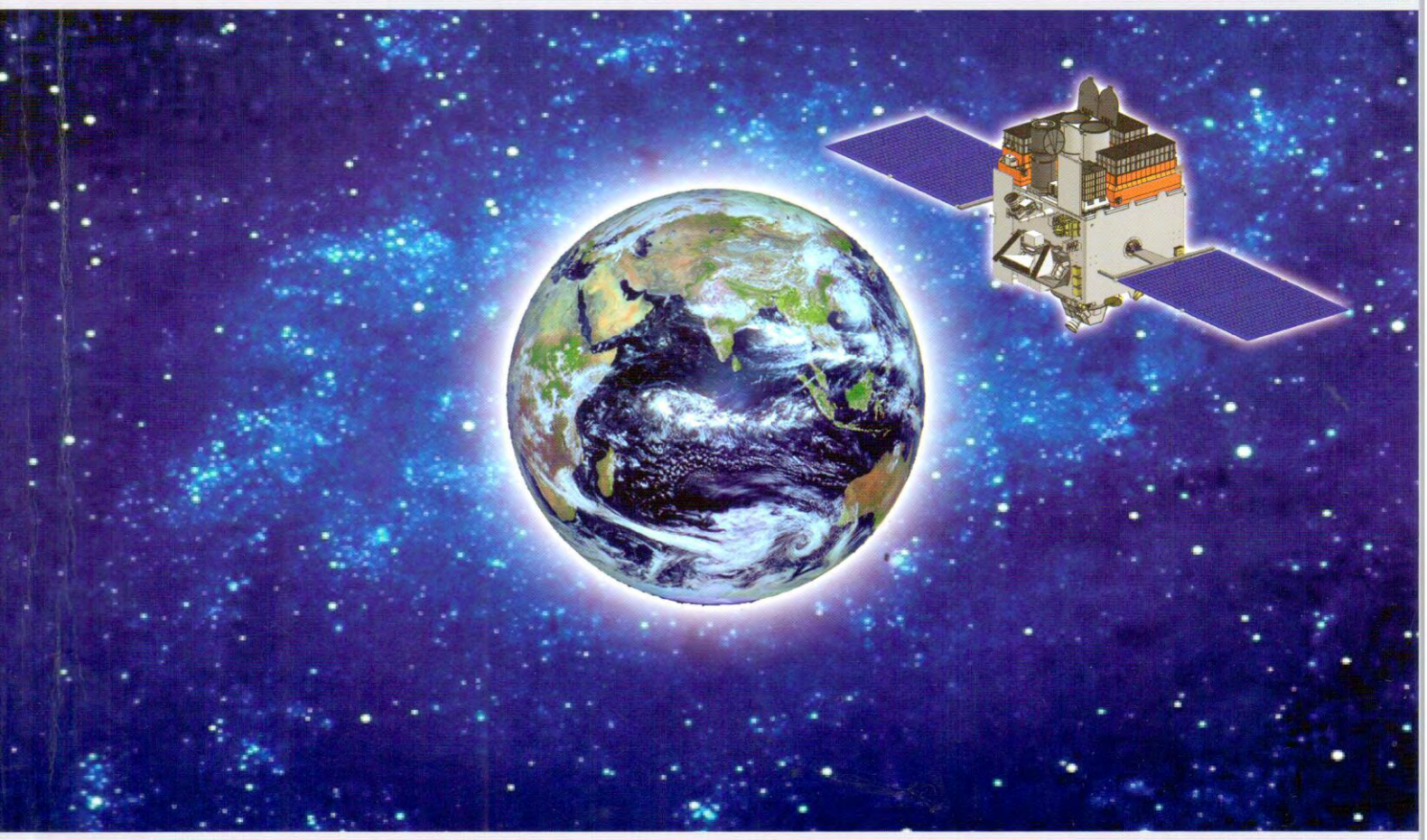
भारत सरकार
अन्तरिक्ष विभाग

सत्यमेव जयते

GOVERNMENT OF INDIA
DEPARTMENT OF SPACE



वार्षिक रिपोर्ट

Annual Report

2015 - 2016

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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) satellite 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/GSAT, IRS and IRNSS 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:

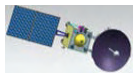
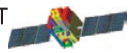
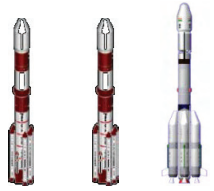
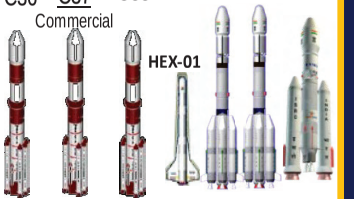
- Carrying out research and development in satellite and launch vehicle technology with a goal to achieve total self reliance
- Provide national space infrastructure for telecommunications and broadcasting needs of the country
- Provide satellite services required for weather forecasting, monitoring, 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 various 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

Contents

SPACE MISSIONS 2012 -2017

MISSIONS	2012-13	2013-14	2014-15	2015-16	2016-17
EARTH OBSERVATION SATELLITES	RISAT-1  SARAL 				RESOURCESAT-2A  SCATSAT  INSAT-3DR 
COMMUNICATION & NAVIGATION SATELLITES Procured Launch Service	GSAT-10 	IRNSS-1A  GSAT-14  INSAT-3D  GSAT-7 	IRNSS-1B  IRNSS-1C  IRNSS-1D  GSAT-16 	IRNSS-1E  IRNSS-1F  IRNSS-1G  GSAT-6  GSAT-15 	GSAT-9  GSAT– 19 E  GSAT-11  GSAT-18  GSAT-17 
SPACE SCIENCE & PLANETARY EXPLORATION SATELLITES		Mars Orbiter 		ASTROSAT 	
TECHNOLOGY DEVELOPMENT LAUNCH VEHICLES PSLV  GSLV  GSLV-MkIII 	C19 C21 Commercial C20 	C22 C25 D5 	CARE  Mk III-X C24 C23 Commercial C26 C27 	C28 C29 C30 C31 C32 C33 D6 Commercial 	RLV-TD  Mk III- D1 C36 C37 Commercial C38 HEX-01 F05 F09 

Highlights

The year 2015 witnessed many significant achievements of the Indian Space programme which caught the attention of the country as well as the outside world. With the successful completion of the intended six month period by Mars Orbiter Spacecraft in its orbit around Planet Mars, India became the first country to achieve total success in its maiden attempt to explore Mars. Besides, the second consecutively successful launch of GSLV-MkII carrying the indigeneous Cryogenic Upper Stage (CUS) underscored ISRO's capability in cryogenic rocket propulsion. The year also saw the launch of India's multi wavelength Space Observatory ASTROSAT and its successful operationalisation.

Additionally, launch of IRNSS-1D and IRNSS-1E - the fourth and fifth satellites of the Indian Regional Navigation Satellite System (IRNSS) - by PSLV-C27 and PSLV-C31 respectively into the required sub-Geosynchronous Transfer Orbits (sub-GTO), also occurred during the year 2015-16. The year also witnessed the launch of India's latest communication satellite GSAT-15 carrying communication transponders and GAGAN payload. And, the launch by the workhorse PSLV of 17 foreign satellites, 11 of them in two dedicated commercial PSLV missions, is yet another highlight of the Indian space programme during the reporting period.

The significant events of the Indian space programme during 2015-16 in chronological order are:

- On March 24, 2015, India's Mars Orbiter Spacecraft, which had earlier successfully entered into the scheduled orbit around planet Mars, completed the intended six month period in Mars orbit. As of February 2016 end, the spacecraft had completed seventeen months of operation in Mars orbit.
- IRNSS-1D, the fourth of the seven satellites constituting the IRNSS Constellation, was successfully launched by PSLV-C27 into a sub GTO on March 28, 2015. It was the 29th launch of PSLV as well as its 28th 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 neighbouring regions.
- PSLV-C28, the 30th flight of PSLV, was conducted on July 10, 2015, in which the vehicle placed United Kingdom's three DMC3 satellites, each weighing 447 kg, along with two auxiliary payloads, also from United Kingdom, into the required Sun Synchronous Orbit of 647 km height.
- GSLV-D6, the ninth flight of GSLV as well as the third flight of GSLV carrying indigenously developed Cryogenic Upper Stage (CUS), conducted on August 27, 2015, successfully launched 2117 kg GSAT-6 communication satellite into a Geosynchronous Transfer Orbit (GTO). It was the second consecutive success for GSLV carrying indigenous Cryogenic Upper Stage (GSLV-MkII).
- ASTROSAT, India's first multi wavelength astronomy mission, was successfully launched by PSLV-C30 along with six co-passenger satellites from abroad, into a 650 km orbit of 6 deg inclination on September 28, 2015.

- GSAT-15, India's latest communication satellite carrying communication transponders as well as GPS Aided Geo Augmented Navigation (GAGAN) payload was launched into GTO by the European Ariane-5 from Kourou, French Guiana on November 11, 2015.
- PSLV-C29, the thirty second flight of PSLV carrying six customer satellites from abroad including the 400 kg TeLEOS-1 of Singapore, successfully placed them in an orbit of 550 km height on December 16, 2015. This was the thirty first consecutive success of PSLV.
- IRNSS-1E, fifth of the seven satellites constituting IRNSS Constellation, was successfully launched on-board PSLV-C31 on January 20, 2016 into a sub Geosynchronous Transfer Orbit (sub GTO).

By February 2016 end, ISRO had a constellation of several commercial Communication satellites, exclusive Meteorological satellites, Earth Observation satellites, Navigation Satellites, a multi wavelength astronomical observatory 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-1D and 1E in the required sub Geosynchronous Transfer Orbits in two separate flights - PSLV-C27 and PSLV-C31. Besides, the 'XL' version of PSLV launched five satellites from United Kingdom successfully into a 647 km Sun Synchronous Orbit in its 30th flight (PSLV-C28). PSLV-XL also launched India's first multi-wavelength space observatory ASTROSAT along with six customer satellites from abroad, in its thirty first flight (PSLV-30). In its 'Core Alone' version, PSLV placed six satellites from Singapore including the 400 kg Satellite TeLeos-1 into a 550 km Orbit, further proving its reliability and versatility.

Another prominent development in the Indian launch vehicle programme was the second consecutively successful flight (GSLV-D6) of GSLV-MkII on August 27, 2015, which was equipped with indigenous cryogenic upper stage. This flight further highlighted ISRO's strength in cryogenic propulsion technologies.

Activities pertaining to LVM3 (GSLV-MkIII) launch vehicle, capable of launching four ton satellites into a Geosynchronous Transfer Orbit (GTO), progressed well during the year with the successful ground test of its S200 booster to validate the changes in its head end segment as well as the flight and the extended duration hot (ground) tests of CE-20 cryogenic engine of its third stage.

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

Satellite Programme

IRNSS-1D and 1E, the fourth and fifth satellites of the IRNSS Constellation, were successfully launched on board PSLV-C27 and PSLV-C31 on March 28, 2015 and January 20, 2016 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 three predecessors, IRNSS-1D and IE 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-1D and 1E have been successfully completed during the year and the satellites have been cleared for Navigation activities.

The 2117 kg GSAT-6, an advanced communication satellite providing services through five spot beams in S-band and a national beam in C-band, was successfully launched by GSLV-D6 on August 27, 2015 into GTO. Later, the satellite was placed in its geostationary orbital slot with the help of its own propulsion system.

GSAT-15, India's latest communication satellite carrying Ku-band communication transponders, launched on-board European Ariane-5 VA227 on November 11, 2015, was later successfully taken to its geostationary orbital slot by firing its Liquid Apogee Motor in steps from MCF, Hassan.

The new satellites being built for meeting the country's future requirements include IRNSS-1F, and 1G which are planned to be launched on-board PSLV, and GSAT-9 and GSAT-6A communication satellites to be launched by GSLV-MkII, GSAT-19 by GSLV-MkIII (LVM3), GSAT-17, GSAT-18 and GSAT-11 communication satellites planned to be launched through procured launch.

In the domain of earth observation satellites, it is planned to design, develop and build Cartosat-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, INSAT-3DR and GISAT-1 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 envisaged 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 successfully placed in orbit around Mars on September 24, 2014. Mars Orbiter 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. The spacecraft successfully completed six months in its elliptical orbit around Mars on March 24, 2015, there by fulfilling all its primary objectives. All systems onboard the spacecraft are functioning normally in its orbit around Mars and it has already sent a number pictures of Mars disc showing many details. By February 2016 end, the spacecraft had successfully completed 17 months in its orbit around Mars.

Another prominent highlight of the year was yet another space science mission – ASTROSAT – which was successfully launched on September 28, 2015 by India's workhorse launch vehicle PSLV. ASTROSAT is India's first multi wavelength observatory capable of simultaneously viewing the Universe in the visible, Ultra violet and X-ray regions of the electromagnetic spectrum. After its launch into the planned orbit, ASTROSAT became operational following extensive in orbit test of its five payloads.

The future space science missions of ISRO include Chandrayaan-2, a follow-on mission to Chandrayaan-1 with an Orbiter, Lander and Rover to explore the moon, is to be launched onboard GSLV and Aditya-1, a scientific mission for solar studies carrying five scientific payloads including a Coronagraph. ADITYA is planned to be placed in a halo orbit around the L1 Legrangian 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 and 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 now cover 380 hospitals connecting 302 rural hospitals and 18 mobile vans to 60 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. The major activities during the year were monitoring all the flood events, supporting the disaster management during the Nepal Earthquake and monitoring the landslide dammed Phutkal river in Jammu and Kashmir. In 2015, flood monitoring and mapping was carried out for floods in 10 states and more than 105 flood maps were disseminated to the concerned State and Central officers in addition to making available to Users on the web through Bhuvan and NDEM web portals. LIDAR based experimental flood depth maps for part of Lakhimpur district of Assam were generated and disseminated to the state agencies for severe floods during August 23 and 25 and September 4, 2015.

Several depressions caused heavy rainfall during the year. All depressions and cyclones originated in the Indian ocean region were monitored and the track, intensity and landfall were predicted. Related information was regularly updated on the MOSDAC website.

During 2015, satellite data support (28 scenes) was provided for 10 emergency requests from Vietnam, Pakistan, Indonesia, Bangladesh, Japan, Myanmar, Nepal and Taiwan for floods, oil spill, landslides and Typhoon disasters.

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 commercial contract with Antrix, 57 international customer satellites have been successfully launched by PSLV since 1999. During 2015, PSLV successfully launched 17 satellites from abroad. Many proposals from international Customers for the launch of their satellites onboard PSLV are under discussion and active consideration.

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 various programmes. So far, the Department of Space has transferred about 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 the French, Canadian, Russian and Chinese space agencies as well the US Geological Survey, Jet Propulsion Laboratory and Kuwait Institute of Scientific Research.

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, 99 students of 2011 batch of B. Tech graduates were placed as Scientists/ Engineers at various centres of ISRO in 2015.

Public Awareness on Space Programme

During the year, ISRO organised media visits to SDSC SHAR, Sriharikota, ISRO Satellite Centre (ISAC) and Mission Operations Complex (MOX), ISTRAC Bengaluru for the live coverage of PSLV and GSLV launches, 'GNSS User Meet 2015' and Mars Orbiter Mission coverage respectively. 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. A mobile Tableau on Mars orbiter mission was conspicuously presented during the 'International Fleet Review-2016 (IFR-16)' at Vishakhapatnam on February 07, 2016. 'SAKAAR', an Augmented Reality application for Android devices that helps the users, especially students, to better visualise ISRO launch vehicle, satellite and applications programmes, was launched in 2015.

Right to Information – Ensuring Transparency

Strict compliance with 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://www.dos.gov.in) and on ISRO website (http://www.isro.gov.in). During the period January 2015 to December 2015, 807 applications were received and information was disseminated under the provisions of the RTI Act. 120 appeals were received by the First Appellate Authority and 25 appellants approached the Second Appellate Authority, namely, Central Information Commission.

