics packages and six new types of patch antennas have been realised. Up-linking trials of Telemetry package with satellites were carried out. Actuators have been designed, fabricated and acceptance tested.

Test of the solid booster motor (HS9) with Secondary Injection Thrust Vector Control system was successfully conducted. Structural qualification test of Launch Hold Release System along with base shroud was completed. All the structural joints are successfully tested.

Flight integration activities for the Hypersonic Experiment mission, HEX-01 has commenced. The sub assemblies such as flight fuselage with wings, inter stage and base shroud are under preparation. Silica tiles, Flexible External Insulation (FEI) blankets and Carbon-carbon nose cap have been realised and qualified for flight.

Solid booster motor (HS9) has been positioned at Satish Dhawan Space Centre, Sriharikota. Assembly of vehicle is in progress towards RLV-TD HEX-01 mission targeted for launch during the first half of 2015.

Pre Project activities of Human Spaceflight Programme (HSP)

The objective of Human Spaceflight Programme is to undertake a human spaceflight mission to carry a crew of two to Low Earth Orbit (LEO) and return them safely to a predefined destination on earth. The programme is proposed to be implemented in defined phases. The pre project activities are progressing with a focus on the development of critical technologies for subsystems such as Crew Module (CM), Environmental control and Life Support System (ECLSS), Crew Escape System (CES), etc., and performance demonstration of major systems through Crew Module Atmospheric Re-entry Experiment (CARE) and crew escape system through Pad Abort Test (PAT).
The major developments in the area of critical technologies as part of the pre-project phase are given below.

Crew module: Realisation of Crew Module (CM) inner structure, composite Carbon Fibre Reinforced Polymer structure comprising of conical panels, apex cover with thermal protection system and avionics packages were completed and flight software was realised and tested. Ablative thermal protection systems for crew module such as carbon phenolic tiles and silica phenolic tiles were realised, qualified and assembled to structure. Crew Module structure and systems were qualified through a number of tests including functional/structural test and flight acceptance vibration test.

Deceleration system consisting of two 31 metre main parachutes and Apex Cover was extensively tested and qualified. Integrated air drop test of full-scale Crew Module by dropping from helicopter was successfully carried out off the coast of Satish Dhawan Space Centre to verify the total sequence of parachute deployment and recovery of Crew Module from sea.

The Crew module Atmospheric Re-entry Experiment (CARE) was carried as the payload in the Experimental sub-orbital flight of LVM3 (designated as LVM3-X) to study the re-entry characteristics of the crew module. This maiden flight of LVM3 was successfully conducted on December 18, 2014. The main objectives of CARE were to test and qualify re-entry technologies and flight control algorithms, validate theoretical aero thermodynamic predictions, qualify design of the thermal protection system, parachute system and deployment mechanism and validate recovery procedures of the Crew Module. Aerodynamic configuration and mass properties of CARE were the same as the final configuration of Crew module intended for Human space flights. CARE was equipped with systems necessary for navigation, guidance and control systems.

Crew Escape System: Design of the Crew Escape System has been completed. Fabrication activities have been initiated for realisation of solid propellant motors, nose cone of crew escape system and fairings.

Environmental Control and Life Support Systems: The realisation and developmental testing of thermal control system and odour removal system are in progress.
Air Breathing Propulsion Project (ABPP)

Air Breathing Propulsion along with Reusable Launch Vehicle technology is the key for low cost access to Space. Unlike conventional rockets, Air Breathing Propulsion System makes use of atmospheric oxygen for combustion thus resulting in substantial improvement in payload fraction and reduction in overall cost. Though the developmental activities towards dual mode ramjet engines and its associated technologies have been initiated, the present focus is on development of scramjet engine and flight testing the same through a cost effective method using Advanced Technology Vehicle (ATV).

Towards Scramjet flight testing, Air Breathing Propulsion modules, namely, Scramjet Engine and Fuel Feed System are being realised. Structural qualification of Engine frame structures has been successfully completed. Various sub-systems for flight i.e., engine frame structure, air intake cowl opening mechanism, pilot flame ignition unit, engine fuel feed unit and avionics packages, have been realised. Trajectory study integrating the three phases of scramjet engine testing has been carried out. The Advanced Technology Vehicle flight carrying active scramjet engine is targeted in the first half of 2015.

Activities relating to mechanical, civil and instrumentation for the establishment of Scramjet Propulsion Test Facility have been completed except the ethanol burned air heater which is in the final stages of realisation.

Advanced Technology Vehicle and Sounding Rocket Project (ATVP)

Advanced Technology Vehicle (ATV) has the unique capability to carry a payload of 200-400 kg up to an altitude of 800 km. Ascent of ATV in a direct vertical profile is an excellent platform for studies related to upper atmosphere and short duration transient phenomena in the atmosphere. ATV provides a cost effective platform for the study of micro-gravity providing a dwell time of 10 minutes at levels better than 100 micro-g, which can be used for microgravity experiments in fluid physics, combustion research, material sciences, biology and also to perform precursor experiments for launch vehicles, satellites and human spaceflight mission.

Advanced Technology Vehicle has been identified to carry out the Scramjet characterisation flight with active scramjet engines. The major activities successfully completed towards this mission are the realisation of Mass Optimised sustainer motor case, Static test of ATV motor with modified igniter to evaluate the ballistic performance and Spin qualification test for Expanding Tube Assembly (XTA) based stage separation system. The acoustic test of motor case and nosecone with Fuel Feed System (FFS) is planned to be completed in December 2014.

Sounding Rockets

Totally, Eleven RH200 flights with chaff payload were successfully conducted from TERLS Range for collecting meteorological data. Four RH200 rockets with chaff payload were launched during World Space Week celebrations (October 7-10, 2014). Indigenously developed Lithium-ion battery has been
inducted in RH200 flights for sustainer ignition and chaff ejection. Aerodynamic characterisation of RH560 MKIII has been successfully completed.

Two RH300 MkII and two RH560 MkIII flights have been planned for launch from TERLS, Thiruvananthapuram and Satish Dhawan Space Centre, Sriharikota during the first quarter of 2015.

**Infrastructure**

Major infrastructure facilities/equipments that were realised during the current year are:

- **VSSC**: 250 kN Shaker system, Advanced Powder Metallurgy Laboratory, Cryostat for environmental and functional testing of pyros at cryogenic temperatures, High energy materials analysis laboratory and Remote Mounting Safe Arm (RMSA) production facility and Nozzle and combustor test facility.

- **LPSC**: High Vacuum Stationary Plasma Thrusters test facility, Bearing and Seal laboratory and Semicryo injector characterisation facility

- **SDSC-SHAR**: 4.5 Tonne Vertical Mixer for solid propellant mixing and 40 KL Liquid Hydrogen storage tank.

- **IPRC**: Cryo subsystem facility, Augmentation of Subscale Engine Test Facility (SET) for testing Integrated Turbo pump in boot strap mode and Automatic Robotic Coating facility.

- **IISU**: Ultrasonic cum high speed glass machining centre, High accuracy co-ordinate measuring machine and Fourier Transform Infrared (FTIR) Spectrometer
Space Sciences and Planetary Research

Space Science research has been an important element of the Indian Space programme. Space science research activities are pursued at Physical Research Laboratory (PRL), National Atmospheric Research Laboratory (NARL), Space Physics Laboratory (SPL) of VSSC and Space Astronomy Group (SAG) at ISAC. A number of space science research projects in the field of atmospheric science, astronomy and planetary exploration are supported and implemented at various universities and research Institutes by ISRO through the recommendations of ISRO's Advisory Committee for Space Sciences (ADCOS). ADCOS has initiated the development of a number of space based experiments in the areas of astronomy, astrophysics and aeronomy with the collaboration of various academic institutes. The major activities carried out under space science programme during 2014-15 are summarised below.

MARS ORBITER MISSION

Mars Orbiter Mission (MOM), India's first interplanetary mission to planet Mars was launched onboard PSLV-C25 on November 05, 2013 from Satish Dhawan Space Centre, Sriharikota and successfully put in Martian orbit on September 24, 2014. With this, ISRO has become the fourth space agency to successfully send a spacecraft to Mars orbit. Prior to Indian Mars Mission, only 21 out of 51 Missions succeeded in reaching Mars (success rate of 42%). This is due to the complexity and large number of variables involved in an interplanetary journey. Against this backdrop, it is very pertinent to note that India has succeeded in placing MOM in an orbit around Mars in its very first attempt.

The objectives of this mission are primarily technological and include design, realisation and launch of a Mars Orbiter spacecraft capable of operating with sufficient autonomy during the journey phase of 300 days; Mars orbit insertion / capture and in-orbit phase around Mars.

After launch and the initial earth bound orbits, the Trans Mars Injection manoeuvre was successfully performed on December 01, 2013 to set the course of the spacecraft towards Mars through a Sun-centric trajectory. Enroute to Mars, three Trajectory Correction Manoeuvres were carried out to achieve the precise path towards Mars Orbit. The spacecraft traversed about 666 million kilometres of interplanetary space to reach close to Mars.

The most crucial manoeuvre of Mars Orbit Insertion (MOI) was successfully carried out on September 24, 2014, with which the Mars Orbiter Spacecraft successfully entered into an elliptical orbit of 422 km by 76,994 km around Mars. During the passage of Comet C/2013 A1 Siding Spring, the spacecraft and subsystems were protected by tuning the orbit such that the spacecraft was behind the planet during peak flux from the Comet.

The scientific objectives of the mission are to study the martian surface features, morphology, mineralogy and martian atmosphere by the following indigenous scientific payloads:
i). Mars Colour Camera (MCC) for Optical imaging;
ii). Thermal Infrared Imaging Spectrometer (TIS) to map surface composition and mineralogy;
iii). Methane Sensor for Mars (MSM) to detect the presence of Methane;
iv). Mars Exospheric Neutral Composition Analyser (MENCA) to study the neutral composition of martian upper atmosphere;
v). Lyman Alpha Photometer (LAP) to detect D/H ratio in order to study escape processes of martian atmosphere.

ISRO has been continuously monitoring the Spacecraft and its five scientific instruments which are in good health. All the scientific instruments have been operated and tested successfully. The images of Mars captured by the Mars Colour Camera have been received and are found to be of very good quality. Scientific analysis of the data being received from the Mars Orbiter spacecraft is in progress.

**ASTROSAT Mission**

ASTROSAT, India's first dedicated astronomy satellite, is planned to be launched during 2015. It is a multi-wavelength astronomy mission designed to carry wide-band X-ray instruments with overlapping energy response and UV detectors for simultaneous spectral and temporal studies to identify and
quantify contributions of different components in X-ray sources, and thus to understand their nature and astrophysical processes in them. ASTROSAT will be placed in a 650-km near-equatorial orbit using PSLV.

Integration of ASTROSAT Spacecraft in cleanroom

The payloads onboard ASTROSAT are:

- Three identical Large Area Xenon Proportional Counters (LAXPC) instrument covering 3-80 keV region
- Cadmium-Zinc-Telluride Imager (CZTI) array with coded mask aperture sensitive in 10-100 keV band
- Soft X-ray Telescope (SXT) using X-ray reflecting mirrors and X-ray CCD for imaging and spectral studies in 0.3 - 8 keV band
- Scanning Sky Monitor (SSM) for detection and monitoring of new and known X-ray sources in 2.5 - 10 keV region.
- Ultra Violet Imaging Telescope (UVIT) consisting of two identical telescopes, one covering the FUV band (130 - 180 nm) and the second sensitive in NUV (200 - 300 nm) and Visible (320 - 550 nm) bands.

All the five payloads have been delivered to ISAC. Integration of the payloads with the spacecraft, integration of sub system packages and final testing is under progress at the ISAC clean room.
CHANDRAYAAN-2 Mission

Chandrayaan-2, India’s second mission to the Moon, consists of an Orbiter, Lander and Rover configuration. It is totally an indigenous mission, planned to be launched by GSLV-MkII during 2017 – 2018 time frame. This mission will also be primarily technological to prove our capability to land and to deploy and control the movement of a rover on lunar surface. The science goals of the mission are to further improve the understanding of origin and evolution of the Moon using instruments onboard Orbiter and in-situ analysis of lunar samples using Lander and Rover.

The Lander and Orbiter will be launched as a composite stack and injected into the Earth Parking Orbit (EPO) of 170 X 18500 km. The Orbiter Craft carries the combined stack up to moon and the Lunar Orbit Insertion (LOI) is carried out and the combined stack is inserted into an elliptical lunar orbit which is then reduced to 100 km circular orbit. Subsequently, the Lander Craft is separated from the Orbiter and the Lander would be de-boosted using its propulsion system. The Lander, after touchdown deploys the Rover for carrying out its function.

The payloads and sensors onboard the Orbiter, Lander and Rover have been selected and are at various stages of development. The configuration changes in the Orbiter for accommodating the indigenous lander have been addressed. Orbiter High resolution Camera (OHRC) is configured on Orbiter to provide high quality images of the landing site area before the separation of Lander from Orbiter. The study team has identified the landing strategies for soft landing on the lunar surface and new technologies required for realizing the Lander. The Advanced technology elements needed for this mission are High Resolution Camera, Altimeter, Velocity meter, Throttleable Liquid engines and attitude thrusters, Navigation Camera, Accelerometer, Hazard avoidance camera and related software. The Engineering model of the six wheeled Rover has been realised and tested on the Lunar terrain test facility.
ADITYA Mission

The Aditya mission to the Sun is being proposed as an Indian solar observatory. Aditya-L1 mission is expected to be placed in a halo orbit around the Lagrangian point 1 (L1) of the Sun-Earth system. The scientific objectives are to study the solar dynamics in the chromosphere and corona with a suite of instruments including a coronagraph and a UV imager. The orbit around L1 is favorable as it provides continuous solar observations without any eclipse/occultation and is an excellent outpost outside Earth’s magnetic field to make in-situ measurements of incoming charge particles.

The selected payloads and their scientific objectives are provided below:

• Visible Emission Line Coronagraph (VELC) will study the diagnostic parameters of solar corona and dynamics and origin of Coronal Mass Ejections (CMEs). It can measure the magnetic field of solar corona down to tens of Gauss.

• Solar Ultraviolet Imaging Telescope (SUIT) will image the spatially resolved Solar Photosphere and Chromosphere in near Ultraviolet (200-400 nm) region and measure solar irradiance variations.

• The Solar Low Energy X-ray Spectrometer (SoLEXS) payload is aimed at monitoring the X-ray flares (1 – 30 keV) for studying the heating mechanism of the solar corona.

• High Energy L1 Orbiting X-ray Spectrometer (HEL1OS) is designed to study hard X-ray emission from 10 keV to 150 keV during the impulsive phase of solar flares.

• Aditya Solar wind Particle EXperiment (ASPEX) will study the variation of solar wind properties as well as its distribution and spectral characteristics.

• Plasma Analyser Package for Aditya (PAPA) payload is aimed at understanding the composition of solar wind and its energy distribution.

The Baseline Design Review (BDR) for the payloads is completed and the payloads are under development. The project proposal will be submitted for further approvals shortly.

SMALL SATELLITE PAYLOAD DEVELOPMENT

X-ray Polarimeter Experiment (POLIX)

X-ray polarisation is one crucial aspect which is predicted and is to be observed in X-ray emitting celestial sources. This experiment is aimed to measure the deg and direction of X-ray polarisation of a few bright cosmic X-ray sources including accretion powered binary X-ray pulsars, galactic black hole candidates, rotation powered pulsars and magnetars, supernova remnants and pulsar wind nebulae, and active galactic nuclei to understand some crucial information about these sources using the principle of anisotropic Thomson scattering in the 5-30 keV energy band. This experiment is one of the proposed
payloads for an Indian small satellite and is being developed by Raman Research Institute (RRI), Bengaluru.

The Engineering Model of the experiment is nearing completion. Discussions with the satellite study team have been undertaken for the interfaces for this experiment. Studies have now been completed on sources’ visibility and power generation for different orbital inclinations.

**Infra-Red Spectroscopic Imaging Survey (IRSIS)**

The Laboratory model of the IRSIS payload is under development at Tata Institute of Fundamental Research (TIFR), Mumbai. This experiment is proposed to carry out an infrared spectroscopic imaging survey covering a fraction of the sky, with the wavelength coverage 1.7- 6 micron with the aim of making infrared astronomical measurements to study Interstellar Medium (ISM), stars and Low Mass objects.

**Satellite for Earth’s Near Space Environment (SENSE)**

The primary objective of SENSE payload is to focus on studies of the Earth’s near-space electrodynamical environment, with emphasis on understanding how key aeronomical processes drive the ionosphere-thermosphere (IT) system and determine the space weather at low latitudes. Currently, the objectives are under reformulation and a revised proposal is expected to be submitted to ADCOS for review and recommendations.

**RESEARCH ACTIVITIES IN SPACE SCIENCES**

**Astronomy and Astrophysics**

The Space Astronomy Group (SAG) at ISAC is involved in optical, near-infrared, X-ray and charged particle research with a strong emphasis on scientific payload development for satellite platforms. SAG is also involved in the analysis and interpretation of existing astronomical data from space-based and ground-based facilities around the world.

The complete Scanning Sky Monitor (SSM) payload is developed in-house in this group and currently delivered for integration to the ASTROSAT spacecraft. The new payloads which are being developed are the Large Area Soft X-ray Spectrometer (CLASS) for Chandrayaan-2, Solar Low Energy X-ray Spectrometer (SoLEXS) and High Energy L1 Orbiting X-ray Spectrometer (HEL1OS) for the proposed Aditya-L1 mission. First quantitative evidence for 2-3% Sodium (Na) in the plagioclase of the highlands regions of the lunar surface was found based on the data analysis from the Chandrayaan-1 low energy X-ray Spectrometer (C1XS) payload.
Atmospheric Sciences

On April 11, 2014, the Space Physics Laboratory (SPL) completed 30 years of its existence as a premier research laboratory of ISRO exploring the energetics, dynamics and chemistry of the terrestrial and planetary environments and its implications to the mankind. Mars Exospheric Neutral Composition Analyser (MENCA) payload has been flown onboard the Mars Orbiter Mission and is making in situ measurements of the composition and distribution of the Martian exosphere. The development of CHandra’s Atmospheric Composition Explorer-2 (CHACE-2), Chandra’s Surface Thermophysical Experiments (ChaSTE), and Radio Anatomy of Moon Bound Hyper Atmosphere and ionosphere (RAMBHA) payloads for Chandrayaan-2 mission and Plasma Analyser Package for Aditya (PAPA) payload for the proposed Aditya-L1 mission are under progress.

The significant results include i) Discovery of the sputtered oxygen atoms from lunar surface from the Sub-keV Atom Reflecting Analyzer (SARA) experiment of Chandrayaan-1. These oxygen atoms are of lunar surface origin, which are released by the sputtering process when protons and He++ ions of solar wind impact the lunar surface. The sputtered flux is about 4-8% of the incident solar wind flux. ii) Quantitative assessment of the impact of Mie scattering correction applied to the radar reflectivity observed using MRR and subsequent retrieval of rain rate suggest that the uncorrected Micro Rain Radar data overestimates the rain rates by as large as 26%. The effect is more prominent at higher rain rates. iii) The first-ever regional synthesis of long-term primary data on Aerosol Optical Depth, obtained from the ARFINET stations has revealed a statistically significant increasing trend. Seasonally, the rate of increase is consistently high during the dry months (December to March) over the entire region whereas the trends are rather weak during the pre-monsoon (April to May) and summer monsoon (June to September) seasons.

Planetary Sciences

The Planetary Science and Exploration (PLANEX) Programme at PRL focuses on the isotopic investigations of meteorites to understand pre-solar and early solar system processes and timescales, and the evolution of terrestrial planets and their atmospheres. Further, it is aimed to understand surface features and processes on Mars using remote sensing data from lunar and Mars missions. Development of science payloads for planetary missions to Moon and Mars is another important objective of the PLANEX.

Katol chondrite shower fell in Nagpur district, Maharashtra on May 22, 2012. Using mineral chemistry, petrography and oxygen isotopic composition, it is classified as troilite-metal nodule bearing highly equilibrated L6-7 ordinary chondrite with metamorphic equilibrium temperature of 900°C-950°C. A large nodule was observed in Katol that mostly comprises immiscible troilite- metal melt and intensely fractured silicates without any silicate-melt phase. This nodule is an end-product of impact- induced frictional melting. Cosmic ray produced radioactive (60Co) and stable (noble gas) isotopes have been studied in Katol, to understand its pre-atmospheric size and interplanetary sojourn. Activity of 60Co and clear presence of 36Ar, 82Kr and 128Xe indicates that the pre-atmospheric radius of Katol is ≥ 100 cm. Based on cosmogenic 21Ne, an exposure age in the range of ~50 Ma is derived, for a pre-atmospheric radius of 100-150 cm.
Broken surface of Katol meteorite shows fusion crust, silicate matrix and troilite-metal nodule.

Image of fizzed troilite and metal droplets within troilite-metal nodule.

Investigations of Moreux crater (~135 km, centered at 41.66° N, 44.44° E in the Protonilus Mensae region) in Mars reveals phases of glacial activities as (1) piedmont lobes/lobate debris aprons/linear valley fills (500-100 Ma) (2) viscous flow features (100-5 Ma) and (3) gullies/thermal contraction crack polygons (5-0.4 Ma). The diversity of glacial and periglacial features within the crater was possibly controlled by differences in the amount of accumulated ice/snow, and the rate at which the terrain responded to the shifts in climate during the periods of higher obliquity.

Two payloads for Chandrayaan-2 Lander and one payload for the proposed Aditya-L1 mission have been selected and the development is in progress.

Currently, 18 projects are being supported by PLANEX. A review meeting of the PLANEX PIs was held during March 28-29, 2014. Twenty publications in national and international journals have resulted from the above projects during the year. A workshop on ‘Mars Orbiter Mission-Data Analysis and Science Plans’, was held during August 20-21, 2014, with the objective of building science teams for MOM payloads data analysis, and to initiate discussions regarding science proposals for a second Mars Orbiter Mission.

Solar Terrestrial Atmospheric Research Programme (STARp) - India

ADCOS has constituted a National Science Steering Committee for the formulation of a Science Programme entitled “Solar Terrestrial Atmospheric Research Programme (STARp)- India” to address the scientific aspects of the entire gamut of Sun-Earth-Climate system, their variabilities and responses in an integrated manner by involving the researchers across the virtual boundaries of different scientific disciplines, multi-institutional collaboration, and pooling of expertise and resources across the country.

A brainstorming session of STARp has been conducted during November 4-5 2014 to identify themes and specific scientific issues that could be taken up under this programme, which will address science
problems relevant in the National and International context and the possible linkages with the upcoming International programmes. The session was attended by thirty nine scientists who include solar physicists, atmospheric and space scientists across the country representing various research/academic centres, institutes and universities.

SPACE SCIENCE PROMOTION

**ISRO’s Space Science Promotion Scheme: ISRO-SSPS**

ISRO-SSPS is an ADCOS initiative towards supporting and strengthening of research in space sciences in the Universities as part of its Human Resource Developmental activities. This scheme has been implemented in eight Universities. ADCOS has reviewed the programme implemented in universities which have completed more than two years and evaluated the progress made and found it to be satisfactory.

**Astronomy Olympiad**

Indian Astronomy Olympiad Programme (IAOP) is intended to encourage students with good foundations in Physics and Mathematics and an interest in Astronomy to pursue further studies in this field. Homi Bhabha Centre for Science Education (HBCSE) is coordinating this activity with the support of ISRO/DOS. Indian team won one gold and four silver medals at the International Olympiad in Astronomy and Astrophysics held at Suceava, Romania during August 1-11, 2014.
Sponsored Research

RESPOND (Research Sponsored) programme started in the 1970s, aims at encouraging academia to participate and contribute in various space related activities. Under RESPOND, projects are taken up by universities/academic institutions in the areas of relevance to Space Programme. Apart from this, ISRO has also set up Space Technology Cells (STC) at premiere institutions like Indian Institute of Technologies (IITs) - Bombay, Kanpur, Kharagpur and Madras; Indian Institute of Science (IISc), Bengaluru and Joint Research Programme (JRP) with University of Pune (UoP) to carry out research activities in the areas of space technology and applications.

The main objective of the RESPOND Programme is to establish strong links with academic institutions in the country to carry out research and developmental projects which are of relevance to space and derive useful outputs of such R&D to support ISRO programmes. RESPOND programme aims to enhance academic base, generate human resources and infrastructure at the academic institutes to support the space programme. The major activity of RESPOND is to provide support to research projects in a wide range of topics in space technology, space science and applications areas to universities / institutions. In addition, conferences, workshops and publications, which are of relevance to space programme, are also being supported.

Activities

During the year, RESPOND supported 18 New Projects and 44 Ongoing Projects and five space technology cells and joint research programme with UoP. In addition, ISRO Chairs and 50 conferences/symposia/publications and other scientific/promotional activities have been supported. During the year, 27 projects sponsored earlier have been successfully completed. Several scientific publications have emerged out of these projects apart from fulfilling the objectives. Principal Investigators (PI), Co-PIs and research fellows involved in various projects had interacted with various ISRO focal points/experts in realizing the projects.
RESPOND has supported 13 Universities/Colleges, 4 National Institutes and one research Centre to take up 18 new research projects. Further, 25 Universities/Colleges, 9 National Institutes and 10 Research Centres have been supported to continue the 44 ongoing Projects. During the year, RESPOND has supported totally 27 Universities/Colleges, 9 National Institutes and 8 Research Centres to take up Projects both new and ongoing. During the year, a good number of projects has been supported in all three broad areas, namely Space Science (17), Space Applications (19) and Space Technology (26).

**Projects at STC:** During the year, RESPOND has supported 60 new projects and 115 ongoing projects of five Space Technology Cells and Joint Research Programme at UoP and further 28 projects have been completed. Details are given in the table below:

<table>
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<tr>
<th>Sl. No</th>
<th>Name of the STC/JRP</th>
<th>No. of Projects</th>
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<td></td>
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<td>1.</td>
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<td>2.</td>
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<td>IIT Bombay</td>
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<td>Total</td>
<td>60</td>
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The projects are reviewed by domain experts in ISRO and later by Joint Policy Committees consisting of experts from ISRO and the academia. In addition to the R&D Projects, ISRO under RESPOND programme has established research Chairs to guide advanced research in niche areas of space at Indian Institute of Science (IISc) Bengaluru, National Institute of Advanced Studies (NIAS) Bengaluru, IIT Kharagpur, University of Pune (UoP) and Bangalore University.

**Highlights of few Major RESPOND Projects**

- **Design and development of 32-bit RISC processor based IP core for space application:** LEON-3 processor is a 32 bit RISC (Reduced Instruction Set) Processor which is open source soft processor core used in most of space related embedded application. The project has successfully designed LEON processor based SoC (Systems on a Chip) architecture and peripheral IP (Intellectual Property) cores. The application of this project is particularly in the domain of on board data handling in space application. LEON-3 understanding and acquaintance with software development tools has been gained as a part of this project. LEON-3 IP core could be used in 32-bit microprocessor based on-board control sub systems.
• **Morpho-Tectonic evaluation of the Kosi river basin, Bihar using Remote Sensing Data:** Under the project regional interpretation of the fluvial landforms and its linkage with tectonics of the Kosi Megafan has been carried out using multi-temporal (pre-monsoon / post monsoon) and multi sensor (Resourcesat-1 AWIFS and LISS-IV) remote sensing data. It has been concluded that the morphology of the basin is the product of the complex behavior of hydrological, sedimentological and tectonic factors. The structural and non-structural flood protection measures have been suggested for management of floods in the region.

• **Study of ionospheric behavior during Total Solar Eclipse of July 2009 using the characteristics of Very Low Frequency (VLF) signals:** The main objective of the project was to study the ionospheric response due to effect of solar eclipse by simultaneous analysis of VLF signals recorded from several receiving instruments placed at different locations in the country. The project has been completed successfully. During the time period of this project, signals have been recorded for more than a dozen of places in India and its sub-continent. For most of the places, the VLF signals show effects of the solar eclipse. A theoretical model has been developed which agrees with the observed signal. By using the wavelet analysis method, the existence of atmospheric gravity wave in the lower ionosphere during eclipse period has been observed.

• **Development of advanced nano ZnO sensors for atmospheric and environmental monitoring:** The objectives of this project were synthesis of ZnO nanostructures, their characterisation and fabrication of prototype gas sensors using the nano-materials and to measure their sensitivities to different gases. All these objectives have been fulfilled satisfactorily. The prototype sensors can be used to monitor CO2, CO, CH4 and NO2, Human Space Programme may make use of these sensors for monitoring gases in the HSP capsule during ground testing.

• **Study and simulation of Landing Dynamics of a Lunar Soft Lander:** In this project, the problem of Lander with its landing gear system during its free fall and touchdown phase as a multibody dynamics system was studied. A method of solving the problem was arrived and a simplified mechanical model of the Lander with only 14 degs of freedom or independent movements was developed. The project has successfully derived equations of motions for Lander body, leg assemblies and the bottom of foot-pads that penetrate into the lunar soil. These consist of Ten 2nd order and Four 1st order differential equations and will help in prediction of its touchdown dynamics.

• **Radio frequency (RF) Local Area Network (LAN) for satellites:** In this project, detailed configuration study, simulation on MATLAB and hardware realisation has been carried out and the performance verified. Under the project, configuration and design details of the RF wireless LAN system has been developed. Based on the study and simulation, issues to be taken care of has been identified and incorporated while prototyping the system as ASIC (Application Specific Integrated Circuit) for use onboard satellites.
Development of High Performance Polycarbonate / Graphite Nanocomposites with Low Percolation for EMI Shielding Application: The main objective of the project was to increase the electrical conductivity of the Thermoplastic Polycarbonate (PC) matrix by adding Expanded Graphite (EG) using solution method followed by hot pressing technique. For comparison purpose, Nickel (Ni) and Cobalt (Co) powders were also added in to the PC matrix. For a given volume%, the PC/EG nanocomposites showed higher electrical conductivity than that of PC/Ni composites. In case of PC/Co composite, the rate of increase in electrical conductivity was lower than those of PC/EG and PC/Ni composites. Due to the good electrical conductivity, dielectric constant and dissipation factors these nanocomposites may be useful for the antistatic / EMI shielding applications.

Preparation of Carbon Nitrides for Space Applications: The aim of the project is to prepare stoichiometric carbon nitrides by a simple Chemical Vapour Deposition (CVD) method by optimizing the preparation conditions. Carbon nitrides has excellent mechanical and physical properties like high hardness, low friction coefficient, wide band gap, wear resistance, oxidation resistance, chemical inertness, low dielectric constant etc. These properties make them as a promising material for various applications such as mechanical cutting tools, protective coatings, bio medical applications, electroluminescence devices, optical materials and insulating layers. Carbon nitride has been prepared successfully by chemical vapor deposition method.
Indian Space Industry

The strong involvement of Indian industry in space programme has resulted in the realisation of operational launch vehicles, heavier class of communication satellites, sophisticated earth observation satellites, interplanetary missions and establishment of new facilities. The scope of industry participation is bound to increase in terms of complexity and scale with ISRO undertaking development of cutting edge technologies. There is a huge opportunity thrown open for industry to contribute in realisation of operational missions, interplanetary exploratory missions and to contribute in upcoming areas like satellite navigation. Larger participation of private industry is required not only for realising programmatic goals but also for self reliance leading to higher throughputs.

The commercial space industry is growing and in order to make a mark in the global arena, it is essential that ISRO-industry partnership is further nurtured. In the near future, it is envisaged that Indian industry will stake bigger claims in space programme and expand India’s space ecosystem.

Technology Transfer

During the year, six new technologies are licensed to industries for commercialisation and regular production. These include Dual Polarisation Light Detection and Ranging (LIDAR), Hard Anodisation process at Room Temperature, Precision Tapping Attachment, Solid State Power Amplifier (SSPA), DK-18 Ceramic and Photosynthesis Irradiance Incubator (PI) Box.

The compact Dual Polarisation LIDAR (DPL) technology developed by ISRO provides an insight into locating the presence of aerosol particles and clouds in the atmosphere. Aerosols and clouds play a major role in regulating earth’s climate and air quality. The novel Hard Anodisation at Room Temperature is a specialised coating technique on Aluminium and its alloys. The process produces faster, better and harder coating than conventional methods and is energy efficient. The process is suitable for variety of components used in aerospace, engineering and automobile industries. Tapping is one of the essential tooling operations to be carried out in mechanical packages used in communication payload. The tapping mechanism developed by ISRO is useful for high precision tapping operations from M1.2 screw size onwards. The Precision Tapping Attachment ensures precise tapping with perpendicularity, no jamming/breaking of tapping tool and operation by an unskilled worker. The 15 watt C band SSPA developed by ISRO is expected to be used in satellite payloads. The Magnesium Titanate based ceramic, DK-18, is widely used as a patch antenna substrate in satellite and GPS communication system. Indigenous DK-18 ceramics are light weight, small size, possesses temperature stability, with the cost of manufacturing being quite low. The PI Box is useful for measuring the parameters of phytoplankton and will be used by research oriented academic institutions, laboratories and organisations involved in marine, oceanographic research and fisheries exploration.