Conclusion

Indian space programme during the year made significant 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 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 its objective.

Organisation

Space activities in the country were initiated with the setting up of the 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 of ISRO for the design and development of launch vehicle technology. 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 different missions. These are sustained by activities towards programme planning & evaluation, human resources development, technology transfer, industry coordination and safety. Planning, execution and maintenance of all civil works related to the Centre is also carries 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.

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), reusable launch vehicles, advanced technology vehicles, air-breathing propulsion and critical technologies towards human spaceflight.

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.

ISITE Building

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 more than 75 satellites 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

Satish Dhawan Space Centre (SDSC) SHAR, Sriharikota, the Spaceport of India, is responsible for providing Launch Base Infrastructure for Indian Space Programme. This Centre has the facilities for solid propellant processing, static testing of solid motors, launch vehicle integration and launch operations, range operations comprising telemetry, tracking and command network and mission control centre.

The Centre has two launch pads from where the rocket launching operations on PSLV and GSLV are carried out. 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 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. The 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 lead centre for development and realisation of earth-to-orbit advanced propulsion stages for launch vehicle and also the in-space propulsion systems for spacecraft. The activities are spread across Valiamala / Thiruvananthapuram and Bengaluru centres.

LPSC Bengaluru

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, project management functions, etc.,

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 the Indian space research programme.

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 programme, etc. A Semi-cryogenic Cold Flow Test facility (SCFT) has been established at IPRC, Mahendragiri for the development, qualification and acceptance testing of semi-cryogenic engine subsystems.

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 continued improvement of its contribution to Indian space programme.

Semi-cryogenic Cold Flow Test facility (SCFT) at IPRC, Mahendragiri

Space Applications Centre (SAC)

Space Applications Centre (SAC) at Ahmedabad is dealing with wide variety of activities from payload development 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) bengaluru 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) located at Bengaluru carries out 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, Shadnagar and Pune and one IRNWT facility at Bengaluru.

In keeping with its long-established TTC support responsibility, ISTRAC has also been mandated to provide space operations support for Deep Space Missions of ISRO, undertake development of radar systems for launch vehicle tracking and meteorological applications, establish and operationalise the ground segment for Indian Regional Navigational Satellite System, provide Search & Rescue and Disaster Management Services and support space based services like telemedicine, VRC and tele-education.

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, INSAT-3A, INSAT-4A, INSAT-4B, INSAT-4CR, INSAT-3D, Kalpana-1, GSAT-8, GSAT-10, GSAT-12, GSAT-14, IRNSS-1A, IRNSS-1B, IRNSS-1C, IRNSS-1D, IRNSS-1E, GSAT-6, GSAT-16 and GSAT-15. To carry out these operations effectively, MCF-Hassan is having an integrated facility consisting of nine Satellite Control Earth Stations.

MCF at Bhopal completed its tenth year of successful operations. The Facility is configured with two Satellite Control Earth Stations (SCES) consisting of Full Motion Antennae and Limited Motion Antennae, a Satellite Control Centre and a Power Complex. MCF Bhopal is currently managing round-the-clock operations of three satellites in close coordination with MCF Hassan.

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. Major systems like Inertial Navigation Systems based on Mechanical Gyros and Optical Gyros, attitude reference systems, Rate Gyro Packages and Accelerometer packages are developed indigenously and used in various missions 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. Integrated Test Complex (ITC) building of IISU was completed during the year for production, integration, assembly and testing of sensors and systems.

ITC Building

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 sensors, 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.

Research & Development programme of LEOS includes development of miniature sensors, Active Pixel Sensor, Miniature star tracker, Vision Sensors, Detectors, MEMS devices, Segmented Mirror Telescope optics and advanced optics for future spacecraft use.

New facilities incorporated during 2015 include installation of Gross Leak Tester, 0.3M Dia Thermovac system and Dome for Telescope Laser Ranging. Sensor production building (Aryabhata Building) and 'Optics & MEMS' building have become operational in 2015. The new facilities established at Aryabhata Building includes ultra precision CNC cell centering and turning machine, 3.5 T Vibration shaker system, 0.8 M Thermovac system, LN2 Tank (15 KL), Temperature test chamber, Humidity chamber, Particle counter, 2-Axis motion simulator, Nitrogen purged chambers (4 Nos.) and DRUPS power supply unit.

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 geo-spatial 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

IIRS Main Building

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)

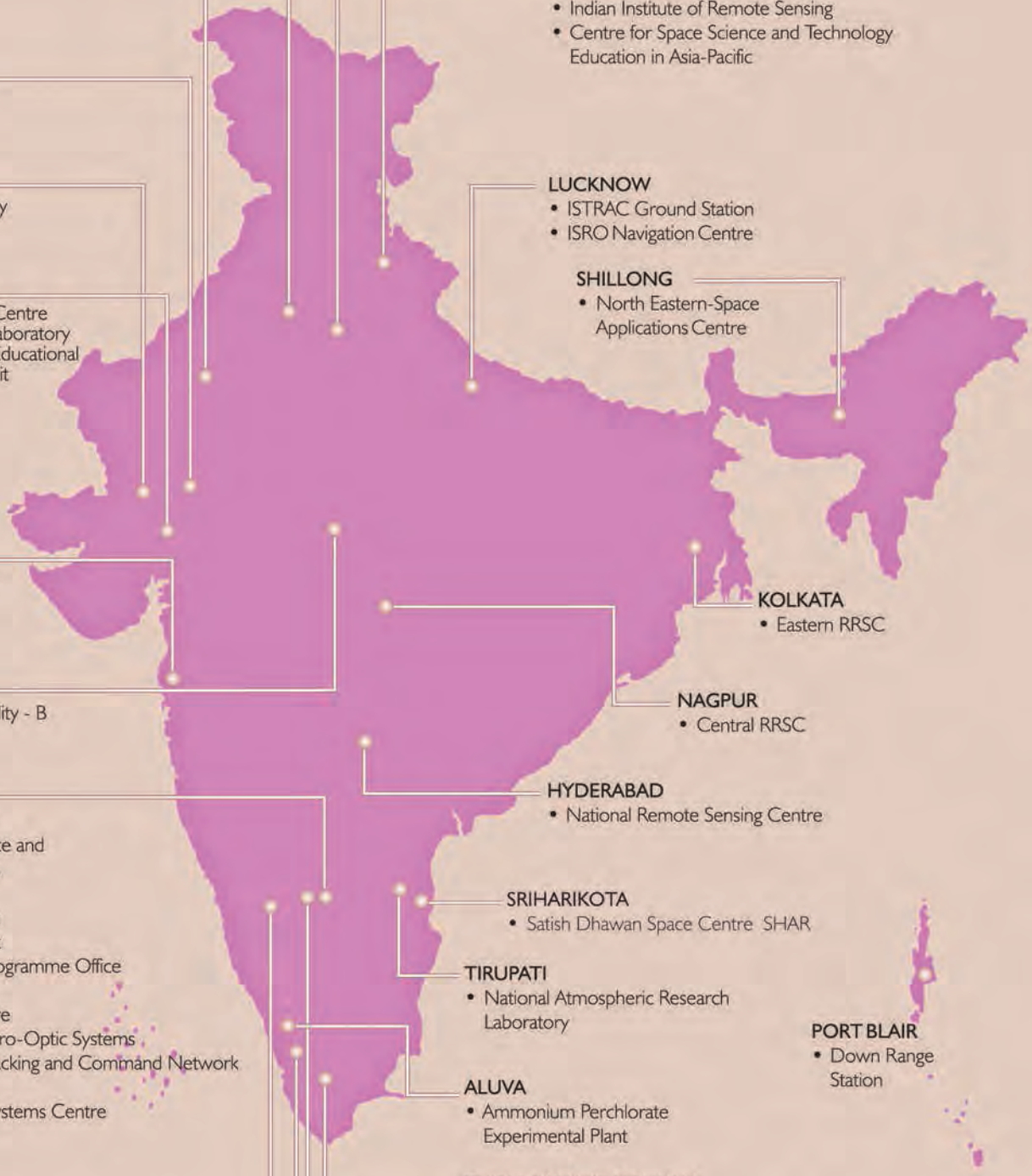
Physical Research Laboratory (PRL) at Ahmedabad is an autonomous unit of DOS and a premier research institute engaged in basic research in the areas of Astronomy and Astrophysics, Solar Physics, Planetary Science and Exploration, Space and Atmospheric Sciences, Geosciences, Theoretical Physics, Atomic,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

Infrared Observatory, Mt. Abu

PRL is actively participating in ISRO's planetary exploration programme and has also developed capabilities for detecting exo-planets 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.

PRL has initiated scientific programmes in frontier areas of research including the search for exo-planets, laboratory studies of interstellar grains, laboratory synthesis of astro-molecules and experimental studies in the field of quantum optics.

The Centres of Indian Space Programme



CHANDIGARH
- Semi-Conductor Laboratory

NEW DELHI
- DOS Branch Secretariat
- ISRO Branch Office
- Delhi Earth Station

JODHPUR
- Western RRSC

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

UDAIPUR
- Solar Observatory

Mt. ABU
- Infrared Observatory

LUCKNOW
- ISTRAC Ground Station
- ISRO Navigation Centre

SHILLONG
- North Eastern-Space Applications Centre

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

MUMBAI
- ISRO Liaison Office

KOLKATA
- Eastern RRSC

BHOPAL
- Master Control Facility - B

NAGPUR
- Central RRSC

HYDERABAD
- National Remote Sensing Centre

BENGALURU
- Space Commission
- Department of Space and ISRO Headquarters
- SCNP Office
- NNRMS 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

SRIHARIKOTA
- Satish Dhawan Space Centre SHAR

TIRUPATI
- National Atmospheric Research Laboratory

PORT BLAIR
- Down Range Station

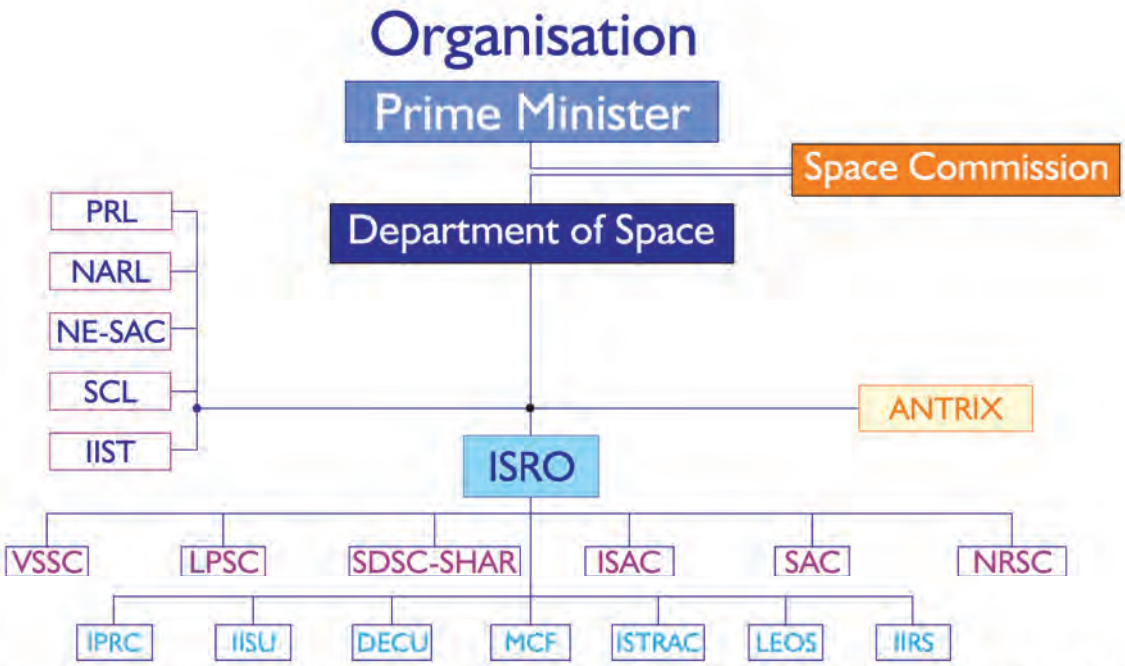
ALUVA
- Ammonium Perchlorate Experimental Plant

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

HASSAN
- Master Control Facility

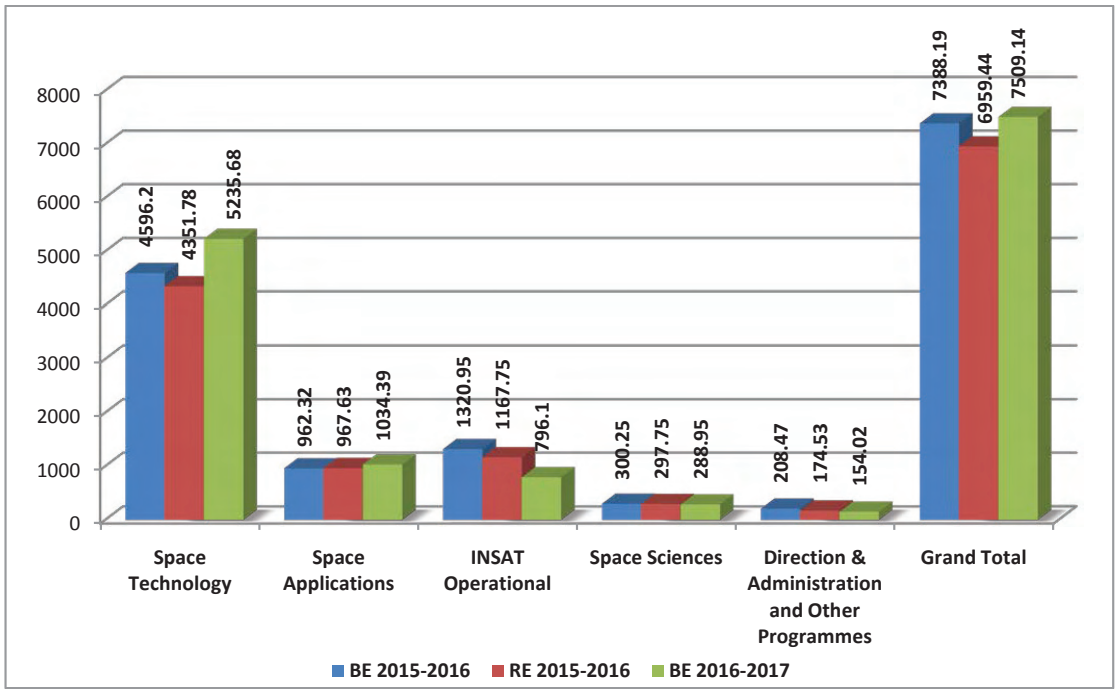
BYALALU
- Indian Deep Space Network
- Indian Space Science Data Centre
- ISRO Navigation Centre

MAHENDRAGIRI
- ISRO Propulsion Complex



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:** Satish 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

Budget Profile (Rs. in Crores)



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.

MST Radar facility at NARL

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.