In addition to this, industries have been shortlisted for the know-how transfer of many new chemical and material technologies. To name a few these include high emissivity coatings, structural adhesives,
ceramics, polyimide film, flame retardant coating etc. The licensing agreements are expected to be concluded in near future for these technologies. SESCO-125, a flame resistant polysiloxane based coating is used in launch pedestals at our spaceport. Its flame retardant, water repellent and weather resistant properties is expected to find general purpose applications. Barium Magnesium Tantalite (BMT) is a typical ceramic which is widely used in oscillators, multiplexers, filters etc in satellite and terrestrial microwave communication system. Globally, a few materials have been manufactured for use in specific range of microwave spectrum. HESC-29 is a special coating system developed as a high temperature resistant enamel coating. This coating finds application as a high solar emissive topcoat on polymer composite surfaces. It is also used as a high emissive and thermal insulative coating on the PCB sensor cards for specific applications. Nickel Hydrazine Nitrate (NHN) is an energetic coordination compound that can replace the widely prevalent lead azide used in conventional detonators. Polyimide is a versatile and strategic material finding many industrial applications. Polyimide remains stable over a wide range of temperature, making it suitable for electrical insulation at low thermal gradient. Adhesive CSNM-0102 is a special epoxy resin for cryogenic structural/thermocouple bonding. It is a high strength adhesive for metal/ceramics/composite bonding. EPY 1061 is an amidoamine modified epoxy based system specially developed to protect the metal surfaces from corrosion in aqueous strontium perchlorate medium.

The productionisation of technologies licensed to Industries has been progressing satisfactorily. The Multi Layer Printed Antenna technology has been successfully used by the licensee industry in realisation of hardware for ISRO's Multi Object Tracking Radar (MOTR) project. Indigenous GIS software (IGIS) continues to be in demand with licenses being given primarily to research and development and academic institutions. The licensee till date has supplied more than 500 licenses. The Distress Alert Transmitter (DAT) continues to be useful with more than 5000 units being supplied to Indian users primarily fisheries department of coastal states. During the year rate contract for 2500 units has been placed on the industry for the supply of DAT by user agencies. Licensee industry has also supplied 12 units of ASIC based demodulators till date. A variety of adhesives, specialty materials and coatings have been successfully developed and being supplied by the licensee industry for meeting our requirements. The fire extinguishing powders, OLFEX and TEC for oil and metal fires respectively, continues to have demand from users, particularly in petrochemical industries. Handholding of licensees to help in productionisation is being carried out. Polyurethane form products and H Digital are two such technologies were industrial interaction helped in improving the assimilation of transferred technologies. Attempts are being made by industries to customise the licensed technologies to suit the requirements of user community.

There are number of technologies identified for know-how transfer from ISRO. These include a variety of adhesives, polymers, speciality materials, surface treatment technologies/coatings, electronic components, sensors, radars, antenna and software. Technologies like Ground Penetration Radar, Raman LIDAR, flame retardant, waterproofing and thermal control coating CASPOL, e-SMART and FEAST software will find wide applications with users. CASPOL is a flame retardant, waterproofing and thermal control coating that can be applied over thatched roofs for flame and waterproofing. The compound is also capable of flameproofing foam materials used in variety of applications including automobile industry. Industries are encouraged to develop innovative spin off applications from space technologies developed by ISRO.
In order to promote the technology transfer activities, an ISRO Technology Transfer Workshop was organised during Bengaluru Space Expo (BSX) 2014. The Technology Transfer Workshop was well attended with the participation of more than 100 industry delegates. Over 115 technologies for know-how transfer from various ISRO Centres/Units were announced during the meet. A compendium on “Technology Offers from ISRO for Know-How Transfer to Industries” was released during the workshop. Many industries have shown interest in the know-how transfer of ISRO technologies.

**Intellectual Property Rights**

**Patents and Copyrights**

Intellectual property plays a significant role in promoting progress in science and technology. Intellectual Property is critical in a world economy that is increasingly dependent on innovation. Intellectual Property Right (IPR) are valuable assets of organisation and realising this, efforts are on to create a strong IPR portfolio which will not only protect novel technologies developed in house but will also significantly strengthen ISRO's effort for finding spin off applications of such inventions. Through conduct of interactive workshops, ISRO scientists are sensitised about the importance of obtaining IPRs for the novel development arising out of their activities.
Five new patent applications were granted during the year including mechatronic test rig for actuators, GPS based programmable search and rescue beacons and method of processing Nickel Titanium (NiTi) based shape memory alloys etc. Patents for 12 new products and processes developed by ISRO were filed during the year.

Copyright protection for various software developed by ISRO for space and non space application has been undertaken during the year. Copyrights for seven software were successfully filed during the year. Concerted efforts are on towards commercialising the IPR assets.

Technical Consultancy

ISRO continues to provide technical consultancy services to industries and R&D institutions in diverse areas of its expertise. During the year, consultancy services were offered whereby specialised test facilities at ISRO centres were utilised by industry. Private sector industries were provided with consultancy services for microsectioning on laser welded units and alumina substrates, mechanical shock test on laser welded samples and specialised test on Monolithic Microwave Integrated Circuit (MMIC) Ku band receivers. Characterisation test for radome was carried out for leading aerospace industry using Comprehensive Antenna Test Facility (CATF).

Industry personnel are being trained regularly for fabrication, assembly and testing of critical components required for spacecraft and launch vehicle projects. During the year, public and private sector industry professionals were trained at ISRO for MIC and SAW assembly, Hi Reliability PCB fabrication and assembly etc.

Certification of industry facility has also been undertaken during the year whereby MIC facility, Electromagnetic Interference and Compatibility (EMI/EMC) lab and other facilities have been certified by ISRO for producing qualified parts for space programme. Under the technical consultancy scheme of ISRO, best practices and expertise of ISRO are shared with industry.

Technology Utilisation and Vendor Development

India has developed a space technology system over the past few decades that play a significant role in sectors ranging from telecommunications to agriculture. The rapid strides made by Indian space programme is attributed to the robust participation of the Indian industries. A number of industries as well as academic and research institutions contribute to the Indian space Programme. Indian industry today is on the threshold of entering into a new era where it is expected to assume greater responsibility in meeting the ever increasing requirements of space programme. The close association of Indian industries with space programme is not only expected to make them internationally competitive but also improve the quality standards, efficiency and manufacturing capabilities.

In the launch vehicle area, initiatives with industry are being undertaken especially to realise propulsion and related components to meet the needs of PSLV, GSLV and new developments of GSLV-Mk III. The
steps undertaken to host productionisation initiatives at external work centres is paying rich dividends in terms of meeting the requirements of increased launches.

A cryogenic rocket stage is more efficient and provides more thrust for every kilogram of propellant it burns compared to solid and earth-storable liquid propellant stages. However, cryogenic stage is technically a very complex system due to its use of propellants at extremely low temperatures and the associated thermal and structural problems. Cryogenic Upper Stage (CUS) and Cryogenic Engine-CE20 realisation continued through two private sector industry. CUS thrusting device assembly, CE20 Engine Gimbal Mount, CUS main turbo pump and CE20 liquid oxygen (LOX) and liquid hydrogen (LH2) turbo pumps were the major hardware realised.

The planning and establishment of facilities for the new integrated production initiatives namely Integrated Cryo Engine Manufacturing Facility (ICMF) and Integrated Cryo Components and Module Assembly and Test Facility (ICMAT) is on full swing. Under ICMF, public sector industry has been identified for establishing exclusive engine manufacturing facility catering to requirements of CUS, CE20 and semi cryo engine subsystems. ISRO is actively working with industry in finalising the equipment specifications. ICMAT initiative is aimed at establishing a dedicated assembly and test facility at ISRO for providing infrastructure to carry out sub assembly preparation, inspection, assembly and testing of cryogenic components and modules.

The approach of industry participation is being adopted in important programme of semi cryo engine subsystem production. During the year, fabrication of LOX booster turbo pump has been successfully completed. Industry is being geared up to realise other packages namely pre-burner, heat exchanger, main turbo pump, mixing head and thrust chamber. Activities are in progress to develop an alternate work centre for realisation of the above systems.

The integrated production approach for realisation of propulsion and related components has been widely appreciated by industry and is expected to go a long way in increasing the throughput of launch vehicles required for meeting national requirements. The Integrated Production of Components and Modules (IPCM) of propulsion system at private sector industry has resulted in industry handling end-to-end production of propulsion system consisting of raw material procurement, fabrication, assembly and testing of components and modules for PS2, GS2, L40 launch vehicle stages and satellite propulsion systems for two PSLV, two GSLV and three Geo-stationary satellites per annum.

The Integrated Production of Control System Components and Modules (IPCS) has made rapid progress with industry carrying out qualification of realised modules. The scope under PCS implemented at industry covers the delivery of fully assembled and tested components and modules for Secondary Injection Thrust Vector Control (SITVC), Reaction Control System (RCS) and Payload Assist Module (PAM) for PSLV and GSLV. IPCS will cater to the requirement of two GSLV and four PSLV launches per year.

The end-to-end production of spacecraft propulsion system components at industry is progressing well. The scope envisages production of fourteen types of components for 42 spacecrafts over a period of 5 years. During the year, industry personnel were given hands on training at our facilities for assembly
and testing activities. Three types of components (14 and 40 micron filters and PS2 hot gas filters) were fabricated, assembled, tested and delivered.

Integrated Components Production Facility (ICPF) and Integrated Production of Injection Valves and Gear Box Assembly Actuators (IPIG) are the new initiatives planned. As part of ICPF, it is planned to establish end-to-end production facility at industry for realising earth storable stage fluid control components and modules, spacecraft propulsion system elements, pressure transducers for catering to the requirement of seven launch vehicle and equal number of satellites. IPIG envisages delivery of injection valves and gear box assembly actuators for PS0/PS1 SITVC and PS1 RCS systems for four PSLV per annum.

The industry consortium partners have significantly contributed towards realising VIKAS engines for L40, PS2, GS2 and L110 stages. Public sector industry based at Trivandrum has supplied L40 conical version VIKAS Engines. The integration of L40 stages for GSLV missions is being carried out at Bengaluru based public sector industry. The integrated production of pressure fed PS4/ RCT engines is being continued by industry. Production of Liquid Apogee Motor (LAM) engines and satellite thrusters is being carried out through multiple industries. During the year, industry has significantly contributed in realisation of 100N thrusters parts for Crew Module Atmospheric Re-entry Experiment (CARE) mission and engine chamber for 800N engine.

ISRO continues to source its requirement of stage propellant tanks, water tanks, feed lines, interface elements from industries; both in public and private sector to meet the requirements of PSLV, GSLV and Cryo programme. Significant progress has been made under the long term contract with public sector industry for production of 63 sets of pressure vessel parts over next five years. During the year, five sets of propellant tanks (390L and 879L) were delivered. Further, fabrication of additional six tanks is nearing completion.

Assembly and testing of transducers through public and private sector industry is progressing well with more than 1400 transducers realised during the year. The development of industry as a dedicated work centre for end-to-end production of pressure transducers is expected to capitulate increased returns. The production of 21 NA pressure transducers is in progress and training on assembly, testing and calibration of differential pressure transducers has been completed.

In the satellite area there has been increase in the number of spacecrafts to be launched with varied payload requirements. Technologically complex missions like Mars Orbiter Mission and Chandrayaan, spacecrafts have to be realised in shorter turnaround time to achieve the mission objectives. The Indian industry has been immensely contributing in this endeavour. In the area of structures, public sector
industry during the year has supplied structures for IRNSS-1E, IRNSS-1F and GSAT-9 spacecraft. In the power systems area, leading public sector industry has supplied Li-Ion batteries apart from delivering 40 square meter of space qualified solar panels. The fabrication, assembly and testing of fourteen wings of Solar Array Drive Mechanism (SADM) and Reflector Deployment Mechanism (RDM) were successfully completed by industry.

Industry participation continued in fabrication and testing of standard AOCE, EED and TMTC packages. Multiple industries in public and private sector have been engaged for supplying DC-DC converters. Magnetic torquers, RF transponders, heat pipes, TCXO, TTC antenna are the other systems being realised by industry. In addition, more than 2500 Hybrid Micro Circuits (HMC) has been supplied by industry. Industry is also engaged in supply of spacecraft checkout systems apart from contributing in mechanical fabrication jobs.

In the electro-optics area, sensors and optic elements are being developed with industry participation. High performance optics consisting of light weight mirror substrates have been realised at industry end. Industry has recently completed the fabrication and supply of 400th unit of Corner Cube Retro Reflector (CCCR) optical components. Alternate vendor has been developed for fabrication and supply of optical components. Industrial partner has been qualified for supply of whiffle tree type support system for testing medium to large size mirror optics. High performance optical coating is being carried out by private industry with several sets of coated stainless steel vanes being delivered for application in star sensor. In addition, a large number of black absorber coated plates for development of photo masks for application in precision sun sensors for IRS and INSAT satellites has been supplied. Industry is carrying out anti reflection coatings on Germanium optics using ISRO technology and realised more than 100 numbers of space qualified hemispherical lenses for bolometer. Industry continued supplying ion implanted / diffused Silicon (Si) wafers for production of Si photo detectors and processed wafers for development of large area Si photo detector arrays required for the current IRS/INSAT projects. Fabrication of mechanical components for onboard sensors and optics is undertaken by multiple vendor industries. Industrial partner has been established for carrying out HMC design, fabrication and packaging of various categories of MEMS devices namely accelerometer, micro-bolometer, RF switch and Si photodiode array. Industry personnel have been trained by ISRO for fabrication, assembly and testing activities related with earth sensor, sun sensor and star sensors. Industry professionals have also been trained in on board PCB wiring activity. Robust industry participation is enabling realisation of sensors and optics for Chandrayaan-2, SRE-II, GSAT-15, GSAT-7A, GSAT-9, Resourcesat-2A, Aditiya-1, Cartosat-2C/2D and Cartosat-3 spacecrafts.
In line with the changing trends, industry is also contributing by providing essential services and building up infrastructure for realising our mission goals. The liquid nitrogen shielded liquid hydrogen tank has been successfully realised with industry participation. The development of Multi Object Tracking Radar (MOTR) has been undertaken at the spaceport for tracking multiple targets in space to meet the future mission requirements. MOTR is being realised with complete indigenous efforts with participation of Indian Industry. During the year, radome, Transmit Receive (TR) module and units, multi layer patch antenna for the realisation of MOTR was supplied by industry. Apart from this, industry also helped in realising the mechanical structure and fabrication of cooling system at the MOTR site.

It is important to recognise the role of indigenisation in achieving self reliance and towards this with industry participation a variety of material and components have been realised. Cu-Cr-Zr-Ti alloy plates, Inconel 718C investment castings and bimetallic adaptors are few of the materials realised indigenously for cryo engine program. DC torque motor has been indigenised for PS1 stage SITVC system of PSLV. It is planned to induct them into future PSLV flights in a systematic manner. Industry has immensely contributed in qualification of indigenous DC electrical actuator and geared motor for PS1 SITVC valves and motor operated valves for GSLV. Public sector industry has indigenised a variety of materials including steel, maraging steel, and filler wires for application in the launch vehicles. The industry is contributing in other areas through the development and supply of forged rods, blocks and connecting pipes etc.

In the years to come, with active participation of Indian industries, ISRO is confident of meeting the demands of space based services in the fields of telecommunications, broadcasting, weather monitoring, earth observation and natural resource management with active participation of Indian industries.
Space Commerce

Antrix Corporation Limited (ACL), a wholly owned Government of India Company under Department of Space, has undertaken a number of initiatives for global marketing of space products and services. During the year, Antrix has continued to expand its market base and there has been an increase in revenues during the year.

Under a commercial contract with Antrix, in the year, SPOT-7, the French Earth Observation satellite from Airbus, France along with four international co-passenger satellites from Germany, Canada and Singapore were launched on-board PSLV-C23 mission during June 30, 2014. Till date, 40 foreign satellites from 19 countries have been launched using PSLV (4 satellites as primary missions; and 36 satellites as co passengers). Discussions are also on with many prospective customers for satellite launches by PSLV in the future. During the year, commercial launch contracts have also been signed for two dedicated satellite launch on PSLV, apart from contract for three microsatellite launches.

The global marketing of IRS data is being pursued in collaboration with its international partners and through a network of re-sellers around the globe. One of the major accomplishments for the year has been the establishment of the International Ground Station for RISAT microwave remote sensing satellite comprising reception and processing facilities at Svalbard and Tromso for KSAT, Norway. Antrix markets IRS data through 20 resellers across the globe. The current offerings include data from Resourcesat-2, Cartosat-1 and RISAT satellite. Antrix is in the process of expanding the IRS ground segment market outreach with setting up of more stations outside India. Upgradation of stations is being planned for customers from United Kingdom and Germany for reception of OCM data from Oceansat-2 satellites.

The transponder provisioning services have registered a significant growth in revenue with the fillip in requirements for capacity for meeting diverse applications. Antrix is supporting the ever increasing requirement of Indian users for supporting the Direct to Home, TV Broadcasting, Very Small Aperture Terminal and Digital Satellite News Gathering Services. Provision of around 200 transponders for more than 100 users continued during the year.

There has been a good progress in the provision of TTC support international customers. As part of the long term Agreement entered into with a leading USA based customer for providing Transfer Orbit Support Services (TOSS) and other on orbit services, TOSS for Ku-band and Ka-band communication satellites were successfully provided from MCF, Hassan. There is a steady demand from foreign customers for mission support from our earth station.

Industry delegations and high level officials from leading global space companies visited Antrix to discuss commercial projects of mutual interest.

Antrix in coordination with Confederation of Indian Industry (CII) organised the fourth edition of Bengaluru Space Expo (BSX) 2014 during Nov 19-21, 2104. The event was well attended by participation of
industry delegates from India and abroad. A concurrent conference World Space Biz 2014 was also held during the event. More than 60 industries had their exhibition stalls; delegate and visitors from countries like France, Malaysia, USA, Japan etc also attended apart from large number of visitors from industry and academia and general public.
Systems Reliability and Safety

Directorate of Systems Reliability and Quality (DSRQ) as an apex body for Quality and Reliability in ISRO continued its advisory services and extended efforts to support various ISRO centres towards improving the Quality standards in their practices. Through its various delivery mechanisms like Integrated Product Assurance Board (IPAB), Industry audits, independent reviews etc., addressed many systemic quality issues across different projects and centres.

DSRQ in association with IPAB held detailed discussions and took review of GSLV – D5, LVM3 –X / CARE mission, and PSLV missions, as well as GSAT-16, Mars Orbiter Mission and IRNSS-1B & 1C spacecraft. Besides this, area specific IPAB’s in the areas of Software Quality Assurance practices, Failure Analysis procedures, Quality issues in Fasteners were also held during this year. Comprehensive Quality Assessment and Audit (CQAAT) on GSLV-MKIII was conducted and provided confidence to the management about the quality of the vehicle. Also, involved in the stage preparation activities, Phase 3 level 1, level 2A & 2B testing, propellant filling etc. Vigorously followed up the aero related studies like steady and unsteady pressure measurements etc., on GSLV MKIII held at M/s NAL, Bengaluru.

Efforts towards revision of ISRO Reliability standards (ISREL) continued this year too, and with the help of experts drawn from across ISRO, revised an ISREL document titled “Test specifications for Multilayer PCBs”. The hardcopies of the same was made available to all the users including external vendors. New teams were formed to generate ISREL documents in the areas of Contamination control requirements for ISRO and the standardisation of aerospace fasteners. The former document is at its final stage.

Based on DSRQ initiative in addressing the on-orbit anomalies in IRS and Communication Satellite, further detailed deliberations were held by two committees, to find out the root cause for all the anomalies noticed One-day seminar was also held at ISAC for generating awareness among the working personnel. Recognizing the importance of consolidating the lessons learned, non-conformances, quality alerts etc., over all our earlier missions and sharing with younger generation, efforts are sowed to establish an integrated database. An inter centre task team was formed to generate the required software, uploading the relevant information from each centre and then integrating all the centres database to have a seamless access across ISRO.

DSRQ in association with the other members of the task team took a lead role and initiated activities for ISO 9001:2008 certification of DOS & ISRO Headquarters. As part of Quality day this year, opportunity was given to workforce i.e., the tradesman and technical assistants, to showcase their innovations (innovations at grassroots). Eminent personalities like Chairman, Quality Council of India, Project Director, GSLV shared their thoughts during this event. Certificate of appreciation were given to all the innovators presented during this event by Chairman, ISRO.
Detailed discussions were held with project directors of IRNSS, ASTROSAT to unearth systemic issues in the realisation of spacecraft and provided necessary suggestions. Visits were also made to external industries like M/s HAL for addressing quality related issues and provided continuous feedback towards improvement. The bi-monthly in-house magazine eNewsletter from DSRQ continued its contribution in sharing quality related information this year too.

Safety Services

The space programme continued to be free from any major incidents during this year. The launches of PSLV-C22 mission with our first dedicated navigational satellite IRNSS-1A, PSLV-C25 with the most challenging MARS orbiter spacecraft, GSLV-D5 with Indigenous Cryogenic Upper Stage and GSAT-14 communication satellite were completed without any safety related problem. As in the case of previous launches, well established safety procedures, standards and emergency preparedness plan were implemented to avoid unforeseen incidence. Safety surveillances were in place during the Launch campaign. Round the clock activities involving production of solid propellants, handling of solid rocket motors, pyrotechnic materials, assembly of rocket stages, earth storable propellants and high pressure gas servicing to launch vehicle propulsion stages, as well as preparation of satellites at launch site. The transportation of propellants, liquid propulsion stages and rocket hardware were carried out under the umbrella of a well co-ordinated safety team, all along the route.

CE20 Engine hot test at Thrust chamber test facility, Proof pressure testing of CUS Helium gas bottles and hot test of Single element injector of Semi cryogenic engine were successfully completed without any incident were the most significant achievement during this year. The other major safety activities, i.e., flight acceptance test of steering engines, testing of various subsystems of GSLV-MK III, qualification test of AOCS, LAM and RCS were conducted under rigorous safety surveillance.

Safety surveillance was in place during fabrication, integration, thermovac test, vibration tests and high pressure tests of GSAT-7, INSAT-3D and Mars Orbiter. Rigorous safety inspections and audits, drills at various hazardous areas, preparation of safety manuals and emergency preparedness plan and review of facilities before critical operations were carried out by the safety groups.

Safety committees at various DOS establishments reviewed and cleared locations, construction and commissioning of new facilities. Safety awareness and promotional activities have continued through the celebration of National safety day, Fire service day, issuing posters, organising safety training programmes, etc.
Human Resources

The total approved sanctioned strength of the department as on 1.3.2014 is 17625 out of which 12155 are in scientific and technical Categories and 5470 are in administrative categories. Welfare measures like housing, medical, canteen, schooling for children, are extended to the existing personnel under different approved schemes. Life insurance coverage from accidents in the work place, namely VISWAS and a special scheme for assistance to families in exigency, namely, ‘SAFE’ are also extended to employees at a relatively low premium through an internal trust.

![Sanctioned Strength as on 1.3.2014](chart.png)

The competency, commitment, dedication, of ISRO/DOS personnel have played a key role in various achievements of Indian space Programme. DOS attaches great importance to the quality in recruitment, training and development of its human resources to meet the stringent requirements of the space programme and realisation of goals and objectives of the Department.

Centralised recruitment of scientists and engineers with degree in Engineering has been continued during the year. The applications were received on ISRO website and selection and induction of engineers have been completed through a process of written test and interview on an all India basis. Centralised recruitment processes has been continued for Officers in Administrative areas, Office Assistants and Jr Personal Assistants during the year.

ISRO/DOS has been absorbing the bright graduates from the Indian Institute of Space Science and Technology on successful completion of their B.Tech programme with certain level of benchmark. The fourth batch of students, who were admitted to B.Tech Programme during September 2010 at the Indian Institute of Space Science and Technology (IIST), Thiruvananthapuram, have graduated during June 2014. A total of 121 students, who have passed out fulfilling the quality benchmark, have been inducted in all DOS/ISRO Centres.

Training

ISRO continued organising the structured training programmes in various fields of its core technical/scientific domains with customised curriculum in thirteen areas to its Scientists/Engineers in SE/SF/SG grades. The programme was conducted in different Centre/Units with an aim of developing both technical skill and techno-managerial abilities amongst various groups of Scientists/Engineers to take up the challenges.
The scheme of induction training programme for newly recruited scientists/engineers which was introduced in 2002, has been continued during the year. The scheme is useful for youngsters to understand various systems in the Indian Space Programme. Similar induction training programmes have been continued for newly recruited administrative staff wherein, they are introduced to various rules, regulation, systems and processes that are in vogue in the organisation.

As a part of strategy of identifying and developing futuristic leaders, a group of 51 senior executives were identified and a customised training programme in five modules were designed and delivered. The customised programme contained five modules. The first three modules covering scientific and technical topics in Spacecraft Technologies, Space Transportation System and Space Applications. A specially designed management module was also administered to these executives at the Indian institute of Management, Ahmedabad. Last module was exclusively developed for administrative systems.

Space Studies Programme (SSP) 2014 for young Scientists/Engineers organised by International Space University at the Campus of HEC, Montreal, University Business School, Montreal, Canada, was continued during the year and six Scientists/Engineers from different Centres/units took part in it.

Customised and exclusive training programmes and Management Development Programmes for middle level scientific, technical and administrative officers, under collaboration with reputed Institutions were also continued. Additionally, all ISRO Centres/Units also administered custom built training modules to its employees to enhance the capability of Human Resources.

I APPRENTICE TRAINING

Under the Apprentices Act, 1961, training has been imparted to 2197 apprentices in Centres/Units of the Department in the Technical and Commercial Trades.

II RESERVATION IN SERVICES:

i) SCHEDULED CASTE AND SCHEDULED TRIBES

The Department has been observing the guidelines for recruitment, promotion and the welfare of Scheduled Castes and Scheduled Tribes. Table-I indicates the status of representation of persons belonging to Scheduled Castes and Scheduled Tribes.

ii) PERSONS WITH DISABILITIES

Position regarding appointment of Persons with Disabilities is given in Table-II.

iii) EX-SERVICEMEN

The status of representation of Ex-servicemen is given in Table-III.
iv) OTHER BACKWARD CLASSES (OBCs)

3287 persons belonging to Other Backward Classes are existing at present. Out of the 3287 OBCs, 96 were appointed during the year.

v) WOMEN EMPLOYEES:

There are 1848 Women Employees in the Scientific and Technical categories and 1305 Women Employees in Administrative categories in the Department as per details in Table IV. They represent 19.94% of personnel in the Department.

vi) JOINT CONSULTATIVE MACHINERY (JCM)

The Scheme of Joint Consultative Machinery (JCM) of the Department continued to function satisfactorily. The last meeting of Departmental Council was held on 10.10.2013.

vii) CONFERENCES AND WORKSHOPS:

(a) Hindi Technical and Rajbhasha Seminars

Hindi Technical and Rajbhasha Seminars have been organised in the various Centres/Units of Department of Space during 2014-15.

(b) National Conference for ISRO Women

National Conference for ISRO Women Employees was organized at Liquid Propulsion Systems Centre at Valiamala on March 4, 2014, on the eve of International Women's Day. The main theme of the National Conference for ISRO women was 'Together We Progress'. Women employees from various DOS/ISRO establishments participated in the Conference as delegates and presented papers.

A National Conference for ISRO Women employees with the theme “Inspiring Change: Equality for women is progress for all” was organised at Vikram Sarabhai Space Centre, (VSSC), Thiruvananthapuram, on March 07 and 10, 2014. More than 62 women employees donated blood on the day of Medical camp conducted in association with Sree Chitra Tirunal Institute of Medical Sciences & Technology and Regional Cancer Centre, Thiruvananthapuram.

Elocution competitions was held in different languages, such as Hindhi, Malayalam and English on March 7, 2014, in three different topics – ‘Challenges of working women in managing dual roles’, ‘Role of men in empowering women’ and ‘Empowerment of women-myth or reality’.

(c) Lecture on Sexual Harassment of Women at Workplace (Prevention, Prohibition & Redressal) Act 2013

In an endeavour to increase the awareness among all the employees on the Act passed by the Government of India on prevention of sexual harassment of women at workplace, a lecture was arranged on prevention of Sexual Harassment of Women at Workplace at VSSC, Thiruvananthapuram on June 18, 2014.
(d) Dr. BR Ambedkar’s Birth Anniversary Celebrations

123rd Birth Anniversary of Bharat Ratna Dr. Bhimrao Ramji Ambedkar, was celebrated in DOS/ISRO establishments.

TABLE - I STATUS OF SCHEDULED CASTE/SCHEDULED TRIBE PERSONNEL

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<th>STRENGTH OF PERSONS WITH DISABILITIES</th>
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Vigilance

Vigilance Awareness Week was observed commencing with administering of pledge to the employees on October 27, 2014 to November 01, 2014.

The theme of observing the Vigilance Awareness Week for this year was “Combating Corruption-Technology as an enabler”. Banners with the caption “Vigilance Awareness Week 27th October, 2014 to 1st November, 2014” were displayed at prominent places in ISRO Hqrs, Bengaluru.

As part of the Vigilance Awareness Week, a debate competition on “Combating Corruption-Technology as an enabler” was also conducted and prizes were distributed to the winners of the competition.

The details of Disciplinary (non-vigilance) and vigilance cases dealt with during 2014 are as below:

<table>
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<tr>
<th>Category of Employees</th>
<th>Type of cases</th>
<th>Cases pending as on 01.10.2013</th>
<th>Cases received during the period 01.10.2013 to 30.09.2014</th>
<th>Total (Col. 3+4)</th>
<th>Disposed during 01.10.2013 to 30.09.2014</th>
<th>Pending (Col. 5-6)</th>
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<td>(1)</td>
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<td>(6)</td>
<td>(7)</td>
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<td>Group - B (non-gazetted) Groups C &amp; D</td>
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<td>16</td>
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Progressive use of Hindi

- Implementation of Hindi in the Department of Space (DOS) continued with vigor during the year. The Official Language Implementation Committees (OLICs) both at the Department level and at Centres/Units held its quarterly meetings to review the progress in the use of Hindi. DOS/ISRO and its Centres and Units have also participated in the meetings of Town OLIC constituted in respective Towns. DOS also participated in the Meeting held at New Delhi regarding effective Implementation of Official Language in the Ministries/Departments of Govt. of India.

- In order to implement Hindi in a more meaningful and effective manner and to evaluate the progressive use of Hindi in DOS/ISRO Centres/Units, an Annual Inspection Programme was drawn up by Department and inspections were carried out. The Officers from Regional Implementation Offices of Department of Official Language have also inspected the various Centres/Units to review the progressive use of Hindi.

- Internal inspections of various Section in Centres/Units were carried out to increase use of Hindi in day to day work.

- The training programme in Hindi through the Correspondence course under Hindi Teaching Scheme, and other Departmental arrangements like Video Conferencing have been strengthened. The percentage of employees possessing working knowledge of Hindi in all DOS/ISRO Centres/Units has considerably increased to more than 80 per cent. The Centres/Units have been requested to prepare an action plan for imparting training to the remaining employees and to complete the training programme at the earliest. Arrangements have been made for imparting training in Hindi Stenography & Hindi Typewriting in all Centres/Units.

- With a view to refresh and update the knowledge of Official Language personnel, an orientation programme was held on February 14, 2014 for all the Hindi Staff of DOS/ISRO Centres/Units. Another ‘Official Language Orientation Programme’ was organised at the National Atmospheric Research Laboratory (NARL), Gadanki during January 28-29, 2015.

- Hindi Day, Hindi Week, Hindi Fortnight/Hindi Month and Hindi Workshops have been organised, in all DOS/ISRO Centres/Units, during which competitions in essay, noting and drafting, typewriting, quiz, poetry writing, story writing, news reading, memory elocution etc., have been held. These competitions have been organised for Hindi speaking and non-Hindi speaking employees separately. The prizes have also been awarded separately for each category.

- In order to implement the recommendation of the JHSS regarding propagating Hindi from house-to-house, the family members of the employees were included during Hindi Fortnight celebrations in all Centres/Units of the Department and there was a very good response. Also, in order to encourage students to study Hindi, three students securing highest marks in Hindi in standard X & XII, were awarded prizes.
• During the year, ISRO Outreach Programme in Hindi was organised by SAC at Mehsana in Gujarat in order to bring awareness among the rural population specially in the student community. Around 5000 students took part in this programme.

• The fourth meeting of JHSS was held on 13.02.2014 under the Chairmanship of MOS(PMO). As the tenure of the Committee had lapsed on 24th Oct., 2014, the work regarding reconstitution of the Committee has been initiated.