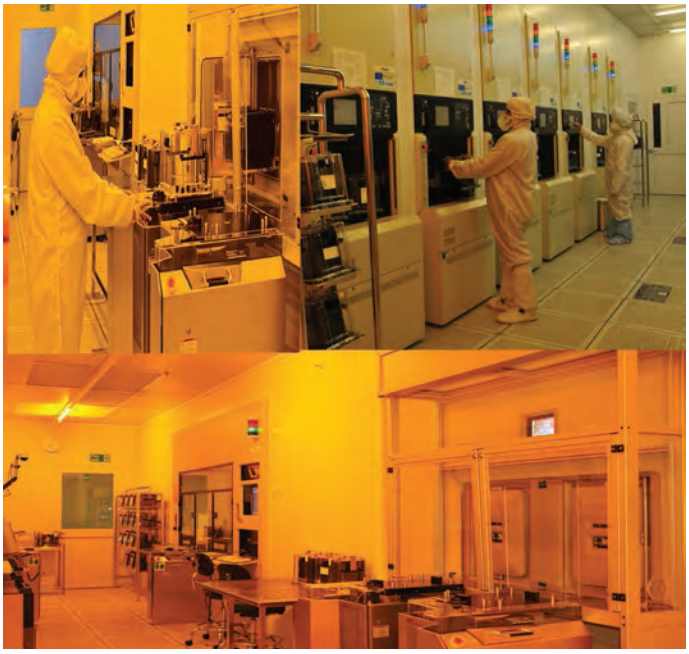
Antrix Corporation Limited

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 continuing its efforts to create a strong microelectronics base in the country and enhancing capabilities in VLSI domain. Activities at SCL are focused on the Design, Development, Fabrication, Assembly, Testing and Reliability Assurance of CMOS and MEMS Devices.



Two views of SCL

Upgradation of Wafer Fabrication Lab has been completed and 8" CMOS Wafer Fabrication Line is geared-up for production activities. Three production lots have been processed with ASICs/IPs/Test Chips designed in-house. In these lots, 28 designs have been fabricated and tested successfully. These chips include some complex ASICs, one of them being Vikram Processor for Launch Vehicles. SCL is also engaged in Hi-Rel Board Fabrication, Component Screening for ISRO units, Indigenisation of Electronics Boards for Indian Air Force and Production of Radiosonde for Atmospheric Studies.

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.

Observatory at IIST with an 8-inch Celestron telescope

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, 99 students of 2011 batch of B. Tech graduates were placed as Scientists/Engineers at various centres of ISRO in 2015.

The IIST has faculty strength of 93 spread over seven departments. 138 undergraduate students, 90 post graduate students and 26 research scholars were admitted for the academic year 2015-16.

Communication and Navigation Satellite System

Communication Satellites

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 commercial communication satellites like INSAT-3A, INSAT-3C, INSAT-4A, INSAT-4B, INSAT-4CR, GSAT-6, GSAT-8, GSAT-10, GSAT-12, GSAT-14, GSAT-16 and GSAT-15. 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 on 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 with footprint covering Indian mainland and C-band transponders with expanded coverage encompassing Indian geographical boundary and area beyond India.

INSAT-4B

Configured with payloads similar 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 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 in September 2007 from Sriharikota. 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.

GEOSAT Series

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 commercial transponders 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 commercial 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 spacecraft was 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 satellites commercial 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 was aimed at further augmenting communication services in the country.

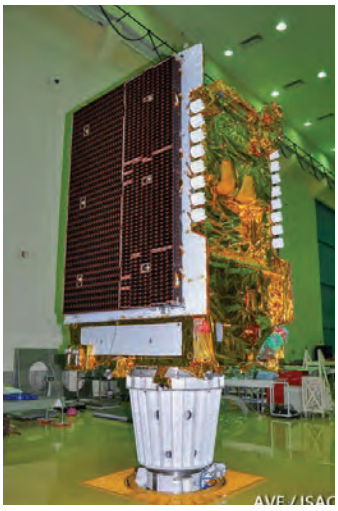
GSAT-6

GSAT-6 is a high power S-band communication satellite that was launched successfully onboard GSLV-D6 mission on August 27, 2015. The satellite is configured around I-2K bus with a lift-off mass of 2117 kg. It is configured with CxS and SxC transponders. This spacecraft has successfully demonstrated and paved the way for the use of new technologies including large unfurlable antenna in satellites, hand held ground terminals and network management techniques that could be useful in future satellite based mobile communication applications.

In-Orbit Deployed View

GSAT-15

GSAT-15 is a communication satellite configured around I-3K bus with 3164 kg lift-off mass and 6200 W power generation capacity. It is designed for a mission life of more than 12 years. The spacecraft's commercial payload includes Ku-Band transponders and a two channel GAGAN payload, which will act as in-orbit back up to the already operational GAGAN payloads on GSAT-8 and GSAT-10. The satellite was launched by Ariane-5 from Kourou, French Guyana on November 11, 2015.



GSAT-15 Satellite

SATELLITES UNDER DEVELOPMENT

GSAT-6A

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

GSAT-9

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

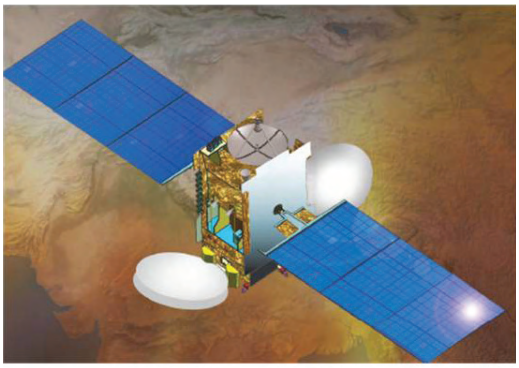
The subsystems of the satellite are in advance stage of realisation and integration activities are in progress. The satellite is planned to be launched onboard GSLV-Mk II.

GSAT-11

GSAT-11 is an advanced communication satellite employing a new class of bus weighing 4000-6000 Kg. The commercial 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. The satellite is contemplated to be ready by end 2016.

GSAT-18

GSAT-18 is a communication satellite configured around I-3K extended bus with a lift off mass of about 3425 kg and 6 KW power generation capacity. The satellite's commercial transponders include Ku, Normal C and Extended C band transponders. The satellite is in advance stage of realisation and is likely to be launched during Mid 2016 onboard Ariane-5 launch vehicle.



GSAT-18

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. Standard subsystem fabrication activities are in progress and the satellite is expected to be ready for the shipment in 2016-17 timeframe for launch on-board Ariane-5 launch vehicle.

GSAT-19

GSAT-19 is planned as the payload for the first developmental flight of the indigenous GSLV-Mk III-D1 Launcher. The satellite is planned to carry Ka and Ku band payload along with a Geostationary Radiation Spectrometer (GRASP) payload to monitor and study the nature of the charged particles and influence of space radiation on spacecraft and electronic components.

GSAT-19 satellite will employ advanced spacecraft technologies including bus subsystem experiments in Electrical propulsion System, indigenous Li ion battery, indigenous Bus bars for power distribution, etc.

Satellite Navigation Programme

Satellite Navigation (SATNAV) has been identified as one of the important programmes of the department that includes activities such as GAGAN and Indian Regional Navigation Satellite System (IRNSS).

GPS Aided Geo Augmented Navigation (GAGAN)

GAGAN is the first satellite based augmentation navigation system over Indian region. Its signals augment those of GPS in order to provide users with more precise positioning and reliability of the GPS signals in terms of 'integrity parameters'. GAGAN is a joint project of Indian Space Research Organisation and Airport Authority 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 provide seamless navigation across regional boundaries.

The GAGAN architecture consists of 3 segments namely, ground segment, space segment and user segment. The ground segment consists of 15 Indian Reference Stations (INRES), 2 Indian Master Control Centres (INMCC), 3 Indian Land Uplink Stations (INLUS).

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 is flown on GSAT-15. The certification will enable the aircraft fitted with SBAS equipment to use GAGAN signal in space for En-Route Navigation and Non-Precision Approaches without vertical guidance over Indian air space. 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.

The Directorate General of Civil Aviation (DGCA), India 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. An MOU is signed between ISRO-AAI in January 2014 for a period of 7 years. The GAGAN System was certified to APV1/1.5 level in April 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.

ISRO Navigation Centre (NIC) at Byalalu, the nerve centre of IRNSS Ground 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 satellites employ the standard I-1K structure with a power handling capability of around 1660W and a lift-off mass of around 1425 Kg and are designed for a mission life of around 10 years. All satellites in the constellation have identical configuration. The whole IRNSS constellation is planned to be realised by 2016.

IRNSS-1A

The first of the seven satellites of the IRNSS Constellation, IRNSS-1A was successfully launched on-board PSLV-C22 on July 01, 2013.

IRNSS-1B

The satellite was launched successfully on April 4, 2014 by PSLV-C24. IRNSS-1B is functioning satisfactorily from its designated geosynchronous orbital position.

IRNSS-1C

The satellite was successfully launched on-board PSLV-C26 on October 16, 2014. satellite performance is satisfactory.

IRNSS-1D

The satellite was launched on-board PSLV-C27 on March 28, 2015.The performance of the satellite is nominal.

IRNSS-1E

The satellite was successfully launched on January 20, 2016 by PSLV-C31.

IRNSS-1E propellant filling operation in progress

IRNSS-1F and IRNSS-1G

The satellites are in various stages of realisation and are likely to be launched by March 2016.

Ground Segment: Ground Segment is responsible for the maintenance and operation of the IRNSS constellation. The Ground segment comprises of the following:

Ground Segment	Status
IRNSS Navigation Centre (INC), Byalalu	Navigation s/w fully operational at INC. Automated generation of primary and secondary navigation parameters.
IRNSS Range and Integrity Monitoring Stations (IRIMS)	13 IRIMS stations established and performing one-way ranging.
IRNSS CDMA Ranging Stations (IRCDR)	Two way CDMA ranging being carried out from all four IRCDR stations.
IRNSS Network Timing Facility (IRNWT)	Timescales are maintained within 20 ns (2$\bar{\delta}$) with respect to UTC
IRNSS Spacecraft Control Facility (IRSCF)	Support for Launch, LEOP, IOT and operations. One 11m FMA and five 7.2m FCA commissioned for operations at Hassan. One 11m FMA and four 7.2m FCA established at Bhopal.
IRNSS Data Communication Network (IRDCN)	Terracom links with all operational ground stations to INC.
Laser Ranging Support from ILRS	Laser ranging successfully performed from 10 ILRS stations across Asia, Europe and Australia, whenever available.

Earth Observation System

Operational remote sensing services were initiated with the launch and commissioning of IRS-1A, the first operational Indian Remote Sensing (IRS) Satellite, in the year 1988. Currently, the remote sensing satellites that are operational in orbit are: Resourcesat-2, Cartosat-1, Cartosat-2, RISAT-1, RISAT-2, Oceansat-2, Megha-Tropiques and SARAL. Though Cartosat-1, Cartosat-2, RISAT-2 and Oceansat-2 satellites have completed their design 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 and facilitate 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 provide high quality images with 2.5 m spatial resolution with a swath of 30 km. The cameras are mounted with a tilt of +26 degree and -5 degree along track with respect to nadir that provide 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 more than 10 years in orbit and is currently providing limited imaging services.

Cartosat-2, launched on January 10, 2007 onboard PSLV-C7, carried a single panchromatic camera with the capability to provide better than 1 m spatial resolution imagery with 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 degree to facilitate frequent imaging of any specific area. The satellite has completed 9 years in orbit and is still providing imaging services.

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 of 12:00 Hrs. Oceansat-2 carried three sensors onboard, namely, Ocean Colour Monitor (OCM), Ku-band pencil beam Scatterometer and a Radio Occultation Sounder for Atmospheric studies (ROSA). The Ku-band pencil beam scatterometer has provided wind vector data over ocean surface. The payload has served the user community for about 4 ¾ years. The eight band OCM data is used to generate Local Area Coverage (LAC) product of 360 m resolution and Global Area Coverage (GAC) product of 1 km resolution. ROSA Payload, designed and developed by Italy, was flown in Oceansat-2 to study temperature and humidity profile of the atmosphere. Both OCM and ROSA payloads are still providing data services.

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 6¾ years in orbit and still providing imaging services.

Resourcesat-2 a follow on mission to Resourcesat-1, provides 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 & LISS-4 and 10 bits to 12 bits for AWiFS. The satellite has completed nearly 5 years in orbit and providing imaging services for resource monitoring applications.

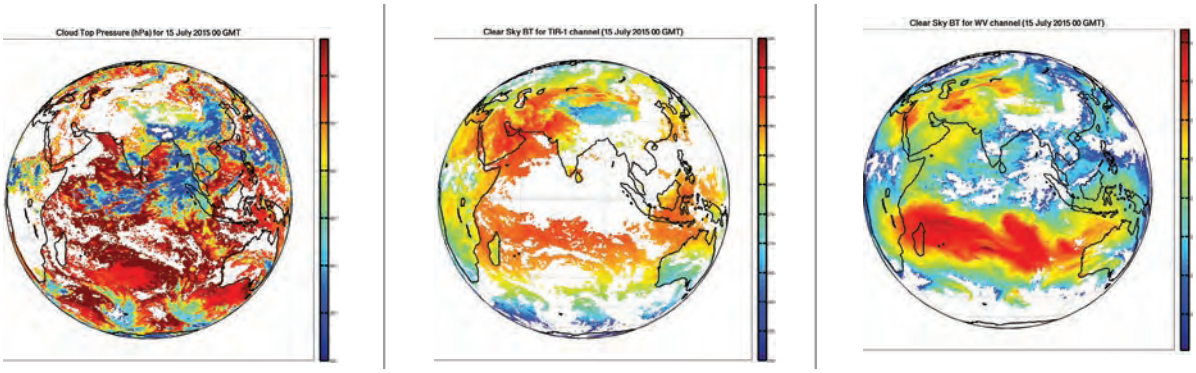
Megha-Tropiques (Megha means cloud in Sanskrit and Tropiques means tropics in French) is a joint ISRO-CNES satellite mission for better understanding of the life cycle of convective systems and their role in the associated energy moisture budget in the tropical regions. The satellite was launched by PSLV-C18 on October 12, 2011 into an 867 km orbit at an inclination of 20 degree with respect to the equatorial plane. The satellite carried four scientific instruments, namely - (i) Microwave Analysis and Detection of Rain and Atmospheric Structures (MADRAS) (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. 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.

Radar Imaging Satellite-1 (RISAT-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 carried 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. RISAT-1 data is being extensively used for applications in the areas of agriculture, particularly for paddy monitoring in kharif season and disaster management support, especially during natural disasters like floods and cyclones.

Satellite with ARGOS and ALTIKA (SARAL) is a joint ISRO-CNES satellite mission to study the sea surface height. It 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 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. SARAL ARGOS Data Collection System contributes to 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.

Meteorological Satellites in Service

INSAT-3D is an advanced weather satellite, was launched on July 26, 2013 and positioned at the orbital slot of 82 deg East longitude in the geostationary orbit. It has added 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 6 Channel Imager, 19 Channel Sounder, Data Relay Transponder (DRT) and Satellite Aided Search and Rescue (SAS & R) Transponder.



(a) Cloud top pressure, (b) clear sky BT for TIR-1 channel and, (c) clear sky BT for WV channel, generated from INSAT-3D imager observations (15 July, 2015)

INSAT-3A, which was launched on April 10, 2003, carries a Very High Resolution Radiometer (VHRR) and Charge Coupled Device (CCD) camera to provide meteorological services. The satellite has completed nearly 13 years of life in orbit.

KALPANA-1 is an exclusive meteorological satellite launched by PSLV-C4 on September 12, 2002. It carries VHRR and DRT payloads to provide meteorological services. The satellite has completed nearly 13 years of life in orbit and continues to provide satisfactory imaging services.

FUTURE EARTH OBSERVATION MISSIONS

India's future Earth Observation (EO) 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-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-2E: Cartosat-2E mission is a follow on mission in the Cartosat series with the primary mission objective of providing high resolution scene specific spot imagery. It will carry panchromatic and multispectral cameras. The lift-off mass of the satellite is around 710 kg with a power generation capacity of 970 watts and a mission life of 5 years. The satellite is planned to be launched by PSLV into a nominal altitude of 500 km. The spacecraft is capable of along track and across track steering, nominally up to ± 26^0 providing spot images in continuous imaging mode. CARTOSAT-2E is a follow on satellite in the Cartographic series.

Resourcesat-2A: It is a follow on mission to Resourcesat-2 and intended to provide data continuity 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 power generation capacity of 1250 W and a mission life of 5 years. The satellite will be placed in SSP orbit of 817 km altitude with an inclination of 98.69 deg. The satellite is scheduled for launch during mid 2016 onboard PSLV.

SCATSAT-1: It is a continuity mission for Oceansat-2 Scatterometer to provide wind vector data products for weather forecasting, cyclone detection and tracking services to the users. The satellite carries Ku-band scatterometer similar to the one flown onboard Oceansat-2. The spacecraft is built around standard IMS-2 Bus and the mass of the spacecraft is 360 kg. The spacecraft will be put in SSP orbit of 720 km altitude with an inclination of 98.27 deg by PSLV. The mission life of the satellite is 5 years. The satellite is scheduled for launch during mid 2016 onboard PSLV.

Cartosat-3: It is an advanced agile satellite to obtain panchromatic and multispectral imagery with an operational life of 5 years. Many new technologies/elements are being developed like highly agile structural platform, payload platform, data handling and transmission systems, advanced onboard computer and new power electronics, dual gimbal antenna, etc. The spacecraft readiness is expected by first quarter of 2018.

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) used. The satellite platform is a modified version of I-1K bus, with a power handling capability of around 2037 W during Equinox with a lift-off mass of 2100 kg. 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 the large areas of the country, under cloud free conditions, at frequent intervals. This means, selected sector-wise image every 5 minutes and entire Indian landmass image every 30 minutes at 50 m spatial resolution. The potential applications include quick monitoring of disasters, natural hazards and calamities, episodic events and any short term events. The readiness of the satellite is planned during first quarter of 2017.

INSAT-3DR: It is a follow-on meteorological satellite mission to INSAT-3D, planned to be positioned at 74 deg East longitude in the geostationary orbit. It carries two meteorological payloads, namely, a 6 channel Imager and 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. The spacecraft readiness is expected by June 2016.

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 (BL1, BL2 & BL3, BL4), Lucknow (I & II), Mauritius (I & II), Sriharikota (SHAR I & II), Port Blair, Thiruvananthapuram, Brunei, Biak-1 & 2 (Indonesia) and the Deep Space Network Stations, namely, DSN-32 and DSN-18. The Mission Operations Complex located at Bengaluru carries out round-the-clock mission operations of all remote sensing and science satellites.

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 ground station at Shadnagar receives data from Indian Remote-Sensing Stations, namely, Resourcesat-2, Cartosat-1, Cartosat-2, Oceansat-2A, RISAT-1 and SARAL through 7.5 mtr S/X band antenna terminals with a station efficiency better than 99%. Besides, data from different foreign satellites AQUA, TERRA, LANDSAT-7, S-NPP, NOAA-19 and METOP-A/B satellites are also being received, processed and archived on SAN storage. Presently, data acquired at SVALBARD ground station is also being transferred to NRSC, Shadnagar for Level-0 processing, product generation, archival and dissemination. About 10935 satellite passes were acquired and archived during April-October 2015.

International Ground Stations (IGS): NRSC has established 7.5 mtr S/X Antenna systems and upgrades at various International Ground Stations for different user based on agreements by ANTRIX. IGS at Euromap, Germany was augmented for Resourcesat-2 data archival and processing. Towards serving RISAT-1 data to global clients from Kongsberg Satellite Services (KSAT), data reception and processing systems are operationalised at KSAT, Norway. .

Satellite Data Processing: NRSC Data centre (NDC) facilitates dissemination of remote sensing data from both IRS and a few foreign satellites. Data is disseminated on order or as free downloads (specific data products) through Bhuvan and Oceansat-2 web portals. During April-October 2015 period, 83,215 data products were disseminated of which 11,910 were through data supply chain and 71,305 as free web downloads. In addition to the above, 1,53,58,398 sq. km of high resolution IRS data and 10,78,294 sq. km of high resolution foreign satellite data was provided to the users.

KSAT Data Reception Station Facility

Web downloads: LISS-3, 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. During April-October 2015 about 1,05,492 products were downloaded by users using the facility.

IGS Downlink: IRS data downlinks were enabled for 7 ground stations (3 stations for Cartosat-1, 2 stations for Resourcesat-2, 2 stations for Oceansat-2 including INCOIS, Mauritius) and cumulative duration of data download from all the stations is 230 h 50 min. KSAT was also operationalised and it provides Near Real Time downlinks.

CartoDEM Generation: CartoDEM v 3.0 was generated for SAARC countries (India, Bangladesh, Nepal, Bhutan, Pakistan and Afghanistan) and 30 m DEM was made available on Bhuvan portal for free download. DEM is seamless across countries. Generation of country wise CartoDEM for Egypt was completed. Generation for Gulf countries including Iran, Yemen, Saudi Arabia and UAE is in progress.

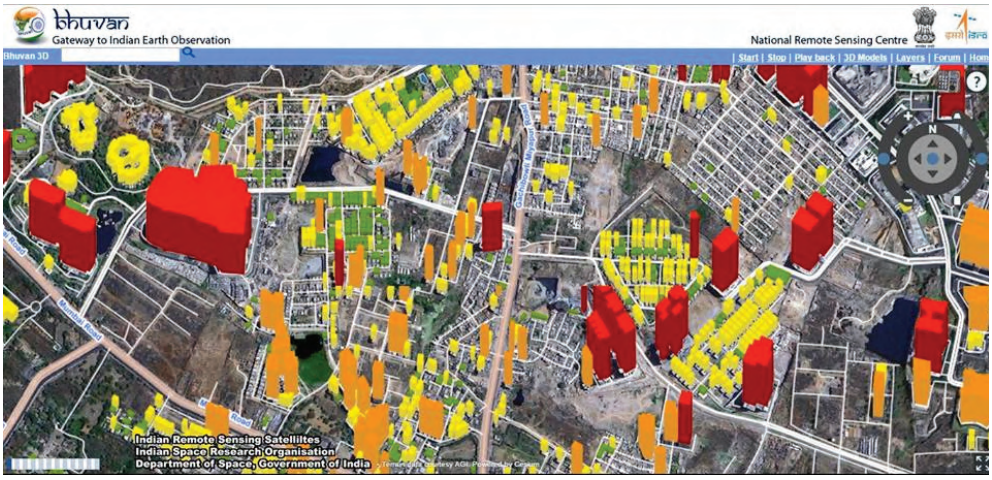
Bhutan Delegation Visit to IMGEOS: In connection with establishment of a new Government Data Centre at Department of Information Technology and Telecom, a delegation from Ministry of Information and Communication of Royal Government of Bhutan visited NRSC Shadnagar Complex on June 5, 2015 to understand the technical, operational, financial, legal and policy issues before design and implementation of their Data Centre.

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 services several users for their remote sensing application needs. The portal has witnessed about 9.5 lakh unique visitors in the last six 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).

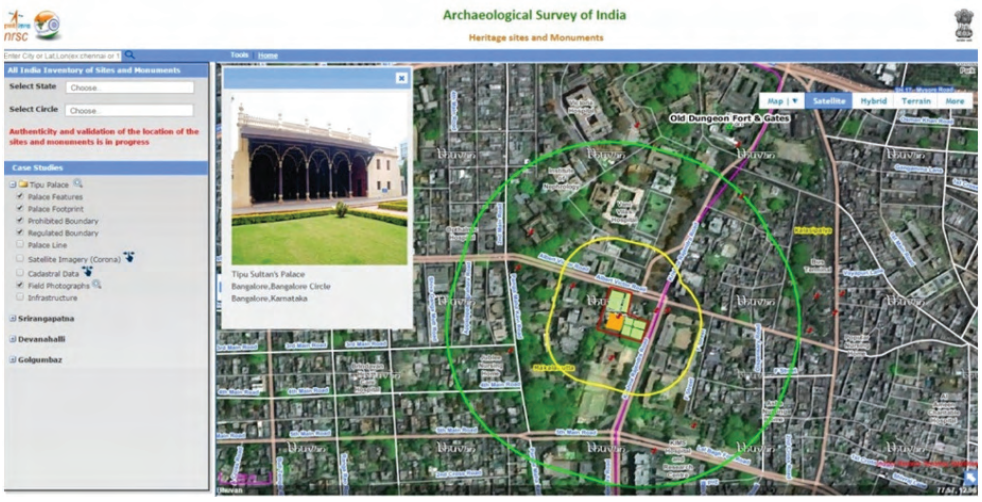
During 2015, Bhuvan had more than 25 new releases of applications and services. Dr Jitendra Singh, Minister of State (PMO), released new services of Bhuvan on August 12, 2015 on the eve of the

sixth anniversary of Bhuvan. The new application services include - 1m images (over 300 cities of the country), applications for Ministry of Forests, Environment & Climate Change, National Highway Authority of India (NHAI) Toll Information System, Andhra Pradesh Housing Corporation, Islands Information System, GIS databases of North East Region (NER), Cultural heritage sites of the country, Virtual 3D city models, Horticulture area mapping, Bhujal database and visualisation, GIS for Schools, GAIL pipeline monitoring system, etc.

As part of new releases, Bhuvan-Ganga application was released by Sushri Uma Bharati, Union Minister for Ministry of Water Resources, River Development and Ganga Rejuvenation. NOEDA was also upgraded with new products like Global Wind products, Cartosat DEM V 2.0 and Version 3.0. Further, Bhuvan G-Governance Pragati portal was identified to monitor the progress of various national projects by the Prime Minister's Office. Bhuvan satellite data is made available as OGC compliant web service for public access towards building map centric applications. As part of capacity building, Bhuvan is conducting bi-monthly training programme to the Central and State Government employees on Bhuvan Services.



3D View of Built-up Area - Hyderabad City



Monuments - Tipu Palace

Release of new application services and user handbooks on the sixth anniversary of Bhuvan GeoPortal of ISRO - August 12, 2015

MOSDAC Services:

MOSDAC is the web portal for archiving, processing and disseminating the meteorological and oceanographic data of ISRO's satellite missions and ground based systems. The data products are disseminated through web based services for the needs of scientific/research community in the country. A web application for disseminating Community Atmosphere Model (CAM) monsoon prediction for 2015 has been developed and made operational on MOSDAC. SCORPIO (Satellite based Cyclone Observation for Real-time Prediction over Indian Ocean) site was updated in near real time for the ASHOBAA cyclone in the Arabian Sea. Satellite based nowcasting method developed for heavy rainfall alerts over India is operational through MOSDAC web portal since the onset of monsoon-2015. Water level over 4 major lakes, namely, Sambhar, Upper Mansarovar, and Rakshatal were estimated using satellite altimetry and the results were released on MOSDAC. The heat wave condition monitoring from the INSAT-3D satellite derived Land Surface Temperature (LST) products were made operational at MOSDAC.

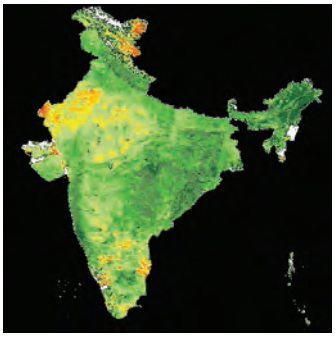
NRDB Services: Natural Resources Database (NRDB) is a systematic archive of thematic layers generated under various National Natural Resources Management System (NNRMS) programmes, which include wasteland, Natural Resource Census (NRC), wetland, desertification, National GIS, etc. The NRDB layers are made available to users as Web Map Service (WMS). The metadata of the NRDB content has been shared with National Spatial Data Infrastructure (NSDI).

Special/Value Added/Information Products:

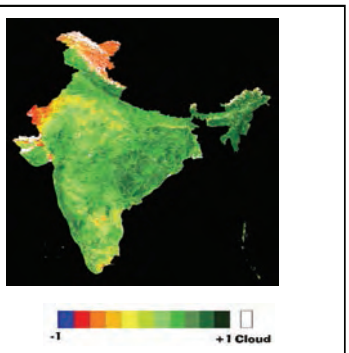
A major thrust has been given to the development Special/ Value added / Information products as per the User Requirements. Some of the important products are described hereunder:

AWiFS Normalised Difference Vegetation Index (NDVI) products: Four cycles of NDVI products were generated from ortho-rectified AWiFS data for Mahalanobis National Crop Forecast Centre (MNCFC), Ministry of Agriculture for assessing Agricultural drought. As requested by the user, current and previous year corresponding cycles NDVI is supplied as a pair in near Real time (Within 2 days of completion of the cycle).

NDVI 8-12 Oct-2014



NDVI 8-12 Oct 2015



Maximum Value Composite (MVC) for Oct 2015

Delineation of coral reeves using RISAT-1 data: Coastal environments, namely, estuarine regions and different types of coral reefs, namely, fringing reefs, barrier reefs and atolls were studied using RISAT-1 data. Products were validated with coral ATLAS generated by SAC using optical satellite data.

Vegetation Health Index (VHI) product from OCM-2: Vegetation Health Index (VHI) product was designed to monitor and warn drought over Indian sub-continent. Fortnightly VHI products at 5 km resolution are being generated and hosted on Bhuvan.

Filtered NDVI products from Oceansat-2 OCM: Filtered NDVI products were developed using modified FASIR (Fourier Adjusted + Spline fit) method to estimate the pixels contaminated by cloud in NDVI time series. Estimation accuracy was validated with MODIS data sets and found better than 90%. NDVI fortnight products, which could not be generated due to persistent cloud throughout 15 days from 2012, were also generated using this method and populated on Bhuvan.

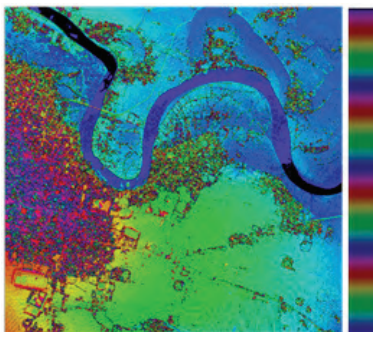
Generation of 15 day water bodies and snow cover area information: Resourcesat-1 AWiFS (56 m) and RISAT-1 MRS (18 m) data were used for the generation of 15 day water bodies information (56 m) and water bodies fraction information at 3'x3' grid at fortnight interval over India and hosted on Bhuvan portal. AWiFS (56 m) data was used for the generation of 15 day snow cover area information at 3'x 3' grid at fortnight interval over Himalayan region and hosted on Bhuvan.

AERIAL SERVICES AND DIGITAL MAPPING AREA

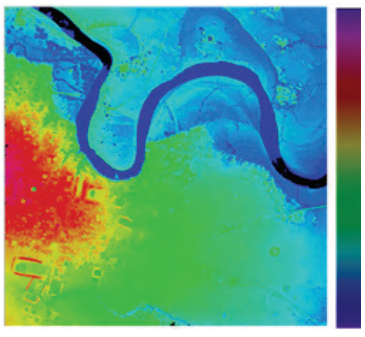
The Aerial Services and Digital Mapping (AS&DM) of NRSC/ISRO is a unique facility that has end-to-end capability and state-of-the-art infrastructure in the domain of aerial remote sensing that comprises acquisition of high resolution data (upto 5 cm GSD), photogrammetric processing, generation of high resolution digital elevation model with vertical accuracy of 25 cm and Large Scale Mapping. NRSC has two SKA-B200 aerial survey aircraft (VT-EQK and VT-EBB) with provision to install airborne sensors like Large Format Digital Cameras (LFDC) or LiDAR flown in conjunction with Medium Format Digital Camera (MFDC). The facility also flies C-band SAR sensor (5.3 Ghz, 60 km swath) developed by SAC/ISRO. Till October 2015, aircraft utilisation was to the tune 104 hours. The data acquisition tasks were completed for Disaster Management Support Programme, ISRO-GBP studies, GCPL enrichment, Topographic Mapping, sensor validation, etc.

LiDAR-DC Surveys for Disaster Management Support Programme (DMSP): As part of DMSP, close contour flood plain mapping is being carried out using airborne LiDAR/LFDC data for use in flood inundation modeling and flood depth assessment.