• World Hindi Day was celebrated on 10th January in all Centres/Units of the Department.

• Department plays an active role in the activities of Town OLIC. It conducts various programmes under the auspices of Town OLIC. A Technical Seminar in Hindi for all the Central Government offices situated in Bengaluru was organised on February 26, 2014, Department under the auspices of Town OLIC which was a grand success.

• During the year, seven (7) Books in Hindi on Scientific subject have been written by the Scientists of Space Application Centre, Ahmedabad which are being considered for printing. Publication of Technical Articles by the Scientists of the Department in leading magazines continued during the year. Also, the articles by the scientists were published in “Rajbhasha Bharati”, the In-house magazine of Dept.of Official Language. About eight (8) articles written by the scientists in various Centres/Units were sent to Department of Official Language, New Delhi to be considered for award under the scheme of the Government - “Award for the Best Articles written in Hindi and published in leading Hindi magazines”.

• Several pamphlets and stickers/posters and other publication material on Indian Space Programme and Booklets, namely, 117 Missions, Glimpses of Indian Space Programme, PSLV-C24, PSLV-C25, IRNSS, GSAT-11, Mars Orbiter Mission etc, were brought out in Hindi. “Antariksh Samachar” a magazine on Hindi activities was brought out by Hindi Section. Maiden issue of the In-house Hindi magazine “DISHA” was released on September 15, 2014 during the Hindi Day celebration. In-house Hindi magazines are also brought out by various Centres/Units of the Department. Space Oddessey, Glimpses of Indian Space Programme were also updated.

• Exhibition on Space in Hindi were organised in schools during the year.

• Hindi Website of the Department is being updated regularly. In addition to Departments own Website, SAC, PRL, NRSC and NARL also have their own Websites. ISAC, VSSC, LPSC, SHAR also have internal web pages on intranet.

• ‘Hindi Fortnight Incentive Scheme’ continued during the year under which the Officers/Employees doing maximum work in Hindi during the Hindi month were awarded. Also, the incentive Scheme for doing their day-to-day Official work in Hindi continued where in employees in large number participated and were rewarded for their work.

• Work regarding the New Incentive Scheme introduced to encourage the Scientist of the Department to Write Books on Scientific Subject in Hindi continued during the year.
• Apart from Technical Seminars in Hindi conducted by various Centres/Units during the year, ISRO Satellite Centre (ISAC), Bengaluru conducted an Inter-Centre Technical Seminar in Hindi for all the Centres/Units of DOS/ISRO during the November 25-26, 2014 on the “Science and Engineering in Space”.

• During the year, Department also initiated the organisation of Rajbhasha takniki Sangosthi (Official Language Technical Seminars) in all its Centres/Units as per the instructions received from Department of Official Language to conduct such Seminars on 12 given topics during 2014-15. Seminars are already held on eight such topics in various Centres/Units including DOS/ISRO HQ and the action for the remaining is on.

• The employees of DOS/ISRO Centres/Units also participated in the activities on progressive use of Hindi organised by various voluntary organisations, namely, Kendriya Sachivalya Hindi Parishad, New Delhi and also of Town OLIC.

• Hindi Implementation introduced as a part of Induction Programme in all the major Centres of DOS/ISRO continued during the year.

• Many new recruits were inducted in Hindi cadre during the year.

Awards:

- Various Centres/Units of the Department have been awarded Prizes under their respective Town Official Language Committees for the Best OL Implementation, namely, ILC-Mumbai, SCL, SAC, MCF, NRSC, ISAC, ISTRAC, LPSC, PRL and ADRIN.

- VSSC has been awarded for Best Implementation of Hindi in the South West Region by the Regional Implementation Office of the Department of Official Language. Also, GAGAN, the In-house magazine brought out by VSSC has been awarded by TOWN OLIC, Thiruvananthapuram under the “Award for the Best In-house Hindi magazine.”
International Cooperation

Indian Space Research Organisation (ISRO) of Department of Space (DOS) continues to pursue successful space cooperation with space agencies of other countries and international bodies in promoting the development and use of space technology for various applications. ISRO works with other space agencies in programmes of mutual interest; participates in international fora dealing with peaceful uses of outer space and also shares its expertise with others in the applications of space technology.

Formal space cooperative arrangements are signed with space agencies of 35 countries and 3 multinational bodies, namely, Argentina, Australia, Brazil, Brunei Darussalam, Bulgaria, Canada, Chile, China, Egypt, European Centre for Medium Range Weather Forecasts (ECMWF), European Organisation for Exploitation of Meteorological Satellites (EUMETSAT), European Space Agency (ESA), France, Germany, Hungary, Indonesia, Israel, Italy, Japan, Kazakhstan, Mauritius, Mexico, Mongolia, Myanmar, Norway, Peru, Republic of Korea, Russia, Saudi Arabia, Spain, Sweden, Syria, Thailand, The Netherlands, Ukraine, United Kingdom, United States of America and Venezuela. The areas of cooperation address mainly Remote Sensing of Earth, Satellite Communication, Launch Services, Telemetry and Tracking Support, Space Exploration, Space Law and Capacity Building.

Specifically, in this year, the following cooperative instruments are signed: (i) Implementing Agreement between ISRO and Korea Aerospace Research Institute (KARI) for cooperation in peaceful uses of outer space (ii) Agreement between ISRO and EUMETSAT for cooperation in exchange, redistribution and utilisation of data and products from meteorological and ocean satellites in support of weather analysis and forecasting (iii) Implementing Arrangement between India and Brazil for establishing cooperation in augmentation of a Brazilian Earth station for receiving and processing data from Indian Remote Sensing satellites; (iv) Cooperative Programme between ISRO and Brazilian Space Agency (AEB) for the direct reception and distribution of Resourcesat-2 data (v) MoU between ISRO and China National Space Administration (CNSA) for cooperation in peaceful uses of outer space (vi) Implementing Arrangement between ISRO and National Aeronautics and Space Administration (NASA) for cooperation on the NASA-ISRO Synthetic Aperture Radar (NISAR) mission for scientific studies on Earth and (vii) MoU between ISRO and Mexican Space Agency (AEM) concerning space cooperation for peaceful purposes.

India-USA space cooperation made significant progress in 2014, especially in implementing the outcomes of the fourth meeting of India-USA Joint Working Group on Civil Space Cooperation (JWG-CSC) with respect to earth observation, planetary exploration and exchange of professionals. Officials of ISRO and Jet Propulsion Laboratory (JPL)/NASA had a series of technical interactions in finalising the configuration of dual frequency synthetic aperture radar mission (NISAR) and modalities for realising the same. A Charter that establishes ‘ISRO-NASA Mars Working Group’ was signed on September 30, 2014, to explore possibilities of enhancing the cooperation between the two agencies in Mars exploration. The working group had the first face-to-face meeting at Bengaluru in January 2015 and identified a few areas of scientific interest for cooperation. Three US Experts in the field of earth observation have visited ISRO Centres under the ISRO-NASA Professional Engineer and Scientist Exchange Programme (PESEP).
Having realised two joint missions ("Megha-Tropiques" for studying tropical atmosphere and "SARAL" to study sea surface altitude), currently ISRO and French National Space Agency (CNES) are discussing on the possibility of realising a joint science mission for earth observation. Megha-Tropiques continues to provide valuable scientific data to the global scientific community from SAPHIR (Humidity Profiler), SCARAB (Radiation Scanner) and ROSA (Atmospheric Sounder) instruments, beyond its nominal operational period of three years. Data from ALTIKA (Ka-band Altimeter) in SARAL is currently made available to global scientific community within 180 minutes of data acquisition. India and France are also pursuing commercial relations mainly in launch services. India’s Polar Satellite Launch Vehicle (PSLV) has successfully launched French earth observation satellite ‘SPOT-7’ (identical to SPOT-6 launched by PSLV in September 2012) on June 30, 2014 on commercial arrangements. Arianespace, a major launch service provider based in France, launched India's advanced communication satellite, GSAT-16 in December 2014.

ISRO and Canadian Space Agency (CSA) are working together to realise Ultra Violet Imaging Telescope (UVIT) to be accommodated on-board ASTROSAT, the first Indian space-based observatory for multi-wavelength observations of the celestial bodies and cosmic sources. This cooperation also envisages data sharing and joint research in astronomy.

Global scientific community, has been using the wind products derived from OCEANSAT-2 Scatterometer for research and operational applications till end March 2014 and has have shown interest in using data from other Indian satellites including RISAT-1 and INSAT-3D.

There has been an element of International cooperation in India’s successful mission to Mars too. Ground stations in USA, Spain, Australia, Brazil, South Africa, Indonesia, Brunei, Mauritius and transportable terminals near Fiji were used for tracking the launch phase, cruise phase and the orbit insertion phase of India’s first inter-planetary probe, the Mars Orbiter Mission (MOM) spacecraft, which entered Martian orbit on September 24, 2014.

India is actively pursuing a proposal with the Association of South East Asian Nations (ASEAN) comprising Brunei, Cambodia, Indonesia, Laos PDR, Malaysia, Myanmar, the Philippines, Singapore, Thailand and Viet Nam to establish a ground station in Viet Nam to receive, process and use data from Indian satellites for a variety of applications including disaster management support and also to provide training in space science, technology and applications.

India hosted several international meetings during year including: Third meeting of ‘CEOS Working Group on Capacity Building and Data Democracy’ at Dehradun in April 2014; ‘International SARAL Science and Applications Meet’ at Ahmedabad in April 2014; ‘Science meet on Geodynamics of Himalayas’ at Dehradun in June 2014; and NISAR Science Workshop at Ahmedabad in November 2014.

In the field of capacity building, ISRO continues to share its facilities, expertise in the application of space science and technology through the United Nations (UN) affiliated Centre for Space Science and Technology Education in Asia and the Pacific (CSSTTE-AP) at Dehradun. As of now, there are more than 1400 beneficiaries from 52 countries. In addition to the regular courses, the centre has organised
two special courses on disaster management including the ‘SAARC Regional training programme on Geographical Information System (GIS)’ and ‘Remote Sensing technology in disaster risk and emergency management in South Asia’.

ISRO continues to play an active role in the deliberation of the United Nations Committee on Peaceful Uses of Outer Space (COPUOS) and other multilateral fora including the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP), Asia Pacific Regional Space Agency Forum (APRSAF), International Astronautical Federation (IAF), International Academy of Astronautics (IAA), International Institute of Space Law (IISL), Committee on Earth Observation Satellites (CEOS), International Society for Photogrammetry and Remote Sensing (ISPRS), the Coordination Group for Meteorological Satellites (CGMS), Space Frequency Coordination Group (SFCG), International Committee for Global Navigation Satellite Systems (ICG), Committee on Space Research (COSPAR), International Space Exploration Coordination Group (ISECG), Inter-Agency Space Debris Coordination Committee (IADC), International COSPAS-SARSAT system for search and rescue operations, International Charter ‘Space and Major Disasters’ and UN Platform for Space based Information for Disaster management and Emergency Response (UNSPIDER).
‘Space’ In Parliament

Indian Space Programme continued to attract the attention of both the Houses of Parliament. Questions were answered in Parliament during the year of 2014 as shown below:-

<table>
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<tr>
<th>Questions</th>
<th>2nd Part of</th>
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<th>Winter Session</th>
<th>Total</th>
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<td>Total</td>
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The Questions were related to GSLV and Cryogenic Technology, Village Resource Centres, Manned Space Missions, ISRO’s Fellowships Programme, Antrix-Devas Deal, Launch of Private Satellites, Chandrayaan-2, Mars Mission, SAARC Satellite, EDUSAT, Regional Positioning System/IRNSS, Worlds largest Telescope and Indian Space Telescope, Funds for Research and Experiments, Satellites launched by India and accruals from Sending Satellites to Space, Pricing of Transponders, Bilateral Cooperation in the Space programme, Satellite Launch Pad in the Country, Flood Forecasting, Waste Deposit in Space etc.,
Space Programme Publicity

India has made remarkable progress in the area of space science and technology and space based services are touching all facets of human life in the country. Creating awareness among the general public, especially students, about the benefits that have accrued from India’s applications driven space programme to the society and the progress made by the country in space science and technology has been given utmost importance. Media campaigns on important events, campaign through social media, organisation of exhibitions, educational activities like lectures, interactive sessions with students, quiz programmes, water rocket making and launching events, publications, video documentaries, etc., have helped in not only keeping the public abreast of the latest developments in our space programme but also to evoke interest in them on the nuances of space science and technology.

Publicity Through Media

Print and Electronic Media

Doordarshan and many private TV channels provided prominent live coverage to the launch of PSLV-C24/IRNSS-1B on April 04, 2014, PSLV-C23/SPOT-7 on June 30, 2014, PSLV-C26/IRNSS-1C on October 16, 2014 and LVM3-X/CARE on December 18, 2014 from SDSC SHAR, Sriharikota. For these launches, media from Chennai, Nellore, Tirupati and Sullurpetta were taken to Satish Dhawan Space Centre, Sriharikota to witness the launch. Besides, media was taken to Sriharikota on a familiarisation visit to acquaint with LVM3-X/CARE mission prior to launch. Doordarshan also provided live coverage of the launch of GSAT-16 by Ariane-5. But, the event for which local, national and even international media provided conspicuous live coverage was the successful Mars Orbit Insertion (MOI) manoeuvre performed on India’s Mars Orbiter Spacecraft on September 24, 2014. A large number of local, national and international media personnel converged on Mission Operations Complex (MOX) of ISRO Telemetry, Tracking and Command Network (ISTRAC) in Bengaluru to cover that crucial event live during which Honourable Prime Minister of India was also present at MOX.

These events were widely covered in all the leading newspapers and electronic media. Additionally, national and international print and electronic media provided conspicuous coverage to India’s Mars Orbiter Mission during various phases. Also, Press Meets scheduled by ISRO on special occasions were well attended by the media and extensively covered.

Special video capsules on the Indian space programme including one on Mars Orbiter Mission were produced and telecast. Besides media coverage on specific events of importance, several articles have appeared in various regional and national newspapers and magazines about the Indian space programme, especially on Mars Orbiter Mission. This apart, many news agencies, newspapers and TV channels made and telecast programmes on Indian Space activities, highlighting the accomplishments of the Indian Space Programme in the context of Mars Orbiter Mission progress.
Information on the Indian space programme is available to public through the highly interactive and user friendly ISRO website http://www.isro.gov.in, the new version of which was launched during the year. The Website also provides DOS Annual Report, Space India, press releases, employment opportunities, RTI related information, etc.

**Social Media**

Considering the importance of social media during contemporary times, the official ISRO Facebook on Mars Orbiter Mission was launched. Based on the overwhelmingly encouraging response, an official ISRO facebook was also subsequently launched. This was followed by the launch of an official ISRO twitter to inform about important events and developments concisely.

**Exhibitions**

During the year, ISRO organised many exhibitions at national conferences, important public congregations like cultural festivals, trade fairs and events and also at academic institutions. Exhibitions were also organised in association with Non-Governmental Organisations in various places and at prestigious events. A large number of scientists, academicians and students from India as well as delegates from abroad visited many of these exhibitions.

Exhibition of ISRO during 102nd Indian Science Congress - 2015 at Mumbai
In order to create interest and awareness on rocketry, Water Rocket Launch events were held in a few educational institutions of Bengaluru. Students and teachers enthusiastically participated in these events. The permanent exhibitions at Liquid Propulsion Systems Centre (LPSC), Vikram Sarabhai Space Centre (VSSC), Space Applications Centre (SAC) and ISRO Satellite Centre (ISAC) continued to attract a large number of visitors. The Space Museums at ISRO centres have been refurbished to make them more attractive and educative for the visiting public.

Static models of satellite and launch vehicles as well as display panels were provided to various schools and colleges on loan basis for display during science exhibitions organised by these institutions. Besides, conspicuous models and displays on Indian space programme have been provided to a few institutions.

Publications: Science writers are being encouraged to publish books on space programme. Publicity materials such as posters, stickers, etc., have been brought out in English, Hindi and Kannada during the year on important events.

**General**

The World Space Week was celebrated with great enthusiasm in DOS Centres during October 4-10, 2014. The programmes included space quiz, debates, special lectures and video shows. Essay competition and space model making for students and special public lectures were also part of the World Space Week celebrations. On National Science Day on February 28, some of the DOS Centres observed open house wherein the visitors were allowed to see them. Several competitions and events like essay writing, painting, quiz, model making, exhibition, etc., were also organised.
Right to Information

Right To Information (RTI) Act 2005 is implemented in the Department with strict compliance to the requirements of the act by identifying Central Public Information Officers (CPIOs) for receiving applications and dissemination of information, Assistant Public Information Officers (APIOs) for receiving applications, First Appellate Authority for disposal of stage one appeals and Transparency Officer. As required under the Act, DOS has published the requisite information on the web page www.isro.gov.in / Right to Information.