During the year, geodatabase generation was completed for Mahanadi river basin covering an extent of 8,177 sq. km. Sample Digital Elevation Model (DEM) and corresponding orthoimages for part of the area near Balasore are shown in the following figures.



Digital Surface Model
(Near Balasore)



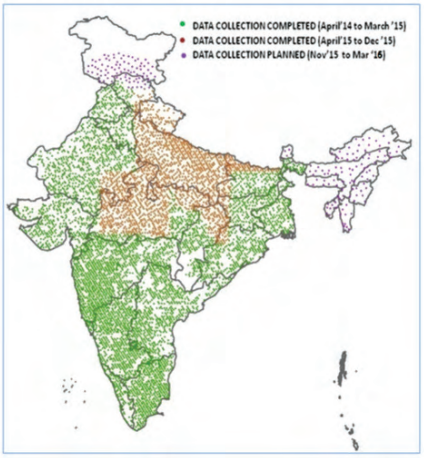
Digital Terrain Model
(Near Balasore)

Corresponding Orthoimage
overlaid with Map

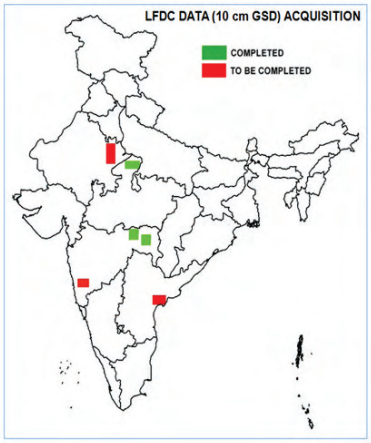
Aerial Surveys and Topographic Mapping over Indian Coast: Towards the establishment of Tsunami Warning Centre, geospatial database of Indian coast is being generated for Indian National

Centre for Ocean Information Services (INCOIS), Ministry of Earth Sciences. The deliverables include orthophotos with 50 cm GSD, DEM and spatial database in 1:5,000 scale with 1 m contour interval. Under phase-II, airborne LiDAR data acquisition was taken up over the West Coast (Cochin-Gujarat; 10,026 Sq km) during March 2015. Flying is completed for part of the study area (3,412 sq km) and data pre-processing is completed.

GCPL Phase-III: The project was taken up to densify the Ground Control Points (GCPs) for geometric location accuracy of future Cartosat mission requirements as well as to improve the planimetric accuracy of current missions. Airborne LFDC derived data will be used to generate high precision ortho rectified data for six test sites (Nagpur, Savner, Ranchi, Alwar, Bhind and Pune) for calibrating the satellite platform. The total task includes 8,500 GCPs, including 1,100 Pre-Signal Points (PSPs), with accuracy better than 50 cm and their collection in two modes - using GAGAN SBAS/ Commercial DGPS services in first mode and PSPs with monumentation in the second mode.



GCP Data Collection Status



Aerial photography (LFDC)

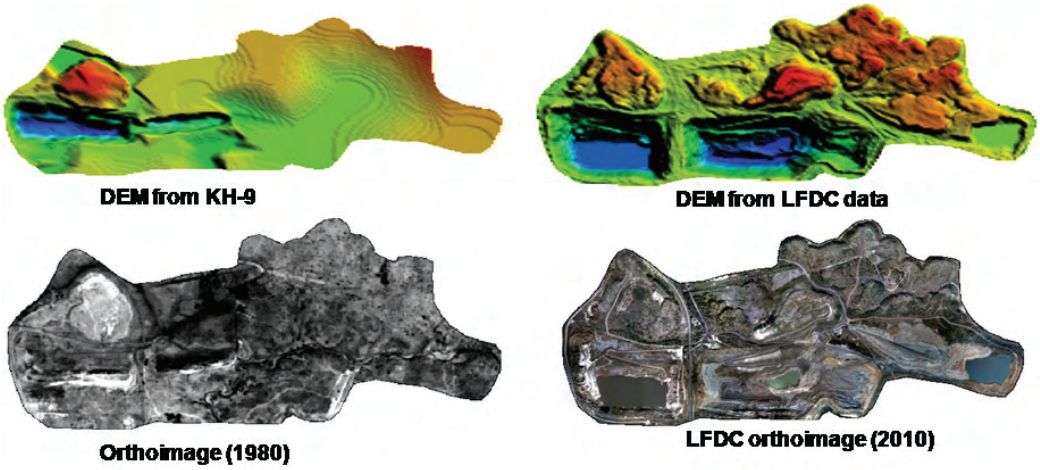
Sample Pre-signal point (PSP) as seen on World view-1 image

During the current year, a total of 4570 GCPs and 620 PSPs are planned covering South India, North India, J&K and NE regions. So far, GCP collection and database generation was completed for 4060 GCPs and 580 PSPs covering South India and North India. GCP data collection for 550 points covering J&K and NE regions is in progress. Also, airborne LFDC data was acquired over Bhind area in Madhya

Pradesh with 10 cm GSD for calibration. Aerotriangulation of data and Digital Surface Model (DSM) generation are completed.

Establishment of Digital Archival Facility: The aerial data and products acquired since its inception in NRSC (1976) are being archived in digital format as a centralised repository. A high precision photogrammetric scanner and a unified storage System (NAS & SAN) with 100 TB usable disk space were commissioned for the purpose. Photogrammetric scanning of aerial negative films was completed for about 174,000 out of 249,000 photos pertaining to various projects/tasks.

Photogrammetric processing of historical data to study changes in land dynamics: Hexagon (KH9) is a photo reconnaissance satellite program launched and operated by United States during 1970-1980, which acquired image data in high resolution over several parts of the world. This data was declassified for the period 1995 and 2002 for civilian use. The products like DEM and orthoimage generated from this program (Hexagon- KH9) will be useful for various studies on change detection, climate studies, volumetric analysis, etc. For Korba (Chhatisgarh) mining site, volume computation is done by generating difference DSM from KH-9 and airborne digital data.



Space Applications

Satellite Communication Applications

A fleet of commercial communication satellites, namely, INSAT-3A, INSAT-3C, INSAT-4A, INSAT-4B, INSAT-4CR, GSAT-6, GSAT-8, GSAT-10, GSAT-12, GSAT-14, GSAT-15 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/DOS has supported programmes like Telemedicine, Tele-education 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 97 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. DOS has made available the required transponders through INSAT/GSAT satellites and through leased capacity to cater to the needs of television service.

Doordarshan is presently operating 34 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. The details of satellite channels operated by Doordarshan are shown below:

Table: 34 Satellite channels of Doordarshan

All India Channels (6)	DD National, DD News, DD Sports, DD Bharati, DD Urdu and DD Kisan
Regional Channels (16)	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
State Networks (11)	Himachal Pradesh, Jharkhand, Chhatisgarh, Haryana, Uttarakhand, Tripura, Mizoram, Meghalaya, Manipur, Arunachal Pradesh and Nagaland
International Channel (1)	DD India

For terrestrial transmission, 1416 transmitters of varying power, installed throughout length and breadth of the country are in operation. Break up of these transmitters is as under:

Service	HPTs	LPTs	VLPTs	Transposers	Total
DD1 Transmitters	138	733	355	18	1244
DD News Transmitters	73	78	17		168
Other Transmitters (digital)	4				4

In terrestrial mode, DD1 (National) Channel coverage is estimated to be available to about 92% population of the country. Signals to these transmitters are beamed through satellites. In satellite mode, the signals are accessible to 100% population in 100% geographical area in the country.

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 antennas all over India.

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 09. Capacity of DD's DTH platform recently augmented to 112 channels. Presently, 64 TV channels are being uplinked on DTH platform. DD has plans to augment the capacity to 250 channels during 12th Five Year Plan.

Apart from Doordharshan, the public broadcaster, 6 private DTH operators are providing service in India. It is estimated that (TRAI Report - August 2015) there are about 76.05 Million registered DTH subscribers and 41.15 active DTH subscribers and about 829 TV channels are beamed in India as on March 31, 2015.

About 84 Ku-band transponders from both Indian and Leased satellites are catering to DTH television services. Apart from DTH, about 30 C-band transponders are being used for supporting Television uplink. Doordarshan alone is using a total of 19¼ Transponders (12.25 C-Band & 7 Ku-Band) of 36 MHz each on INSAT System.

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 16 C-band and 18 Ku-band Digital Outdoor-Broadcast Digital Satellite News Gathering terminals operating through INSAT satellites. About 11 transponders are used for DSNG services of various operators.

Radio Networking

Radio Networking (RN) through INSAT provides a reliable high-fidelity programme channels for National as well as Regional Networking. Around 414 All India Radio (AIR) stations and about 600 radio transmitters 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 connectivity in the mainland.

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.

About 1400 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 2.40 Lakh 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 around 20,000 IPSTAR VSATs as well as one by two voice channel connectivity to remote areas through around 6,000 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

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 was sent to specialist doctors, who studied and provided diagnosis and treatment during videoconference with the patient's end. During the pilot phase, more than 25,000 patients were provided with Tele-consultation and treatment.

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 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, Orissa, Andhra Pradesh, Maharashtra, Jharkhand, Rajasthan, etc., are also covered under Telemedicine programme.

Presently, the Telemedicine network of ISRO covers around 380 nodes including around 60 speciality and 18 mobiles, installed across the country, including Andaman & Nicobar, Lakshadweep, Jammu & Kashmir and North-East States.

On request from the Ministry of Health & Family Welfare (MoHFW), seven new telemedicine nodes at Chardhams, Kailash Mansarovar, Amarnath & Ayyappa pilgrimage places are being set up. Additionally, 8 new telemedicine nodes covering one district each in Himachal Pradesh, Odisha, Arunachal Pradesh and Meghalaya are planned for set up in this financial year. On request from Ministry of Labour & Employment, four telemedicine nodes at ESI hospitals are also planned before March 31, 2016.

Continuing Medical Education (CME) programmes are conducted on monthly basis from DECU studio wherein medical experts/doctors share their knowledge and experiences and interact with the connected remote hospitals. Eight CMEs were conducted by Nov 2015 and about 1500 medical professionals participated in these CMEs. Five more are CMEs are planned during the year by March 31, 2016.

As an on-going/continuous activity, tech support is provided to interested hospitals for conducting Continuing Medical Education (CME); operations of Hub are monitored and continuous follow-up is done with all users for optimum utilisation

Tele-education

'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 conferencing, computer conferencing, web-based instructions, 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 of two types of terminals, namely, Satellite Interactive Terminals (SITs) and Receive Only Terminals (ROTs). In due course of time 83 networks were implemented, which had around 5000 SITs and 55000 Receive Only Terminals (ROTs), covering 26 States & 03 Union Territories. At present, around 70 networks are operational.

During the year the network of National Council of Science Museums (NCSM) was migrated to GSAT-12. The tele-education network of Abdul Nazir Saab State Institute of Rural Development (ANSSIRD), Mysore is planned for migration to GSAT-12, during Dec 2015. Technical support has been extended to States for operations and sustenance of the tele-education networks. Many states have expressed their keen interest to upgrade their networks and DOS is extending necessary technical assistance towards upgradation and expansion.

Mobile Satellite Services

S-band Mobile Satellite Service (S-MSS) is being provided using INSAT-3C and GSAT-6 satellites.

MSS Services through INSAT-3C

Two classes of services, namely, Type-C and Type-D are identified for MSS using INSAT-3C. The MSS Service provides the communication to the portable and moving devises.

- ### INSAT Reporting (Type-C) Service

  It is a low bit rate one-way reporting service using shared channels with portable and hand-held terminals. 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. 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. Continuity to INSAT-3C MSS services is planned through GSAT-17 satellite which is planned for launch during end 2016.

MSS Services through GSAT-6

GSAT-6 launched on Aug 27, 2015 is a multi-beam S-band satellite supporting four types of terminals (Reporting Terminal, Broadcast Receiver, Satellite Mobile Radio & Portable Multimedia Terminal). The terminals have been indigenously developed and tested. The functioning of all the four types of terminals was successfully demonstrated to Space Commission members and subsequently to the government users.

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. IMDPS is capable to receive and process the data of all three existing geostationary meteorological satellites. The performance of the system during the current year has been maintained to the level of 98% operation efficiency (24x365 bases). The output generated by the system is used for efficient and successful forecasting the major weather events, particularly major cyclones in 2015.

The products derived from the satellite data include: Cloud images in the Visible, Shortwave 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 and Humidity profiles, Total ozone, Total/Layer Precipitable Water Vapour and Stability Indices. All these images and products are disseminated on a real time 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 like fog and thunderstorms.

Two new additional products generation for Land Surface Temperature (LST) and insolation from both KALPANA-I and INSAT-3D have been started from March, 2015 on half hourly/daily/weekly and monthly basis. The validation of atmospheric Motion Vector (wind products), sea surface temperature, outgoing long wave radiation (OLR) vertical Profile of temperature and humidity has been carried out for the period of July, 2014 to October, 2015 and the feedback are used for fine tuning of algorithm of these products.

A joint calibration/validation (Cal/Val) campaign (April 28, 2015 to May 03, 2015) was carried out successfully at Runn of Kutch, Gujarat to characterise the site for INSAT-3D Cal/Val site by IMD and SAC, ISRO. Results were analysed and a report prepared.

IMD has installed 678 Automatic Weather Stations (AWS) and other agencies have installed about 1200 AWS all over the country. IMD has also installed 1293 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.

IMD's Area Cyclone Warning Centres generate special warning bulletins and transmit them every hour in local languages to the affected areas. During the recent past, in cases of Ashobaa (Cyclonic Storm) during 06-12 June, Komen (Cyclonic Storm) during 27-30 July, Chapala (Very severe Cyclonic Storm) during 26 October- 3rd November and Megh (Very severe Cyclonic Storm) during 04-10 November 2015, Cyclones warnings were disseminated to all stake holders 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 222 systems have been successfully installed.

In order to improve navigation accuracy, Fixed Grid Navigation and Automatic Template Based Registration package for INSAT-3D Imager was developed and operationalised at Space Application Centre, Ahmedabad and IMD, New Delhi. Ancillary Data Products Generation Software (ADPS) capability was enhanced to include HRIT/LRIT products, AWS (Automatic Weather Station) Data Decoding, archival and report generation. The Heat wave condition monitoring from the Satellite Derived LST Products were made operational at MOSDAC. A new High resolution Sector product with district boundary was provided to IMD.

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. 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.

Qualification process through international agencies is under progress for indigenously developed search and rescue beacons.

The Satellite Aided Search and Rescue system has so far supported rescue of 2072 lives in 103 SAR incidents so far and 51 lives out of 7 incidents during the last one year. Online Beacon registration system has been upgraded based on user requirements.

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.

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.

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 workload for operators, coverage of oceanic area for air traffic control, high position accuracy, etc. Directorate General of Civil Aviation (DGCA) certified GAGAN for enroute services (RNP 0.1) on the December 30, 2013 and further certified for precision approach (APV 1) on April 21, 2015. With this, GAGAN signal is available for both civil Aviation and Non-Aviation users. GAGAN Payloads are operational through GSAT-8, GSAT-10 and GSAT-15 satellites.

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.

Some of the specific application initiatives are summarised below:

Surveying: (a) Karnataka forest department has used GAGAN dongle (a low end receiver devised to receive and process GAGAN) for forest surveys. (b) AAI is using GAGAN based surveys for airport survey requirements. (c) NRSC is using GAGAN for Ground Control Point Library recording.

Railway: NRSC, along with Indian Railways, are experimenting on various GAGAN based applications, particularly in providing unmanned level crossing warning to drivers using GAGAN – BHUVAN applications. NRSC is doing pilot work on Train tracking using GPS-GAGAN.

Marine: DG, Shipping had a meeting at ISRO HQ and is in the process of assessing GAGAN for marine operations and are coordinating for the same.

Space weather studies: GAGAN data is being used for space weather studies by SAC/ISAC and has also been used for developing regional IONO model for Asia Pacific region.

Applications of IRNSS

Two types of services are envisaged by using IRNSS, 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 will 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
- Power Grid Synchronisation
- Location Based Services
- Earth and Atmospheric Studies
- Integration with mobile phones
- Fisheries
- Mining
- Precise Timing
- Mapping and Geodetic data capture
- Terrestrial navigation aid for hikers and travellers
- Visual and voice navigation for drivers
- Improved Availability of Position fix in Multi GNSS environment

The GNSS (GAGAN – IRNSS) User Meet 2015 was jointly hosted by the Indian Space Research Organisation (ISRO) and Airports Authority of India (AAI) on October 8, 2015 at ISRO Satellite Centre, Bengaluru. The theme of the meet *"Towards Self Reliance in Satellite Navigation" with emphasis on the vision of "Make In India".* The meet has brought together the GNSS-based industries, receiver manufacturers, PNT service providers, application developers, policy makers and the user community along with the academia on a common platform and made them to explore various avenues to utilise the Indian satellite-based navigation services for the socio-economic benefits of the country.

In association with DG Shipping, trials have been conducted to study the performance of IRNSS receivers for the marine applications. Receivers have been installed on 11 ships cruising in different directions within and across Indian Territory.

Disaster Management Support (DMS) Programme

The Disaster Management Support - Decision Support Centre (DMS-DSC) established at National Remote Sensing Centre (NRSC) is actively engaged in monitoring natural disasters such as flood, cyclone, landslides, earthquakes and forest fires. The major activities during the year were monitoring all the flood events, supporting the disaster management during the Nepal Earthquake and monitoring the landslide dammed Phutkal river in Jammu & Kashmir.

Floods: During 2015, floods were mapped and monitored in 10 states and more than 105 flood inundation maps were provided in near real-time to the concerned State Relief Commissioners, Ministry of Home Affairs, National Disaster Management Authority, National Disaster Response Force, Central Water Commission and India Meteorological Department. Value added flood products were populated on the Bhuvan and NDEM web portals. LIDAR based experimental flood depth maps for part of Lakhimpur district of Assam were generated and disseminated to the state agencies for severe floods during August 23, 25 and September 4, 2015.

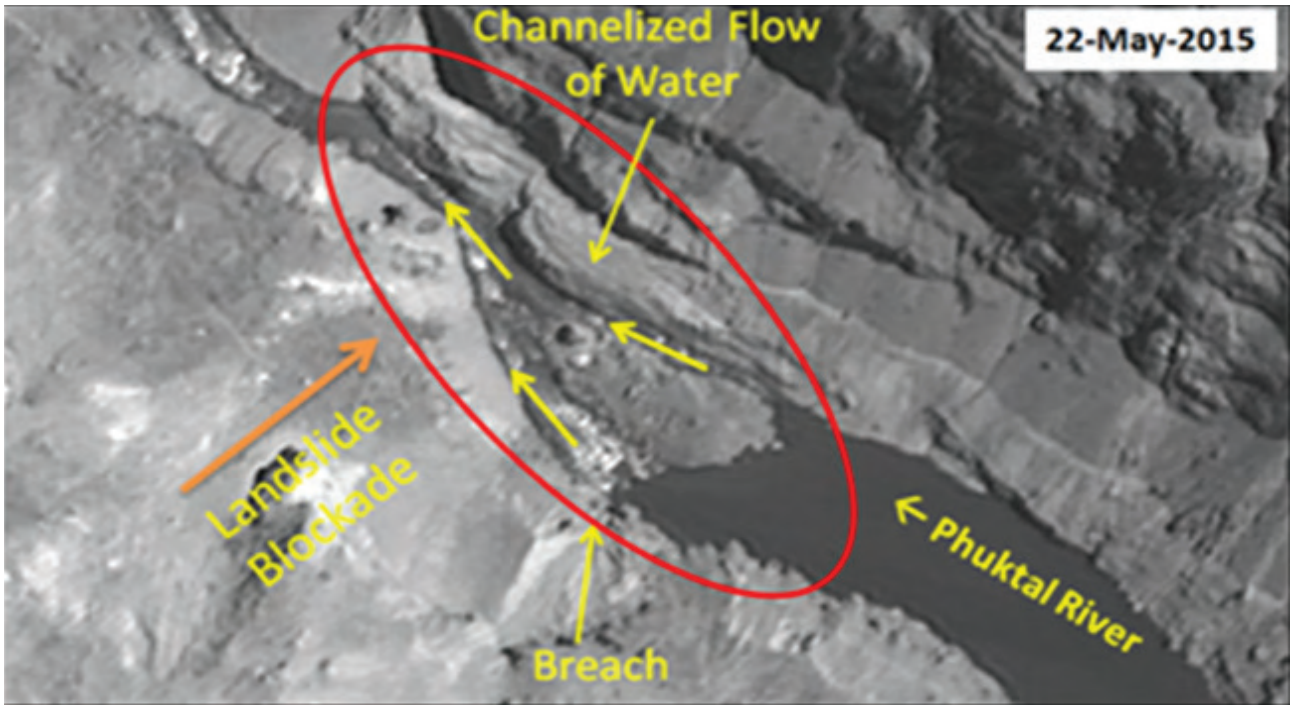
National Remote Sensing Centre (NRSC), Hyderabad being a member of committee on scientific assessment of flood prone area, has provided inputs on flood prone area based on DEM, water level and historic satellite data as input. Inputs provided for part of Burbalang basin, Odisha have a 90% match with ground based observations.

Cyclones: In 2015, no cyclone has made landfall in the Indian region. However, several depressions have caused heavy rainfall during the year. All the depressions and cyclones originated in the Indian Ocean region were monitored and the track, intensity and landfall were predicted. All the information was regularly updated on the MOSDAC website (http://www.mosdac.gov.in) as part of information dissemination.

Forest Fire: The Indian Forest Fire Response and Assessment System (INFFRAS) provides observations of active forest fires (Feb – Jun) daily at 10:30, 12:30, 14:30 and 22:30 hrs from TERRA and AQUA MODIS data on a near real time basis. Active forest information is available to users within

30 minutes of acquisition on Bhuvan as well as through Forest Survey of India. In 2015 fire season, a total of 22,539 active fires were observed.

Landslides: Landslide on Phuktal River (Zanskar Region), Kargil District, J&K was monitored during Feb-May, 2015 using CARTOSAT data and regular updates on impoundment area, volume of water and possible scenario due to breach was provided to NDMA. The inputs were used by NDMA to assess the threat and clear the blockade. Monitoring of the status of Lhonak Lake in Sikkim and Pareechu Lake in Tibet was carried using CARTOSAT data and information was furnished to CWC.



Landslide on Phutkal River causing blockade to the river flow

Earthquake: The Nepal earthquake in April 2015 caused widespread damage and loss of lives in many parts of Nepal, and some damages and deaths in India, too. The DMSP responded to this event with planning for quick satellite coverage for acquisition of Indian EO data, activation of the International Charter on Space and Major Disasters, building damage assessment in the urban areas like Kathmandu valley and rapid inventory of earthquake induced landslides. Android application for crowd sourcing was also developed and published. The landslides triggered by this event were rapidly mapped in 19 worst hit districts of Nepal (36,000 km^2.) Pre- and post-disaster high-resolution satellite images (Cartosat-1/2, Resourcesat LISS IV) and 10 m DEM were used to map co-seismic landslides triggered during the earthquake. More than 5000 landslides have been mapped in this attempt. Many landslide-dammed lakes have also been mapped.

The processed data and information were sent to Ministry of Home Affairs (MHA), National Disaster Management Authority (NDMA) and National Disaster Response Force (NDRF), in addition to uploading to Bhuvan and NDEM web portals of ISRO. The information derived from satellite data is shared among various international agencies for unifying the efforts and coordinating rescue operations.

Early Warning Systems Development: Medium range flood forecast models were developed for the Godavari, and Mahanadi and operationally used in real-time in collaboration with Central Water Commission during 2010 to 2015. The study has been extended to the other major flood prone rivers of the country (Mahanadi, Ghagra, Gandak, Kosi, Brahmani-Baitarani, and Krishna). Web-enabled spatial flood early warning system has been developed for the Godavari and being implemented in real-time during the monsoon period of 2015.

The Flood Early Warning System (FLEWS) in Assam has started its second operational phase of three years starting 2015 after successful implementation of the first operational phase (2012 to 2014) at the request of the Government of Assam. All flood prone districts of Assam are covered as part of the project. The percentage of success of early warnings has increased from a modest 25% in 2009 to an encouraging 80% in 2015.

An experimental early warning system for rainfall triggered landslides was developed and implemented along the pilgrimage route corridors leading to Gangotri, Badrinath and Kedarnath as well as along the Pithoragarh-Malpa route in Uttarakhand. The early warning is generated based on the statistical relation between the spatial (geological, morphological and terrain factors) and temporal (triggering factor; primarily long term rainfall events and the triggered landslides) controls of slope failure. This experimental early warning system is under validation.

Space Applications Centre (SAC), Ahmedabad has developed a model for thunderstorm predictions and it is being experimentally carried out for Uttarakhand and Himachal Pradesh regions. Further, a prediction model for heat waves was developed in 2015. Satellite derived information such as landuse/ land cover, vegetation cover, albedo, etc., are major influencing factors for the model. The experimental forecast output is overlaid on a GIS format with base data layers such as district boundaries, roads, railway lines, land use/land cover, etc. Both the forecasts were made available in MOSDAC and the links were given in Bhuvan and NDEM portals.

National Database for Emergency Management (NDEM): NDEM version 2.0 was launched with improved features and functions on ISRO satellite based Virtual Private Network (VPN). This portal consists of multi-scale geospatial database covering base, thematic, infrastructure, disaster specific products and satellite imagery along with a set of customised decision support tools. Generation of multi-scale geospatial services for 36 States / UTs at 1:50,000 scale, 209 out of 350 most vulnerable and multi hazard prone districts at 1:10,000 scale and high resolution satellite data for 210 towns has been completed. Satellite data derived value added disaster specific products (~209) covering 11 States covering disaster events in 2015 were hosted on NDEM portal. Mobile apps and user manuals were also uploaded in NDEM private and public portals for better utilisation of the services. Simultaneously, NDEM Public portal is hosted on ISRO Bhuvan platform through internet connectivity.

Seven regional training programmes for Central/State government departments (150 officers) have been organised across the country (Guwahati, Dehradun, Kolkata, Gandhinagar, Thiruvananthapuram, Bhopal and Delhi) during June – August 2015 for the familiarisation of NDEM private and public portals for enabling the better utilisation of NDEM products and services.

Aerial survey for large-scale mapping: Close contour flood plain mapping is being carried out using airborne LiDAR / LFDC data for use in flood inundation modelling and flood depth assessment. During the year, Geodatabase generation is completed for Mahanadi river basin covering an extent of 8,177 sq.km.

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 operational.

Establishment of Doppler Weather Radars: S-Band DWR System installation has been completed at Cherrapunji and IMD site at Gopalpur, Orissa. C-Band DWR transmitter and other subsystems have been integrated at TERLS; VSSC and weather data is being acquired since June 2014. An S-band DWR is being established at IMD site at Kochi and the S-Band DWR at SHAR is planned to be upgraded with Mark – II DWR.

Satellite Aided Search and Rescue: The Satellite Aided Search and Rescue system which provides services to 7 neighboring countries has so far supported rescue of 2072 lives in 103 SAR incidents so far and 51 lives out of 7 incidents during the last one year. Online Beacon registration system has been upgraded based on user requirements.

International cooperation in DMS: ISRO has carried out the Lead Role in International Charter Operations during April-October 2015. During this period, ISRO managed 17 activations, published three communications and Universal Access was extended to 5 countries. During 2015, satellite data support (28 scenes) were provided for 10 emergency requests from Vietnam, Pakistan, Indonesia, Bangladesh, Japan, Myanmar, Nepal and Taiwan for floods, oil spill, landslides and Typhoon disasters.

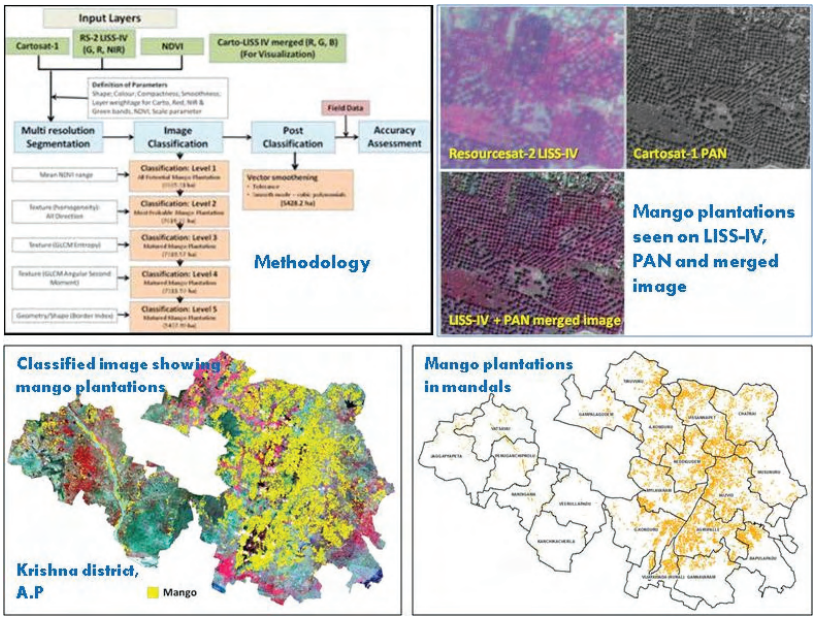
Remote Sensing Applications

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. Regional Remote Sensing Centres (RRSCs) of NRSC, North-Eastern Space Application Centre (NE-SAC), Shillong and the 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 2015-16 are highlighted as follows:

National Land Use/Land Cover (LU/LC) mapping on 1:250,000: 11th cycle (2014-15) LU/LC assessment has been made using semi-automated approach which includes automated processing of AWiFS quadrant data and classification using rule based approach. Water spread as well as snow cover information has been generated though automated process. Rule based data integration of temporal datasets was adopted to derive final LU/LC output.

Crop Acreage and Production Estimation: Wheat acreage and production are estimated at national level. The semi-physical spectral-spatial wheat yield model was developed and provided to Mahalanobis National Crop Forecasting Centre (MNCFC) and required training was imparted to MNCFC personnel for running the model and deriving planting date from time series NDVI data. The MNCFC has used the yield outputs for giving final production forecast on April 10, 2015. The rabi pulses estimation was made in six states of Madhya Pradesh, Uttar Pradesh, Rajasthan, Maharashtra, Andhra Pradesh and Karnataka. The total area under rabi pulses in India was 8.963 Mha which include gram, lentil, peas, green gram, red gram, black gram and miscellaneous pulses. The behavioural pattern for cotton crops was studied in hybrid polarimetric RISAT data for Gujarat during kharif 2013-14. Area estimation for cotton crop using RISAT data was taken up for six districts of Madhya Pradesh (Dhar, Dewas, Burhanpur, Barwani, Khandwa and Khargone). Due to delayed rain and irregular monsoon pattern, poor growth for cotton for late sown cotton was observed in the field during September. A Training programme on “Remote Sensing, GIS, Image Analysis” was organised for the officials of MNCFC at New Delhi during October 5 - 9, 2015.