The following information is available on the website:

- Organisation, functions and duties
- Powers and duties of the Officers and Employees
- Procedures followed in the decision making process, including channels of supervision and accountability
- Norms set by the Department of Space for the discharge of its functions
- Rules, regulations, instructions, manuals and records of the Department of Space used by its employees for discharging their functions
- Statement of the categories of documents held by the Department of Space or under its control
- Statement of Boards, Councils, Committees and other Bodies and as to whether meetings of such boards, etc., are open to public, or the minutes of such meetings are accessible to public
- Directory of officers holding functional designations
- Number of Officers/Employees on the rolls and structure of emoluments
- Budget provisions of the Department of Space
- Manner of execution of subsidy programmes and details of beneficiaries of such programmes
- Particulars of recipients of concessions, permits or authorisations granted by the Department of Space
- Details of Information available or held by the Department of Space in the electronic form
- Names, designations and other particulars of the Public Information Officers, Assistant Public Information Officers, Nodal Officer, First Appellate Authority and Transparency Officer
- Achievements of the Department of Space/ Indian Space Research Organisation

During the period January 2014 to December 2014, 832 applications were received and information was disseminated under the provisions of the RTI Act. 122 appeals were received by the First Appellate Authority and 18 appeallants approached the Second Appellate Authority, namely, Central Information Commission.
Performance Evaluation of Department of Space Based on Result Framework Document (2013-14)

Department of Space is maintaining the Result Framework Document (RFD) as a useful internal mechanism for reviewing and monitoring of its key programmes. Department of Space started using this mechanism from the financial year 2011-12.

RFD reflects the Vision, Mission and Objectives of the Department and includes programmatic objectives on Launch Vehicle Programme, Satellite Programme (Earth Observation, Communication, Navigation and Space Science), Space Applications, Advanced Technologies, Infrastructure and Facility Development as well as the promotion of space technology, training and capacity building and international cooperation.

RFD for Department of Space for the year 2013-14 contained 161 milestones (success indicators) in respect of 84 specific action/projects identified towards 15 programmatic objectives under Indian Space Programme and five mandatory objectives. The composite score of the RFD of Department of Space in the year 2013-14 was 80.46.

The main accomplishments that contributed to this composite score pertain to:

- Successful launch of two PSLV and one GSLV missions, namely, PSLV-C22, PSLV-C25 and GSLV-D5.
- Successful realisation of six satellite missions, namely, IRNSS-1A, IRNSS-1B, INSAT-3D, GSAT-7, GSAT-14 and Mars Orbiter Mission.
- Significant progress in realisation of IRNSS-1C, IRNSS -1D and GSAT-16.
- Significant progress in realisation of S-200 solid motors and L110 liquid engine for GSLV Mk-III experimental mission and Crew module Atmospheric Re-entry Experiment (CARE).
- Delivery of 1,10,575 data products from Earth Observation Satellites.
- Near real time support during cyclone “Phailin” in Odisha, Jharkhand and Bihar to minimise human life loss through early warnings and constant tracking of cyclonic system.
- Significant achievements under “Advanced Technologies and Newer Initiatives” and “Infrastructure and facility development for Space Research”.

The RFD for 2014-15 has also been prepared and submitted. The current RFD contains 145 milestones (success indicators) in respect of 87 specific action/projects identified under 15 programmatic objectives and four mandatory objectives. These targets have been identified in coherence with the projections and programmatic priorities as identified in the 12th Five Year Plan Document of the Department.

The Department has completed the mid-term appraisal by September 2014 and uploaded the achievements within the stipulated time to the Results Framework Management System.
## Audit Observations

### (A) Status of the Action Taken Note (ATN)

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<th>Sl. No</th>
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<th>No. of Paras/ PA reports on which ATNs have been submitted to PAC after vetting by Audit</th>
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<th>No. of ATNs not sent by the Ministry even for the 1st time</th>
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<th>No. of ATNs which have been finally vetted by audit but have not been submitted by the Ministry to PAC</th>
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</table>
(B) Summary of Important Audit Observations


The C&AG in its Performance Audit Report Appropriation of accounts had made certain observations on (a) Failure to obtain legislative approval for augmenting provisions (b) Incorrect classification of expenditure under Revenue accounts instead of capital account and vice versa (c) Misclassification with same section of the grant/appropriation (d) Expenditure incurred without prior authorisation by DOS (e) Issue of deficient sanction order in DOS.


(a) Para 4.1 titled ‘Inordinate delay in realisation of SRE-2 mission’

The launch of Space Capsule Recovery Experiment - 2 mission of Department of Space, originally scheduled for August 2008 was delayed by more than five years which resulted in wasteful expenditure of `52 lakh due to expiry of parachutes and floats procured for the mission and non-achievement of objectives of the mission as of March 2014 in spite of incurring expenditure of `30.66 crore on the mission.

(b) Para 4.2 titled ‘Loss in allocation of Satellite Capacity’ – reg.

The Department of Space, Indian Space Research Organisation provided communication satellite capacity free of cost to the Government of Andhra Pradesh in violation of the decision of the Government of India to charge all users of satellite services, resulting in loss of revenue to the tune of `19.16 crore.

(c) Para 4.3 titled ‘Avoidable expenditure due to improper contract management’ - reg.

ISRO Satellite Centre, Bengaluru included price escalation clauses in two fabrication contracts entered with Hindustan Aeronautics Limited, without specifying definite time periods for completing the fabrication works. Further, after three years from the date of signing the contracts, it amended the contracts by increasing the fixed ceiling of man hours without changing the scope of work. The improper contract management resulted in avoidable expenditure of `4.35 crore.

(d) Para 4.4 titled ‘Infructuous expenditure on procurement of components’

ISRO Satellite Centre, Bengaluru failed to properly assess requirement of solid state switches for use in a project. The switches were eventually not used in the project, thereby resulting in infructuous expenditure of `1.47 crore incurred on their procurement.
Queries have been raised on planning, allocation and leasing of satellite capacity. It is stated that DOS failed to provide satellite capacity (Ku-band transponders) on domestic satellites as it was not able to realize the communication satellites as planned. Even though sufficient funds were available, DOS did not consider procured launches for its ready satellites or acquire satellite in orbit and position it under the orbital slot coordinated by India, DOS was unable to maintain the satellite capacity already used for DTH service due to technical problems and could not satisfactorily fulfil the competing needs of critical, strategic and commercial DTH users to foreign satellite systems.

The launch of GSAT-8 initially intended for DTH use was delayed by more than three years and even after launch it was not earmarked and the satellite was finally allocated for non DTH use. GSAT-10 satellite was launched in order to swap the capacity allocated to Tata Sky, which was functioning with reduced power. Since the proposal was declined by Tata Sky, DOS did not allocate capacity on GSAT-10 to any other service provider, as first right of refusal on Ku-band capacity for INSAT-4A was given to Tata Sky. Inability of DOS to realise its communication satellites and failure to utilise available satellite capacity led to competitive disadvantages to DOS vis-à-vis foreign satellite system and only 10 percent of the satellite capacity for the DTH service were serviced by INSAT system. The future requirement of transponders for DTH services was also planned to be met largely from foreign satellites.

Non achievement of targeted Ku-band capacity to meet its commitments for DTH service providers was fortuitous for the foreign satellite owners, who were ready at the opportune time to place their satellites in Indian skies for providing DTH service in India. Crowding of the foreign satellites over India and consequent increase in demand for the orbital slots would not only affect INSAT system, but would also result in non-availability of the strategically important slots for India. As DOS could not realise its communication satellites in time, most of the DTH service providers moved to foreign satellites and did not prefer to return to INSAT system due to trust deficit.

As DTH service is ‘location specific’ any change in the position of the satellite would result in migration expenses to the DTH service provider besides causing inconvenience to the customers. When satellite capacity for DTH usage was available with DOS, it was not earmarked, instead lease agreements with foreign satellite providers were renewed.

INSAT Coordination Committee (ICC), which was to earmark satellite capacity, was not convened after June 2004, ICC was reconstituted by the Govt. of India only in May 2011, during which 3 satellites were launched and capacity was allocated to DTH service providers directly by DOS, which was not as per SATCOM policy. Ministry of Information and Broadcasting (MIB), was responsible for matters relating to broadcasting in India and being a member MIB had not convened ICC and was not involved in the satellite capacity allocation decision making process. The procedures for allocation of satellite capacity was not framed by ICC. As there was no prescribed procedure within DOS for allocation of
satellite capacity for DTH service providers, by initiating DTH service in India, DOS committed satellite capacity to various DTH service providers without an ICC approved procedure.

Since DOS committed the exclusive first right of refusal to Tata Sky for using Ku-band transponders, DOS faced a difficult situation in allocation its Ku-band transponders in the slot to other provider or usage.

Transponder lease agreements did not safeguard financial interest of Government. The lease period in transponder lease agreements for INSAT Ku-band satellite capacity for DTH service ranged from 5 to 10 years without provision for revision of prices and the transponder lease agreements with foreign satellite operators were valid for one to six years only. Prices of transponders leased from foreign satellite systems were increased by 5 to 33% over a period of 2 to 6 years whereas DTH service providers availing INSAT transponders capacity paid the same charges for over 6 to 10 years.

Transponder lease agreements entered with Tata Sky gave certain benefits to Tata Sky but not to others. The agreement with Sun DTH for lease of 6.25 transponder units in INSAT-4B satellites at the rate of ₹4.75 crore per transponder but DOS actually charged only 6 transponders which resulted in loss of ₹46.92 lakh to DOS. As DOS allowed bonus free access to satellite capacity for 1.5 months after permitted three months to DTH, an amount of ₹3.56 was benefited to Sun DTH. Based on the request of Prasar Bharati, DOS allocated one additional transponder without entering into a firm agreement/MoU. Prasar Bharati later informed that the additional transponder was not used since MoU was not signed.
Milestones

1962
• Indian National Committee for Space Research formed and works on establishing Thumba Equatorial Rocket Launching Station (TERLS) started

1963
• First sounding rocket launch from TERLS (November 21, 1963)

1965
• Space Science and Technology Centre (SSTC) established in Thumba

1967
• Experimental Satellite Communication Earth Station (ESCES) set up at Ahmedabad

1968
• TERLS dedicated to the United Nations (February 2, 1968)

1969
• Indian Space Research Organisation (ISRO) formed (August 15, 1969)

1972
• Space Commission and Department of Space (DOS) set up. ISRO brought under DOS (June 1, 1972)

1972-76
• Air-borne remote sensing experiments

1975
• ISRO becomes Government Organisation (April 1, 1975)
• First Indian Satellite, Aryabhata, launched (April 19, 1975)

1975-76
• Satellite Instructional Television Experiment (SITE) conducted

1977-79
• Satellite Telecommunication Experimental Project (STEP) carried out
1979
- Bhaskara-I, an experimental satellite for earth observations, launched (June 7, 1979)
- First Experimental launch of SLV-3 with Rohini Technology Payload on board (August 10, 1979). Satellite could not be placed in orbit

1980
- Second Experimental launch of SLV-3. Rohini satellite successfully placed in orbit (July 18, 1980)

1981
- First developmental launch of SLV-3. RS-D1 placed in orbit (May 31, 1981)
- APPLE, an experimental geostationary communication satellite successfully launched (June 19, 1981)
- Bhaskara-II launched (November 20, 1981)

1982
- INSAT-1A launched (April 10, 1982). Deactivated on September 6, 1982

1983
- Second developmental launch of SLV-3. RS-D2 placed in orbit (April 17, 1983)
- INSAT-1B launched (August 30, 1983)

1984
- Indo-Soviet manned space mission (April 1984)

1987
- First developmental launch of ASLV with SROSS-1 satellite on board (March 24, 1987). Satellite could not be placed in orbit

1988
- Launch of first operational Indian Remote Sensing satellite, IRS-1A (March 17, 1988)
- Second developmental launch of ASLV with SROSS-2 on board (July 13, 1988). Satellite could not be placed in orbit
- INSAT-1C launched (July 22, 1988). Abandoned in November 1989

1990
- INSAT-1D launched (June 12, 1990)
1991
• Launch of second operational Remote Sensing satellite, IRS-1B (August 29, 1991)

1992
• Third developmental launch of ASLV with SROSS-C on board (May 20, 1992). Satellite placed in orbit
• INSAT-2A, the first satellite of the indigenously-built second-generation INSAT series, launched (July 10, 1992)

1993
• INSAT-2B, the second satellite in INSAT-2 series, launched (July 23, 1993)
• PSLV-D1, the first developmental launch of PSLV with IRS-1E on board (September 20, 1993). Satellite could not be placed in orbit

1994
• Fourth developmental launch of ASLV with SROSS-C2 on board (May 4, 1994). Satellite placed in orbit
• PSLV-D2, the second developmental launch of PSLV with IRS-P2 on board (October 15, 1994). Satellite successfully placed in Polar Sun Synchronous Orbit

1995
• INSAT-2C, the third satellite in INSAT-2 series, launched (December 7, 1995)
• Launch of third operational Indian Remote Sensing Satellite, IRS-1C (December 28, 1995)

1996
• PSLV-D3, the third developmental launch of PSLV with IRS-P3 on board (March 21, 1996). Satellite placed in Polar Sun Synchronous Orbit

1997
• INSAT-2D, fourth satellite in INSAT-2 series, launched (June 4, 1997). Becomes inoperable on October 4, 1997. (An in-orbit satellite, ARABSAT-1C, later renamed INSAT-2DT, was acquired in November 1997 to partly augment INSAT system)
• PSLV-C1, the first operational launch of PSLV with IRS-1D on board (September 29, 1997). Satellite placed in orbit

1998
• INSAT system capacity augmented with the readiness of INSAT-2DT acquired from ARABSAT (January 1998)
1999

- INSAT-2E, the last satellite in the multipurpose INSAT-2 series, launched by Ariane from Kourou, French Guyana (April 3, 1999)
- Indian Remote Sensing Satellite, IRS-P4 (OCEANSAT-1), launched by Polar Satellite Launch Vehicle (PSLV-C2) along with Korean KITSAT-3 and German DLR-TUBSAT from SDSC SHAR, Sriharikota (May 26, 1999)

2000

- INSAT-3B, the first satellite in the third generation INSAT-3 series, launched by Ariane from Kourou, French Guyana (March 22, 2000)

2001

- Successful flight test of Geosynchronous Satellite Launch Vehicle (GSLV-D1) on April 18, 2001 with an experimental satellite GSAT-1 on board
- Successful launch of PSLV-C3 on October 22, 2001 placing three satellites – India’s TES, Belgian PROBA and German BIRD into Polar Sun Synchronous Orbit

2002

- Successful launch of INSAT-3C by Ariane from Kourou, French Guyana (January 24, 2002)
- Successful launch of KALPANA-1 by ISRO’s PSLV-C4 from SDSC SHAR (September 12, 2002)

2003

- Successful launch of INSAT-3A by Ariane from Kourou, French Guyana (April 10, 2003)
- GSLV-D2, the second developmental test flight of GSLV with GSAT-2 on board from SDSC SHAR successfully launched (May 8, 2003)
- Successful launch of INSAT-3E by Ariane from Kourou, French Guyana (September 28, 2003)
- Successful launch of Resoursesat-1 by ISRO’s PSLV-C5 from SDSC SHAR (October 17, 2003)

2004

- GSLV-F01, the first operational flight of GSLV from SDSC SHAR. EDUSAT successfully placed in GTO (September 20, 2004)

2005

- Successful launch of Cartosat-1 and HAMSAT by PSLV-C6 from the newly established Second Launch Pad at SDSC SHAR (May 5, 2005)
- Successful launch of INSAT-4A by Ariane from Kourou, French Guyana (December 22, 2005)
2006

- GSLV-F02, the second operational flight of GSLV from SDSC SHAR with INSAT-4C on board (July 10, 2006). The satellite could not be placed in orbit

2007

- PSLV-C7 successfully launches four satellites – India’s Cartosat-2 and Space Capsule Recovery Experiment (SRE-1) as well as Indonesia’s LAPAN-TUBSAT and Argentina’s PEHUENSAT-1 (January 10, 2007)
- Successful recovery of SRE-1 after manoeuvring it to re-enter the earth’s atmosphere and descend over the Bay of Bengal about 140 km East of Sriharikota (January 22, 2007)
- Successful launch of INSAT-4B by Ariane launch vehicle from Korou, French Guyana on March 12, 2007
- PSLV-C8 successfully launches an Italian satellite AGILE on April 23, 2007 under a commercial contract with Antrix Corporation
- Launch of GSLV-F04 with INSAT-4CR on board from SDSC SHAR on September 2, 2007

2008

- PSLV-C10 successfully launches TECSAR satellite on January 21, 2008 under a commercial contract with Antrix Corporation
- PSLV-C9 successfully launches ten satellites on April 28, 2008: India’s Cartosat-2A, Indian Mini Satellite-1 (IMS-1) and eight Nano Satellites for International Customers under a commercial contract with Antrix Corporation
- PSLV-C11 successfully launches Chandrayaan-1 spacecraft on October 22, 2008
- European Ariane-5 launch vehicle successfully launches W2M satellite on December 21, 2008 jointly built by Antrix/ISRO and EADS Astrium on a commercial basis

2009

- PSLV-C12 successfully launches RISAT-2 and ANUSAT, on April 20, 2009
- PSLV-C14 successfully launches OCEANSAT-2 and six nanosatellites for international customers under a commercial contract with Antrix Corporation (September 23, 2009)

2010

- Successful static testing of GSLV-Mk III Launch Vehicle’s S200 Solid Propellant Booster Rocket Stage (January 24, 2010)
- GSLV-D3, the first launch of GSLV with indigenous Cryogenic Upper Stage and GSAT-4 satellite onboard. GSAT-4 could not be placed in orbit (April 15, 2010)
• PSLV-C15, the seventeenth flight of PSLV, successfully launches India’s Cartosat-2B and STUDSAT, Algeria’s ALSAT-2A, Canada’s NLS-1 and NLS-2 on July 12, 2010

• Successful Static Testing of GSV-MkIII Launch Vehicle’s L110 Liquid Core Stage (September 8, 2010)

• European Ariane-5 launch vehicle successfully launches HYLAS satellite on November 27, 2010 jointly built by Antrix/ISRO and EADS Astrium on a commercial basis

• GSV-F06, the seventh launch of GSV with GSAT-5P satellite onboard, could not place the satellite in orbit (December 25, 2010)

2011

• PSLV-C16 successfully launches India’s Resourcesat-2, YOUTHSAT and X-SAT from Singapore on April 20, 2011

• GSAT-8 Communication Satellite launched by Ariane launcher from Kourou, French Guiana on May 21, 2011

• PSLV-C17 successfully launches GSAT-12 Communication Satellite on July 15, 2011

• Second successful static testing of S-200 booster to be used in GSV-Mk III on September 4, 2011

• PSLV-C18 successfully launches the Indo-French satellite Megha-Tropiques and three co-passenger satellites – Jugnu from IIT, Kanpur, SRMSat from SRM University, Chennai and VesselSat-1 from Luxembourg – on October 12, 2011

2012

• PSLV, in its twenty first flight (PSLV-C19), launches India’s first Radar Imaging Satellite (RISAT-1) from Sriharikota on April 26, 2012

• In its twenty second flight (PSLV-C21), PSLV successfully launches French earth observation satellite SPOT-6 along with Japanese micro-satellite PROITERES from Sriharikota on September 09, 2012

• India’s heaviest communication satellite, GSAT-10, successfully launched by Ariane-5 VA 209 from Kourou, French Guiana on September 29, 2012

2013

• PSLV, in its twenty third flight (PSLV-C20), successfully launches Indo-French Satellite SARAL along with six smaller satellites from abroad from Sriharikota on February 25, 2013

• PSLV, in its twenty fourth flight (PSLV-C22), successfully launches India’s first dedicated navigational satellite IRNSS-1A from Sriharikota on July 01, 2013

• India’s advanced weather satellite INSAT-3D successfully launched by Ariane-5 VA-214 from Kourou, French Guiana on July 26, 2013

• India’s advanced communication satellite GSAT-7 successfully launched by Ariane-5 VA-215 from Kourou, French Guiana on August 30, 2013
• Mars Orbiter Mission, the India’s first interplanetary mission to planet Mars, successfully launched by PSLV-C25 from Sriharikota on November 05, 2013

• Trans Mars Injection Manoeuvre performed on Mars Orbiter Spacecraft on December 01, 2013 to place it in Mars Transfer Trajectory

2014

• In its first successful flight with indigenous Cryogenic Upper Stage, GSLV successfully places GSAT-14 into GTO on January 05, 2014

• PSLV, in its twenty sixth flight (PSLV-C24), successfully launches IRNSS-1B, the second satellite of the Indian Regional Navigation Satellite System (IRNSS) from SDSC SHAR, Sriharikota on April 04, 2014

• PSLV-C23 Successfully launches French Earth Observation Satellite- SPOT 7 and four other co-passenger satellites from SDSC SHAR, Sriharikota on June 30, 2014

• India’s Mars Orbiter Spacecraft successfully enters into an orbit around planet Mars on September 24, 2014

• PSLV, in its twenty eight flight (PSLV-C26) successfully launches IRNSS-1C, the third satellite of the Indian Regional Navigation Satellite System (IRNSS) from SDSC SHAR, Sriharikota on October 16, 2014

• India’s communication satellite, GSAT-16 successfully launched by the Ariane-5 VA221 from Kourou, French Guiana on December 07, 2014