Coordinated programme on Horticulture Assessment and Management using Geoinformatics (CHAMAN): This national level project has been taken up, with the major objectives of (i) area assessment and production forecasting of major horticultural crops in selected districts in India; (ii) geospatial applications for horticultural development and management planning; and (iii) detailed scientific field level studies for developing technology for crop identification, yield modelling and disease assessment. A pilot study was taken up to validate the operational methodology of inventorying three major fruit crops, namely, mango, banana and citrus. Temporal high-resolution data (LISS-IV and Cartosat-1) has been used for delineation of spatial extent of the crop of interest. A mobile application ‘CHAMAN app’ was developed to aid in faster and efficient collection of ground information, as well as in building geodatabase through Bhuvan platform. A familiarisation programme was conducted for officials from Telangana and Andhra Pradesh State Governments. The scope of this training was primarily focused on the aspect of field information collection towards generation of a database for inventory of horticulture crops and their delineation with specific examples.



Coordinated programme on Horticulture Assessment and Management using Geoinformatics

Crop insurance studies: The potential benefits of the currently available satellite datasets, derived indices, improved weather data sets, geospatial tools and techniques suggest the scope for improving the crop loss assessment methodologies for insurance purpose. Integration of tools and technologies to evolve robust products for crop insurance is a major research challenge to be addressed. A new initiative with multi-institutional participation has been taken up to study the feasibility of using satellite data for crop assessment in the insurance units. The Crop Cutting Experiments (CCE) for crop yield estimation being conducted by the State departments was supervised by the respective study teams. The CCE plots are georeferenced and the measured crop yield data along with ancillary information was transferred to Bhuvan in near real-time, through a specially designed application tool. The yield data of CCE plots and related spectral and weather data are being analysed to study the crop yield variability in the insurance units.

Development of spectral signatures of cotton cultivars and assessment of cotton crop area: Cotton is one of most important fiber and cash crop of India. A study was undertaken with Central Institute for Cotton Research (CICR, Nagpur), to generate spectral signatures of cotton cultivars using spectro-radiometer and to study its spectral properties; and to identify and assess cotton crop areas using remote sensing techniques in selected study areas of cotton dominant districts.

Cotton crop area mapping: Multi-temporal satellite (Landsat-8) data was classified and interpreted for cotton crop identification, discrimination and mapping for Wardha Taluka in Wardha district, Maharashtra. Land Use/Land Cover, forest, settlement, water bodies and ancillary data was used to mask the non-crop area. It was observed that around 17,900 ha area of study area was covered by cotton crop (21.4% of total geographical area). The results were subsequently validated in the field.

Indian Forest Cover Change Alert System (InFCCAS): A remote sensing based technique was developed for automated detection of forest cover loss of an area greater than 2 hectare for rapid annual monitoring. The forest pixels are identified on Resourcesat-2 AWiFS data (2^0 x 2^0 tiles) for Andhra Pradesh, Bihar, Chhattisgarh, Goa, Gujarat, Himachal Pradesh, Jharkhand, Karnataka, Madhya Pradesh, Maharashtra, Orissa, Punjab, Rajasthan, Telangana, Uttar Pradesh and West Bengal).

Identification of suitable sites for social forestry activities: A study was undertaken to identify suitable sites for raising plantations (avenues – road, rail, canal and block – open lands) using high resolution satellite (Cartosat) data. Multi criteria based decision making method was adopted integrating both spatial (land use/ cover, wastelands, slope, base details – road, rail, canal networks, village locations) and non spatial (soil texture, depth, socio-economic details like population, employment, etc., datasets in GIS environment to find out suitable areas in five districts of Maharashtra for linear and block plantations. Results (suitable sites) for Nagpur, Wardha and Bhandara Districts were submitted to social forestry department, Maharashtra.

Study on Sundarban mangrove system: The mangrove ecosystem of Sundarbans region plays an important ecological and socio-economical role in both India and Bangladesh. The present study is aimed at analysing the impact of cyclone of varying intensity and at different period of phonological cycle on mangrove forests in Sundarbans region. MODIS time-series (2001-2011), Enhanced Vegetation Index (EVI) and Land Surface Temperature (LST) products were used to compute the MODIS Global Disturbance Index (MGDI). In the present study, instantaneous disturbance caused by the super cyclones was analysed using MGDI approach. The combined impact of 'SIDR' and 'Rashmi' was successfully captured by the MGDI images of 2008. In case of 'Aila', the disturbed area was reasonably less in comparison to the areas with higher EVI changes (-50% to -30%). The spatial extent of disturbance in each island was mapped, which can further be integrated on a temporal scale to generate spatio-temporal severity map. This will help forest management to identify chronically disturbed areas, which may have potential for biological invasion.

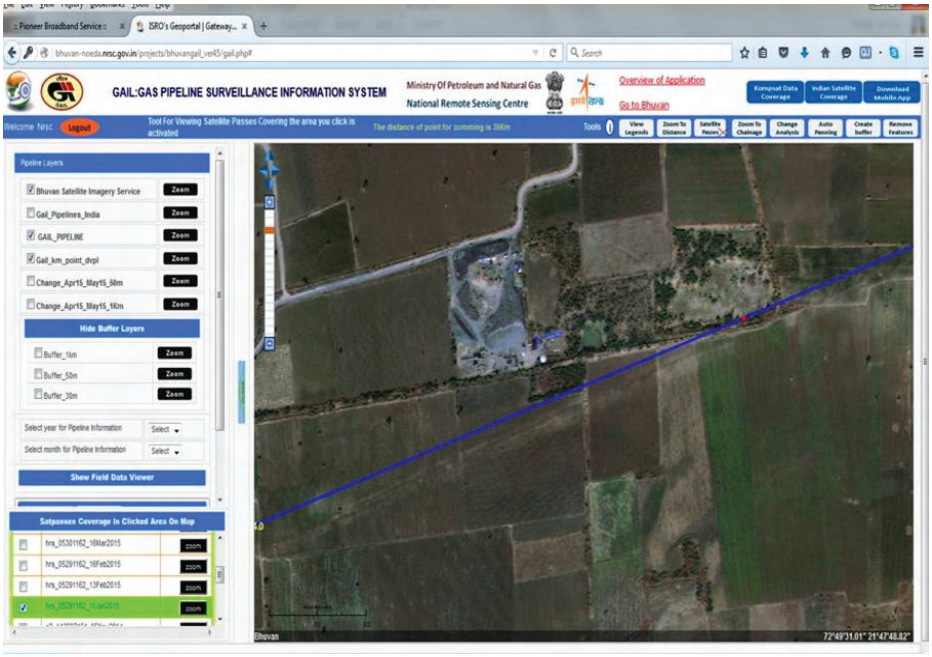
Inventory and Monitoring of Glacial Lakes/Water Bodies: The project is being carried out at the behest of Central Water Commission. The inventory of glacial lakes and water bodies was carried out for the year 2009 using IRS satellite data and monitoring in the months from June to October was completed for last four years (2011, 2012, 2013 and 2014). Similar activity for the year 2015 was taken up in June, 2015 for 477 glacial lakes and water bodies. Monthly monitoring reports of June, July, August and September were already submitted. As part of institutionalisation, training of CWC officials was carried out during October 15-19, 2015.

Assessment of Irrigation Potential Utilisation (I.P.U) using geospatial data: The study has been initiated in April 2015 to assess Irrigation Potential Utilisation (I.P.U) during 2015-16 and 2016-17 years under Major & Medium (M&M) irrigation projects in Krishna basin using the geo-spatial data. Temporal AWiFS data, canal network, project boundaries and LULC data available under various projects (India WRIS, SIS DP, NRC) are being utilised. The data bases such as basin, sub-basin

boundaries, M&M projects, their canal network, river/ stream network and other base layers are being organised. Field validation of selected commands is in progress for 2015-16 Rabi season.

Re-assessment of basin scale water resources using Space inputs: ISRO and Central Water Commission (CWC) jointly executed demonstrative pilot studies in Godavari and Brahmani-Baitarani river basins wherein Space based geo-spatial inputs were used to estimate basin-level mean annual water resources. Ministry of Water Resources recommended upscaling the study to other river basins of the country by regional offices of CWC. A five-day orientation training programme was conducted at NRSC for Central Water Commission (CWC) officers during May 25 to 29, 2015 and a two week capacity building programme during October 5-16, 2015 on detailed methodology and hands on training. Subsequent to the above training, CWC regional offices will carry out the study and NRSC will provide technical support and hand holding during the study execution.

Monitoring of Gas Pipelines of Gas Authority of India Ltd (GAIL): GAIL has about 15,000 line km gas pipeline network in India. GAIL and ISRO have undertaken a joint project for studying feasibility of remote sensing, as an alternative/ complement to the helicopter survey, for monitoring the Right of Usage (ROU) of the pipeline for any physical encroachments. A pilot study has been carried out for "Dahej-Vemar-Vijaipur" pipeline segment of about 610 line km. Results indicates that satellite remote sensing techniques (high resolution data) can be used to monitor the pipeline assets through periodic repeat coverage (say monthly) during the cloud-free season. A web application was also developed to demonstrate the usefulness and quick communication within the GAIL monitoring teams.

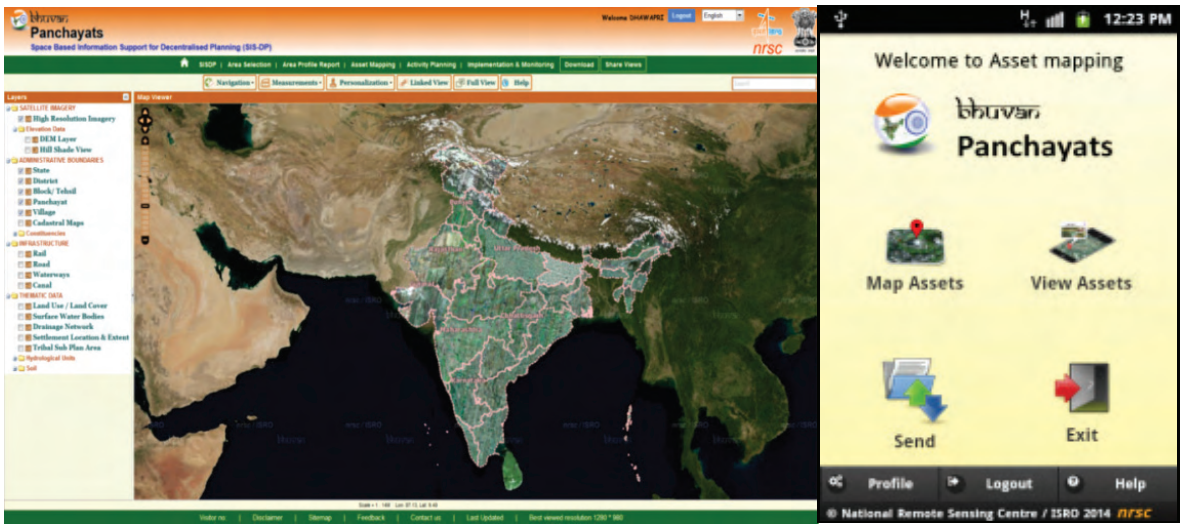


Web application interface for GAIL pipeline Surveillance

Island Information System (IIS): Department of Border Management, Ministry of Home Affairs constituted a Task force for holistic development of Islands in Maritime zones of India, with participation of all concerned Ministries/ Departments/ Agencies. Towards this, ISRO has prepared a geospatial inventory of all islands using satellite images and developed an Island Information System. A total of 1238 islands have been identified and reconciled by NRSC/ISRO, SOI, NHO and RGI. The Island Information System (IIS) has been shared with different ministries and departments.

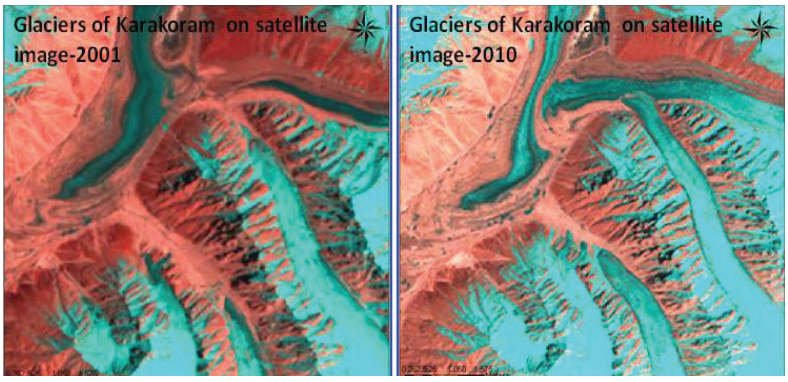
Monitoring of Integrated Watershed Management Programme (IWMP) watersheds using geospatial technologies: Bhuvan – SRISHTI, a Web based GIS application (Geoportal), has been developed to enable monitoring and evaluation of IWMP watersheds, using satellite remote sensing and sample field data (collected using mobile application). This Geoportal would facilitate monitoring and evaluation of all IWMP watersheds for 10 states and 50 identified districts in 28 states. Bhuvan – DRISHTI, an android based interface tool, has been developed for field data capture of the development activities undertaken for the IWMP Projects and includes a facility to upload photos to Bhuvan IWMP Server.

Space-based Information Support for Decentralised Planning (SIS-DP): The project aims at providing web based spatial information comprising of ortho-rectified satellite image, thematic and field data, resource maps, cadastral maps, administrative boundaries, infrastructure layers, climate and socioeconomic data which will act as input for Decentralised Planning at Panchayat level. The project is being executed by respective State Remote Sensing Applications Centres (SRSAC) under the technical guidance and financial support from Overlay of cadastre maps over high resolution satellite image has been completed for 5 States (AP, Telangana, Haryana, Assam and Kerala) and 2 Districts of West Bengal; Bhuvan-Panchayats portal version - 2.0 and Mobile app for Panchayat Raj Institutions (PRI) asset data collection has been demonstrated for operational use. Training on decentralised planning and use of SIS-DP data for planning is being implemented with PRIs through Bhuvan Panchayat.



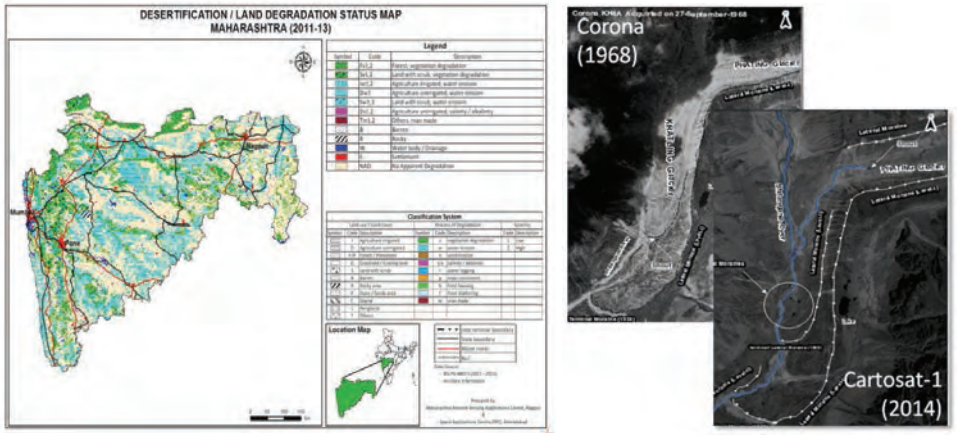
Home Page of Bhuvan Panchayat Portal and Mobile app for Asset Mapping

Snow and Glacier Studies: It is a joint initiative of Ministry of Environment, Forest & Climate Change and Department of Space. Retreat/advance for 73 glaciers spread over different parts of the Himalayan region were estimated using CORONA (1965) and LISS-III (2001) images. Snow cover Atlas of the Bhutan was completed. RISAT-1 MRS scenes of Chhota Shigri and Zemu glaciers were processed and analysed. Highest snowline altitude of Chhota Shigri glacier for the 2014 was observed at 4973 m which is lower than the previous two years highest snowline altitudes (2012 – 5020 m; 2013 – 4982 m). The highest snowline altitude of Zemu glacier was observed around 5560 m altitude for the year 2014, which is higher than previous two years (2012 – 5510 m; 2013 – 5470 m). Estimation of Equilibrium Line Altitudes (ELAs) for the Durung Drung, Chhota Shigri, Gangotri and Zemu glaciers for the year 2012-2015 is completed using RISAT SAR data and used to compute the mass balances based on Accumulation Area Ratio (AAR) approach. RISAT-1 MRS data over Durung Drung glacier for the year 2015 are processed and analysed for temporal changes. The highest snowline altitude is observed at 5251 m on August 25, 2015.