• The first experimental flight (LVM3-X/CARE) of India’s next generation launch vehicle LVM3 (GSLV Mk-III) was successfully conducted from Satish Dhawan Space Centre SHAR, Sriharikota on December 18, 2014
# Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>AAI</td>
<td>Airports Authority of India</td>
</tr>
<tr>
<td>ABPP</td>
<td>Air Breathing Propulsion Project</td>
</tr>
<tr>
<td>ACL</td>
<td>Antrix Corporation Limited</td>
</tr>
<tr>
<td>ADCOS</td>
<td>Advisory Committee for Space Sciences</td>
</tr>
<tr>
<td>AEB</td>
<td>Agência Espacial Brasileira</td>
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<tr>
<td>AEM</td>
<td>Agencia Espacial Mexicana (Mexican Space Agency)</td>
</tr>
<tr>
<td>AFTN</td>
<td>Aeronautical Fixed Telecommunication Network</td>
</tr>
<tr>
<td>AGEOS</td>
<td>Antarctica Ground Station</td>
</tr>
<tr>
<td>AHRHySI</td>
<td>Advanced High resolution Hyperspectral imager</td>
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<tr>
<td>AHRMX</td>
<td>Advanced High resolution Multispectral Camera</td>
</tr>
<tr>
<td>AHRPAN</td>
<td>Advanced High resolution Panchromatic Camera</td>
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<tr>
<td>AIBP</td>
<td>Accelerated Irrigation Benefit Program</td>
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<tr>
<td>AIR</td>
<td>All India Radio</td>
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<tr>
<td>AIS</td>
<td>Automatic Identification System</td>
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<tr>
<td>AIT</td>
<td>Assembly, Integration and Testing</td>
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<tr>
<td>ALTIKA</td>
<td>Ka-band Altimeter</td>
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<tr>
<td>AMS</td>
<td>Agro Met Stations</td>
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<tr>
<td>AOCE</td>
<td>Attitude and Orbit Control Electronics</td>
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<tr>
<td>AOD</td>
<td>Aerosol Optical Depth</td>
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<td>AOI</td>
<td>Area of Interest</td>
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<tr>
<td>APEP</td>
<td>Ammonium Perchlorate Experimental Plant</td>
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<tr>
<td>APIOs</td>
<td>Assistant Public Information Officers</td>
</tr>
<tr>
<td>APLD</td>
<td>Advanced Propulsion and Laser Diagnostics</td>
</tr>
<tr>
<td>APRSAF</td>
<td>Asia Pacific Regional Space Agency Forum</td>
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<tr>
<td>ARG</td>
<td>Automatic Rain Gauge</td>
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<tr>
<td>AS&amp;DM</td>
<td>Aerial Services &amp; Digital Mapping</td>
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<tr>
<td>ASEAN</td>
<td>Association of South East Asian Nations</td>
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<tr>
<td>ASIC</td>
<td>Application Specific Integrated Circuit</td>
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<tr>
<td>ASPEX</td>
<td>Aditya Solar wind Particle Experiment</td>
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<tr>
<td>Abbreviation</td>
<td>Full Form</td>
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<tr>
<td>ATV</td>
<td>Advanced Technology Vehicle</td>
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<tr>
<td>AWiFS</td>
<td>Advanced Wide Field Sensor</td>
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<td>AWS</td>
<td>Automatic Weather Station</td>
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<tr>
<td>BDR</td>
<td>The Baseline Design Review</td>
</tr>
<tr>
<td>BMT</td>
<td>Barium Magnesium Tantalite</td>
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<tr>
<td>BSX</td>
<td>Bengaluru Space Expo</td>
</tr>
<tr>
<td>CARE</td>
<td>Crew Module Atmospheric Re-entry Experiment</td>
</tr>
<tr>
<td>CATF</td>
<td>Comprehensive Antenna Test Facility</td>
</tr>
<tr>
<td>CCD</td>
<td>Charge Coupled Device</td>
</tr>
<tr>
<td>CCRR</td>
<td>Corner Cube Retro Reflector</td>
</tr>
<tr>
<td>CDMA</td>
<td>Code Division Multiple Access</td>
</tr>
<tr>
<td>CE</td>
<td>Cryogenic Engine</td>
</tr>
<tr>
<td>CEOS</td>
<td>Committee on Earth Observation Satellites</td>
</tr>
<tr>
<td>CES</td>
<td>Crew Escape System</td>
</tr>
<tr>
<td>CGMS</td>
<td>Coordinating Group on Meteorological Satellites</td>
</tr>
<tr>
<td>CHACE-2</td>
<td>Chandra’s Atmospheric Composition Explorer-2</td>
</tr>
<tr>
<td>ChaSTE</td>
<td>Chandra’s Surface Thermophysical Experiments</td>
</tr>
<tr>
<td>CHM</td>
<td>Canopy Height Model</td>
</tr>
<tr>
<td>CII</td>
<td>Confederation of Indian Industry</td>
</tr>
<tr>
<td>CLASS</td>
<td>Chandrayaan-2 Large Area Soft X-ray Spectrometer</td>
</tr>
<tr>
<td>CM</td>
<td>Crew Module</td>
</tr>
<tr>
<td>CME</td>
<td>Continuing Medical Education</td>
</tr>
<tr>
<td>CMEs</td>
<td>Coronal Mass Ejections</td>
</tr>
<tr>
<td>CMIS</td>
<td>Coastal Management Information System</td>
</tr>
<tr>
<td>CMOS</td>
<td>Complementary Metal Oxide Semiconductor</td>
</tr>
<tr>
<td>CNC</td>
<td>Computer Numerical Control</td>
</tr>
<tr>
<td>CNES</td>
<td>Centre National d’Etudes Spatiales</td>
</tr>
<tr>
<td>CNSA</td>
<td>China National Space Administration</td>
</tr>
<tr>
<td>Co</td>
<td>Cobalt</td>
</tr>
<tr>
<td>COSPAR</td>
<td>Committee on Space Research</td>
</tr>
<tr>
<td>CPIO</td>
<td>Central Public Information Officers</td>
</tr>
</tbody>
</table>
CQAAT : Comprehensive Quality Assessment and Audit
CRM : Customer Relationship Management
CRS : Coarse Resolution ScanSAR
CSA : Canadian Space Agency
CSR : Clear Sky Radiation
CSSTE-AP : Centre for Space Science and Technology Education in Asia and The Pacific
CUS : Cryogenic Upper Stage
CVD : Chemical Vapour Deposition
CWC : Central Water Commission
CWDS : Cyclone Warning Dissemination System
CZTI : Cadmium Zinc-Telluride Imager
DAT : Distress Alert Transmitter
DC : Direct Current
DCPs : Data Collection Platforms
DCWDS : Digital Cyclone Warning Dissemination System
DD : DoorDarshan
DECU : Development and Educational Communication Unit
DEM : Digital Elevation Model
DES : Delhi Earth Station
DGCA : Directorate General of Civil Aviation
DMS : Disaster Management Support
DMS-DSC : DMS- Decision support Centre
DORIS : Doppler Orbitography and Radio-positioning Integrated by Satellite
DOS : Department of Space
DPL : Dual Polarisation LIDAR
DRT : Data Relay Transponder
DSS : Decision Support System
DSM : Digital Surface Model
DSNG : Digital Satellite News Gathering
DSRQ : Directorate of Systems Reliability and Quality
DTH : Direct-To-Home
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>DTM</td>
<td>Digital Terrain Model</td>
</tr>
<tr>
<td>ECLSS</td>
<td>Environmental Control and Life Support System</td>
</tr>
<tr>
<td>ECMWF</td>
<td>European Centre for Medium Range Weather Forecasts</td>
</tr>
<tr>
<td>ECV</td>
<td>Essential Climatic Variable</td>
</tr>
<tr>
<td>EED</td>
<td>Electrical/Electronic Distribution</td>
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<tr>
<td>EG</td>
<td>Expended Graphite</td>
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<tr>
<td>EMI/EMC</td>
<td>Electromagnetic Interference/Compatibility</td>
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<tr>
<td>EPO</td>
<td>Earth Parking Orbit</td>
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<tr>
<td>ESA</td>
<td>European Space Agency</td>
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<tr>
<td>e-SMART</td>
<td>e-System for Mechanical Workflow Management and Reporting Tool</td>
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<tr>
<td>EUMETSAT</td>
<td>European Organisation for Exploitation of Meteorological Satellites</td>
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<tr>
<td>FASAL</td>
<td>Forecasting Agricultural output using Space, Agrometeorology &amp; Land based observations</td>
</tr>
<tr>
<td>FEAST</td>
<td>Finite Element Analysis of Structures</td>
</tr>
<tr>
<td>FEI</td>
<td>Flexible External Insulation</td>
</tr>
<tr>
<td>FFS</td>
<td>Fuel Feed System</td>
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<tr>
<td>FIR</td>
<td>Flight Information Region</td>
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<tr>
<td>FLEWS</td>
<td>Flood Early Warning System</td>
</tr>
<tr>
<td>FLP</td>
<td>First Launch Pad</td>
</tr>
<tr>
<td>FOP</td>
<td>Final Operational Phase</td>
</tr>
<tr>
<td>FRRF</td>
<td>Fast Repetition Rate Fluorometer</td>
</tr>
<tr>
<td>FRS</td>
<td>Fine Resolution Stripmap</td>
</tr>
<tr>
<td>FTIR</td>
<td>Fourier Transform Infrared</td>
</tr>
<tr>
<td>FTP</td>
<td>File Transfer Protocol</td>
</tr>
<tr>
<td>GAC</td>
<td>Global Area Coverage</td>
</tr>
<tr>
<td>GAGAN</td>
<td>GPS Aided GEO Augmented Navigation</td>
</tr>
<tr>
<td>GCPs</td>
<td>Ground Control Points</td>
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<tr>
<td>GEO</td>
<td>Geostationary Earth Orbit</td>
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<tr>
<td>GEO LUT</td>
<td>GEOSAR Local User Terminal</td>
</tr>
<tr>
<td>GGA</td>
<td>Green House Gas Analyzer</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographical Information System</td>
</tr>
</tbody>
</table>
GISAT : Geo Imaging Satellite
GPS : Global Positioning System
GPS-ROS : GPS Radio Occultation System
GSLV : Geosynchronous Satellite Launch Vehicle
GTO : Geosynchronous Transfer Orbit
GWP : Ground Water Quality mapping
HBCSE : Homi Bhabha Centre for Science Education
HDTV : High Definition Television
HEL1OS : High Energy L1 Orbiting X-ray Spectrometer
HEX : Hypersonic Experiment mission
HMC : Hybrid Micro Circuits
HSCOI : Height scaled canopy openness index
HSP : Human Spaceflight Programme
IAA : International Academy of Astronautics
IADC : Inter Agency Debris Coordination Committee
IAF : International Astronautical Federation
IAOP : Indian Astronomy Olympiad Programme
ICC : INSAT Coordination Committee
ICG : International Committee for Global Navigation Satellite Systems
ICMAT : Integrated Cryo Components and Module Assembly and Test Facility
ICMF : Integrated Cryo Engine Manufacturing Facility
ICPF : Integrated Components Production Facility
ICT : Information and Communication Technology
IDSP : Integrated Disease Surveillance Project
IF : Intermediate Frequency
IGBP : ISRO Geo-sphere Biosphere Programme
IGiS : Indigenous GIS software
IGS : International Ground Station
IIRS : Indian Institute of Remote Sensing
IISc : Indian Institute of Science
IISL : International Institute of Space Law
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>IIST</td>
<td>Indian Institute of Space Science and Technology</td>
</tr>
<tr>
<td>IISU</td>
<td>ISRO Inertial Systems Unit</td>
</tr>
<tr>
<td>IITs</td>
<td>Indian Institute of Technologies</td>
</tr>
<tr>
<td>IMD</td>
<td>India Meteorological Department</td>
</tr>
<tr>
<td>IMDPS</td>
<td>INSAT Meteorological Data Processing System</td>
</tr>
<tr>
<td>IMGEOs</td>
<td>Integrated Multi-mission Ground Segment for Earth Observation Satellites</td>
</tr>
<tr>
<td>IMS</td>
<td>Indian Mini Satellite</td>
</tr>
<tr>
<td>INC</td>
<td>ISRO Navigation Centre</td>
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<td>INCOSPAR</td>
<td>Indian National Committee for Space Research</td>
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<td>India-WRIS</td>
<td>India-Water Resource Information System</td>
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<tr>
<td>InFCCAS</td>
<td>Indian Forest Cover Change Alert System</td>
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<td>INFFRAS</td>
<td>Indian Forest Fire Response and Assessment System</td>
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<td>INLUS</td>
<td>Indian Land Uplink Stations</td>
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<td>INMCC</td>
<td>Indian Master Control Centres</td>
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<td>INPE</td>
<td>National Institute for Space Research, Brazil</td>
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<tr>
<td>INRES</td>
<td>Indian Reference Stations</td>
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<td>INSAT</td>
<td>Indian National Satellite</td>
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<tr>
<td>IOT</td>
<td>In Orbit Tests</td>
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<td>IPAB</td>
<td>Integrated Product Assurance Board</td>
</tr>
<tr>
<td>IPCM</td>
<td>Integrated Production of Components and Modules</td>
</tr>
<tr>
<td>IPCS</td>
<td>Integrated Production of Control System</td>
</tr>
<tr>
<td>IPIG</td>
<td>Integrated Production of Injection valves and Gear Box</td>
</tr>
<tr>
<td>IPR</td>
<td>Intellectual Property Right</td>
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<tr>
<td>IPCR</td>
<td>ISRO Propulsion Complex</td>
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<tr>
<td>IRCDR</td>
<td>IRNSS CDMA Ranging Stations</td>
</tr>
<tr>
<td>IRDCN</td>
<td>IRNSS Data Communication Network</td>
</tr>
<tr>
<td>IRIMS</td>
<td>IRNSS Range and Integrity Monitoring Stations</td>
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<tr>
<td>IRLRS</td>
<td>IRNSS Laser Ranging Service</td>
</tr>
<tr>
<td>IRNSS</td>
<td>Indian Regional Navigation Satellite System</td>
</tr>
<tr>
<td>IRNWT</td>
<td>IRNSS Network Timing Facility</td>
</tr>
<tr>
<td>IRS</td>
<td>Indian Remote Sensing Satellite</td>
</tr>
</tbody>
</table>
IRSCF : IRNSS Spacecraft Control Facility
IRsis : Infra-Red Spectroscopic Imaging Survey
ISAC : ISRO Satellite Centre
ISECG : International Space Exploration Coordination Group
ISITE : ISRO Satellite Integration and Test Establishment
ISM : Interstellar Medium
ISPRS : International Society for Photogrammetry and Remote Sensing
ISREL : ISRO Reliability
ISRO : Indian Space Research Organisation
ISRO-SSPS : ISRO's Space Science Promotion Scheme
ISTRAC : ISRO Telemetry, Tracking and Command Network
IT : Ionosphere-Thermosphere
JCF : Jharia Coalfield
JCM : Joint Consultative Machinery
JHSS : Joint Hindi Salahakar Samiti
JPL : Jet Propulsion Laboratory
JRP : Joint Research Programme
JWG-CSC : Joint Working Group on Civil Space Cooperation
KARI : Korea Aerospace Research Institute
Kbps : Kilo bits per second
KSAT : Kongsberg Satellite Services
LAC : Local Area Coverage
LAM : Liquid Apogee Motor
LAN : Local Area Network
LAP : Lyman Alpha Photometer
LAXPC : Large Area Xenon Proportional Counters
LEO : Low Earth Orbit
LEOP : Launch and Early Orbit Phase
LEOS : Laboratory for Electro-Optic Systems
LEOSAR : Low Earth Orbit Search And Rescue
LH : Liquid Hydrogen
LIDAR : Light Detection and Ranging
LISS : Linear Imaging Self Scanner
LMS : Learning Management System
LOI : Lunar Orbit Insertion
LOX : Liquid Oxygen
LPSC : Liquid Propulsion Systems Centre
LRA : LASER Retro-reflector Array
LULC : Land Use and Land Cover
LUTs : Local User Terminals
MADRAS : Microwave Analysis and Detection of Rain and Atmospheric Structures
Mbps : Mega bits per seconds
MCC : Mars Colour Camera
MCF : Master Control Facility
MEMS : Micro Electro Mechanical System
MENCA : Mars Exospheric Neutral Composition Analyser
MMIC : Monolithic Microwave Integrated Circuit
MNCFC : Mahalanobis National Crop Forecast Centre
MoDWS : Ministry of Drinking Water and Sanitation
MOI : Mars Orbit Insertion
MOM : Mars Orbiter Mission
MOSDAC : Meteorological and Oceanographic Satellite Data Archival Centre
MOTR : Multi Object Tracking Radar
MOU : Memorandum of Understanding
MOX : Mission Operations Complex
MRCCs : Maritime Rescue Coordination Centres
MRF : Magneto-Rheological Finishing
MRR : Micro Rare Radar
MRS : Medium Resolution ScanSAR
MSM : Methane Sensor for Mars
MSS : Mobile Satellite Service
MTF : Modulation Transfer Function
MVC : Maximum Value Composite
NADAMS : National Agricultural Drought Assessment and Management System
NARL : National Atmospheric Research Laboratory
NASA : National Aeronautics and Space Administration
NCA : Nose Cone Adaptor
NCAOR : National Centre for Antarctica and Ocean Research
NCP : National Carbon Project
NDEMS : National Database for Emergency Management
NDVI : Normalised Difference Vegetation Index
NEC : North Eastern Council
NEOC : National Emergency Operations Centre
NEP : Net Ecosystem Production
NER : North Eastern Region
NE-SAC : North Eastern Space Applications Centre
NGLM : Nationwide Geomorphology and Lineament Mapping
NHN : Nickel Hydrazine Nitrate
Ni : Nickel
NIAS : National Institute of Advanced Studies
NICES : National Information System For Climate & Environment Studies
NISAR : NASA-ISRO Synthetic Aperture Radar
NiTi : Nickel Titanium
NNRMS : National Natural Resources Management System
NOEDA : NRSC Open EO Data Archive
NPP : Net primary productivity
NRC : Natural Resource Census
NRDB : Natural Resources Database
NRSA : National Remote Sensing Agency
NRSC : National Remote Sensing Centre
NSDI : National Spatial Data Infrastructure
NUIS : National Urban Information System
NWH : North Western Himalayan
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>OCM</td>
<td>Ocean Colour Monitor</td>
</tr>
<tr>
<td>OGDRs</td>
<td>Operational Geophysical Records</td>
</tr>
<tr>
<td>OHRC</td>
<td>Orbiter High resolution Camera</td>
</tr>
<tr>
<td>OLFEX Power</td>
<td>Oil Fire Extinguishing Powder</td>
</tr>
<tr>
<td>OLIC</td>
<td>Official Language Implementation Committee</td>
</tr>
<tr>
<td>PAM</td>
<td>Payload Assist Module</td>
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<tr>
<td>PAPA</td>
<td>Plasma Analyser Package for Aditya</td>
</tr>
<tr>
<td>PAT</td>
<td>Pad Abort Test</td>
</tr>
<tr>
<td>PC</td>
<td>Polycarbonate</td>
</tr>
<tr>
<td>PCB</td>
<td>Printed Circuit Board</td>
</tr>
<tr>
<td>PC-NNRMS</td>
<td>Planning Committee on National Natural Resources</td>
</tr>
<tr>
<td>PESEP</td>
<td>Professional Engineer and Scientist Exchange Programme Management System</td>
</tr>
<tr>
<td>PI</td>
<td>Principal Investigators</td>
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<tr>
<td>PLANEX</td>
<td>Planetary Exploration</td>
</tr>
<tr>
<td>PLTM</td>
<td>Payload Telemetry</td>
</tr>
<tr>
<td>POI</td>
<td>Point of Interest</td>
</tr>
<tr>
<td>POLIX</td>
<td>X-ray Polarimeter Experiment</td>
</tr>
<tr>
<td>POM</td>
<td>Princeton Ocean Model</td>
</tr>
<tr>
<td>PRI</td>
<td>Panchayath Raj Institutions</td>
</tr>
<tr>
<td>PRL</td>
<td>Physical Research Laboratory</td>
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<tr>
<td>PSLV</td>
<td>Polar Satellite Launch Vehicle</td>
</tr>
<tr>
<td>PSPs</td>
<td>pre-signalised points</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>Research &amp; Development</td>
</tr>
<tr>
<td>RAMBHA</td>
<td>Radio Anatomy of Moon Bound Hyper Atmosphere</td>
</tr>
<tr>
<td>RCCs</td>
<td>Rescue Coordination Centres</td>
</tr>
<tr>
<td>RCS</td>
<td>Reaction Control System</td>
</tr>
<tr>
<td>RDM</td>
<td>Reflector Deployment Mechanism</td>
</tr>
<tr>
<td>RESPOND</td>
<td>Research Sponsored</td>
</tr>
<tr>
<td>RF</td>
<td>Radio frequency</td>
</tr>
<tr>
<td>RFD</td>
<td>Result Framework Document</td>
</tr>
<tr>
<td>RIA</td>
<td>Rich Internet Application</td>
</tr>
</tbody>
</table>
RISAT-1  :  Radar Imaging Satellite-1
RLV     :  Reusable Launch Vehicle
RLV-TD  :  Reusable Launch Vehicle - Technology Demonstrator
RMSA    :  Remote Mounting Safe Arm
RNP     :  Required Navigation Performance
ROSA    :  Radio Occultation Sounder for Atmospheric studies
ROT     :  Receive Only Terminals
RRI     :  Raman Research Institute
RRSCs   :  Regional Remote Sensing Centres
RS      :  Restricted Service
RTI     :  Right To Information
SAC     :  Space Application Centre
SADM    :  Solar Array Drive Mechanism
SAG     :  Space Astronomy Group
SAPHIR  :  Sounder for Probing Vertical Profile of Humidity
SAR     :  Synthetic Aperture Radar
SARA    :  Sub-keV Atom Reflecting Analyzer
SARAL   :  Satellite with ARGOS and ALTIKKA
SAS & R :  Satellite Aided Search and Rescue
SASI    :  Shortwave Angle Slope Index
SATCOM  :  Satellites for Communication
SATNAV  :  Satellite Navigation
SBAS    :  Satellite Based Augmentation System
SCARAB  :  Scanner for Radiation Budget Measurement
SCFT    :  Semi Cryo Cold Flow Test facility
SCL     :  Semi-Conductor Laboratory
SC-OM   :  Standing Committee on Oceanography and Meteorology
SDSC    :  Satish Dhawan Space Centre
SENSE   :  Satellite for Earth's Near Space Environment
SEOCs   :  State Emergency Operations Centres
SET     :  Subscale Engine Test
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>SFCG</td>
<td>Space Frequency Coordination Group</td>
</tr>
<tr>
<td>Si</td>
<td>Silicon</td>
</tr>
<tr>
<td>SIS-DP</td>
<td>Space-based Information Support for Decentralised Planning</td>
</tr>
<tr>
<td>SITE</td>
<td>Satellite Instructional Television Experiment</td>
</tr>
<tr>
<td>SITs</td>
<td>Satellite Interactive Terminals</td>
</tr>
<tr>
<td>SITVC</td>
<td>Secondary Injection Thrust Vector Control</td>
</tr>
<tr>
<td>SKIMS</td>
<td>Sher-i-Kashmir Institute of Medical Science</td>
</tr>
<tr>
<td>S-MSS</td>
<td>S-band Mobile Satellite Service</td>
</tr>
<tr>
<td>SNC</td>
<td>Strapon Nose Cone</td>
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<tr>
<td>SoC</td>
<td>Systems on a Chip</td>
</tr>
<tr>
<td>SoLEXS</td>
<td>Solar Low Energy X-ray Spectrometer</td>
</tr>
<tr>
<td>SPL</td>
<td>Space Physics Laboratory</td>
</tr>
<tr>
<td>SPS</td>
<td>Standard Positioning Service</td>
</tr>
<tr>
<td>SRE</td>
<td>Space Capsule Recovery Experiment</td>
</tr>
<tr>
<td>SSM</td>
<td>Scanning Sky Monitor</td>
</tr>
<tr>
<td>SSP</td>
<td>Space Studies Programme</td>
</tr>
<tr>
<td>SSPA</td>
<td>Solid State Power Amplifier</td>
</tr>
<tr>
<td>SSPO</td>
<td>Sun Synchronous Polar Orbit</td>
</tr>
<tr>
<td>SST</td>
<td>Sea Surface Temperature</td>
</tr>
<tr>
<td>STARP</td>
<td>Solar Terrestrial Atmospheric Research Programme</td>
</tr>
<tr>
<td>STC</td>
<td>Space Technology Cells</td>
</tr>
<tr>
<td>STFS</td>
<td>Standard Time and Frequency Signal</td>
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<tr>
<td>SUIT</td>
<td>Solar Ultraviolet Imaging Telescope</td>
</tr>
<tr>
<td>SVAB</td>
<td>Second Vehicle Assembly Building</td>
</tr>
<tr>
<td>SWH</td>
<td>Significant Wave Height</td>
</tr>
<tr>
<td>SXT</td>
<td>Soft X-ray Telescope</td>
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<tr>
<td>TAT</td>
<td>Turn-Around-Time</td>
</tr>
<tr>
<td>TDI</td>
<td>Time Delay Integration</td>
</tr>
<tr>
<td>TDMA</td>
<td>Time Division Multiple Access</td>
</tr>
<tr>
<td>TDP</td>
<td>Technology Development Programs</td>
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<tr>
<td>TDS</td>
<td>Technology Demonstration System</td>
</tr>
</tbody>
</table>
TDV : Technology Demonstrator Vehicle
TE : Tele-Education
TERLS : Thumba Equatorial Rocket Launching Station
TIFR : Tata Institute of Fundamental Research
TIS : Thermal Infrared imaging Spectrometer
TM : Telem medicine
TMTC : Telemetry Telecommand
TOSS : Transfer Orbit Support Services
TR : Transmit / Receive
TSTC : Technical Support and Training Centre
TSTO : Two Stage To Orbit
TT&C : Tracking, Telemetry & Commanding
TVM : Thiruvananthapuram
TWTAs : Travelling Wave Tube Amplifier
ULBs : Urban Local Bodies
ULV : Unified Launch Vehicle
UN : United Nations
UN-COPUOS : United Nations Committee on Peaceful Uses of Outer Space
UN-ESCAP : United Nations Economic and Social Commission for Asia and the Pacific
UNFCCC : United Nations Framework convention on Climate Change
UNSPIDER : UN Platform for Space based Information for Disaster management and Emergency Response
UoP : University of Pune
UOPS : User Order Processing System
UT : University of Twente
UVIT : Ultra Violet Imaging Telescope
VAB : Vehicle Assembly Building
VCP : Vegetation Carbon Pool
VELC : Visible Emission Line Coronagraph
VHF : Very High Frequency
VHRR : Very High Resolution Radiometer
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Full Form</th>
</tr>
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<tbody>
<tr>
<td>VIC</td>
<td>Variable Infiltration Capacity</td>
</tr>
<tr>
<td>VLF</td>
<td>Very Low Frequency</td>
</tr>
<tr>
<td>VPN</td>
<td>Virtual Private Network</td>
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<tr>
<td>VPT</td>
<td>Video Picture Transmission</td>
</tr>
<tr>
<td>VRC</td>
<td>Village Resource Centre</td>
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<tr>
<td>VSATs</td>
<td>Very Small Aperture Terminals</td>
</tr>
<tr>
<td>VSK</td>
<td>Visakhapatnam</td>
</tr>
<tr>
<td>VSSC</td>
<td>Vikram Sarabhai Space Centre</td>
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<tr>
<td>WMS</td>
<td>Web Map Service</td>
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<tr>
<td>XTA</td>
<td>Expanding Tube Assembly</td>
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