Two advancing glaciers in Karakoram region are seen distinctly on satellite images of 2001-2010

Desertification Status Mapping of India – 2nd Cycle: The project is being carried out at the behest of Ministry of Environment, Forest & Climate Change. Desertification status maps for 2011-13 timeframe on 1:500,000 scale for the entire country is completed. Change detection with respect to 2003-05 and 2011-13 timeframes also has been completed. Seamless mosaics of desertification status maps of entire India were generated for 2011-13 and 2003-05 time frame. The mosaic has integrated state-wise maps prepared using AWiFS data sets on 1:500,000 scale for corresponding time frames.



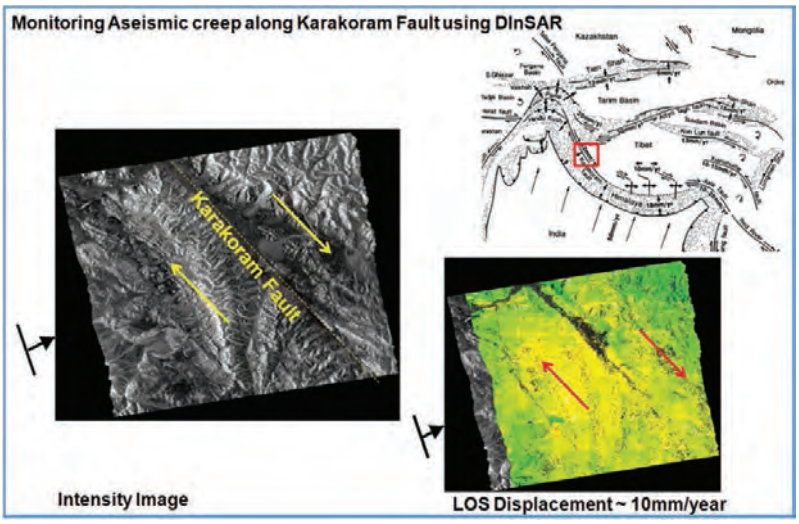
Desertification/Land Degradation Map of Maharashtra prepared using AWiFS data of 2011-13 time frame on 1:500,000 scale

R&D Projects/Studies

Recession of Khatling glacier deduced from Corona to Cartosat: Dynamics of the Himalayan glaciers are quite reliable indicators of changes in the climate system. The extent of the Khatling glacier (Bhilangna Basin, Uttarakhand) as of 1935 has been reconstructed based on the lateral and terminal moraines extent extracted from Corona and Cartosat data. The oldest location of the Khatling glacier in 1935 shows the glacier has receded by 648 m from 1935 to 1965. The Khatling glacier has receded by 4210 m from 1965 to 2014 period. The fastest recession of 4858 m from 1935 to 2014 resulted in the fragmentation of the compound basin glaciers into multiple valley glaciers and hanging glaciers. Systematic observation of glaciers from oldest Corona and latest Cartosat satellite imagery provide reliable information on glacier dynamics.

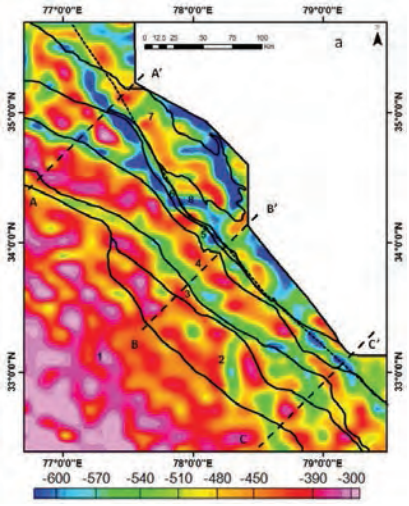
Intra-Plate Geodynamic Profiling in Active Seismic Zones: A study was initiated in collaboration with IIRS, SAC, Snow and Avalanche Study Establishment (SASE, Manali) and Institute of Seismological Research (ISR, Gujarat) to monitor the (i) movement of Indian plate (using the existing IGS/GAGAN reference stations), (ii) segments of Himalayan Thrusts Systems and Kutch fault system (using integrated continuous and campaign mode observation), and (iii) displacement rate analysis along the Karakoram Fault and Himalayan Frontal Thrust (using Differential SAR Interferometry and correlating the geodetic measurements with geomorphic evidences). Under this project, four Continuously Operating Reference Stations (CORS) at Dehradun, Manali & Kutch (2) and eight Campaign mode observation sites (Roorkee, Mussoorie, Uttarkashi, Bhatwari, Chandigarh, Pinjore, Shimla and Sundernagar) were established.

During the first phase of campaign mode survey (in April 2015), using the four of the eight campaign mode survey sites from Uttarakhand, co-seismic deformation associated with the Nepal earthquake (April 25, 2015) was ranging between 2 to 10 mm. The preliminary results from the CORS at Dehradun and Manali in comparison to the IGS stations at Hyderabad and Bengaluru indicate a crustal shortening of about 20cm/year across the western Himalayan region. The displacement rate derived from DInSAR studies at the Karakoram fault indicates about 10mm/year of a seismic creep along this fault.



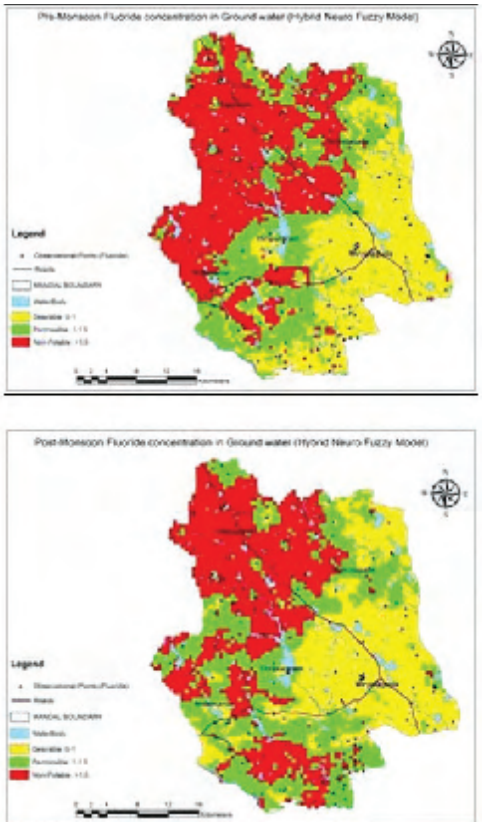
Satellite gravity data analysis for crustal gravity assessment: The objectives of the study are to (i) understand geodynamic processes using 2D modelling of static gravity data from high resolution gravity models and GOCE (Gravity and steady state Ocean Circulation Experiment), and (ii) assess density changes, if any, associated crustal deformation (e.g. earthquakes) using temporal gravity data from GRACE.

The study uses high resolution hybrid global gravity model from ICGEM, GOCE derived gravity model and GRACE multi-temporal monthly gravity solutions. The study is carried out along four different sites, namely, Karakoram fault system (Himalayan Transect-1), HFT-MBT-MCT and Suture Zone (Himalayan Transect-2), Intra-plate passive ridge system (volcanic origin - Laccadive Ridge), and Active subduction zone (Andaman-Sumatran Arc). Preliminary results of geological analysis using high resolution gravity model (EIGEN-6C4) and GOCE derived gravity model along Karakoram shear zone show good agreement between gravity with the geology of the area.



EIGEN-6C4 derived bouguer gravity map of the Karakoram Shear Zone

Coastal aquifer mapping using Ground Penetrating Radar (GPR) data: The present study aims to detect the subsurface anomaly that links the fresh water reservoir below the shallow and thin sand/silt layers using ground based GPR data combined with well observation data in a GIS environment. The study was taken up in a beach and swells complex area hosting 20 habitations in Andhra Pradesh coast. GPR data showed that the water table of the study area varies between 1.4–3 meters below the ground and the depth of the fresh water aquifers varies between 3-6 meters. The fresh water and saltwater interface in these areas occur at a very shallow depth of 4-6 meters. Pre-monsoon volume of the fresh water was estimated in the area using geospatial technique and corroborated with the field data. Ground water being the only source of drinking water in these near-shore habitations, delineation of the fresh water zones helps in solving the drinking water needs of the increasing population in these areas. Over consumption of ground water for drinking, agriculture and domestic purpose resulted in depleting the fresh water resource and the saltwater intrusion into the fresh water aquifers.



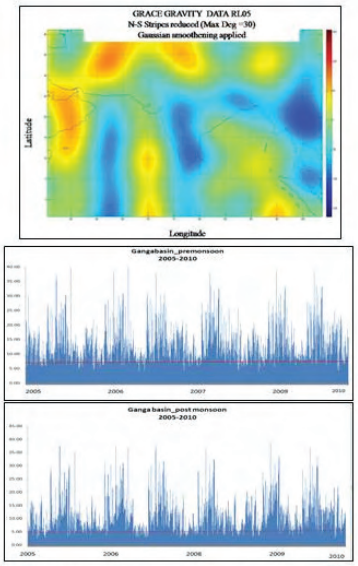
Fluoride concentration in ground water in parts of Nalgonda Dt (Telangana):
Pre-Monsoon (Top) & Post Monsoon (Bottom)

Spatial modeling of fluoride contamination in ground water: Groundwater with fluoride concentration above the permissible limit of 1.5 mg/l has been recorded in several parts of the world. Consumption of water with fluoride concentration above 1.5 mg/l results in acute to chronic dental and skeletal fluorosis. Several rocks have fluoride bearing minerals like apatite, fluorite, biotite and hornblende, and fluoride in groundwater is contributed by the host rocks which are naturally rich in fluoride. Because of rock water interaction, long residence time and evapotranspiration, the concentration of fluoride increases in ground water. Fluoride concentration in ground water is associated with water quality parameters like pH, Total Hardness, Total Alkalinity, Total Dissolved solids and Chloride. Geo-environmental parameters such as lithology, geomorphology, landuse, slope, distribution of water bodies and water channels also contribute to the presence of excess fluoride in ground water.

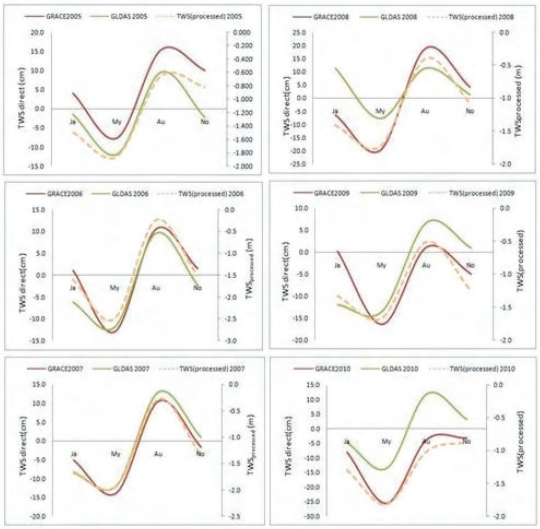
The present study focuses on the spatial modeling of fluoride distribution in ground water using knowledge guided models, data driven models and the combination of both. Fluoride prediction maps generated using hybrid neuro-fuzzy integrated approach compared favourably among the four mathematical models used, namely, weighted overlay, fuzzy overlay, artificial neural network and hybrid neuro-fuzzy models for prediction of fluoride in ground water. Results were validated with field data.

Groundwater storage assessment coupling hydromorphology with lithology: The standard procedure of ground water resource estimation is based on the specific yield parameters of each rock type (lithology) derived through pumping test analysis. However, terrain conditions in the form of geomorphological variations have an important bearing on the net ground water recharge. In the present study, an attempt was made to use both lithology and geomorphology as input variables to estimate the recharge from different sources in each lithology unit influenced by the geomorphic conditions (lith-geom) season wise separately. The study provided a methodological approach for an evaluation of groundwater in a semi-arid hard rock terrain in Tirunelveli, Tamil Nadu. While characterising the gneissic rock, it was found that the geomorphologic variations in the gneissic rock due to weathering and deposition behaved differently with respect to aquifer recharge. The three different geomorphic units identified in gneissic rock (PPS, PPM and BPM) showed a significant variation in recharge conditions among themselves. It was found from the study that peninsular gneiss gives a net recharge value of 0.121 m/year/unit area when considered as a single unit with respect to lithology whereas the same area considered with three lith-geom classes gives recharge values between 0.099 to 0.411 m/year presenting a different assessment.

Groundwater storage change estimation using space based gravity observations: A study was undertaken to model terrestrial Total Water Storage (TWS) in Ganga Plain by combining the groundwater storage information derived from Central Ground Water Board (CGWB) groundwater level information and Global Land Data Assimilation system (GLDAS) direct influence parameters (i.e, soil moisture of depth up to 100 cm top soil along with other influencing parameters like canopy storage and evapotranspiration).



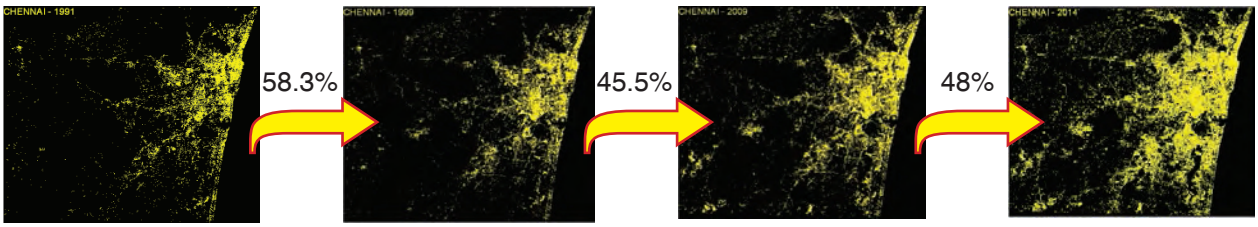
Water levels plotted for 2005-2010 (2500 CGWB wells)



Comparison of TWS derived from GRACE, GLDAS and coupled model; quarterly analysis during January, May, August and November (2005-2010)

TWS derived from the newer release of Gravity Recovery and Climate Experiment (GRACE) time-variable gravity solutions was compared with Global Land Data Assimilation System (GLDAS) TWS for the period 2005-2010. Groundwater level information is recorded 4 times in a year (January, May, August and November) by CGWB and therefore, the model outputs were measured at quarterly cycle corresponding to the CGWB monitoring. Assimilation of GLDAS direct influence parameters with ground water storage components showed increased correlation with GRACE TWS estimates than GLDAS TWS estimates, there by indicating the potential of data assimilation models to downscale TWS data for local hydrological applications using this new model.

Time Series Urban Built-Up: Time series urban built-up is an important input for many applications such as urban planning, infrastructure planning and regional level climate studies. Medium resolution satellite data has been used to generate time series (1991, 1999, 2009 and 2014) built-up for the cities having population more than 1 lakh as per the census 2011. This data has been provided as a service in Bhuvan. Presently,107 cities data has been published in Bhuvan. The figure shows the urban growth in and around Chennai area and also the percentage increase in urban area.



CHENNAI -1991 CHENNAI -1999 CHENNAI - 2009 CHENNAI - 2014

Surface Energy Balance over Agro-ecosystems using Large Aperture Scintillometry: The unique advantage of Scintillometry is its ability to calculate areal averaged sensible heat fluxes over spatial distances comparable to those observed by satellites. The LAS system was set up in 2014 at the agricultural research farm of Indian Agricultural Research Institute (IARI), New Delhi. The LAS measures atmospheric turbulence and heat flux over path lengths between 250 m and 6000 m.

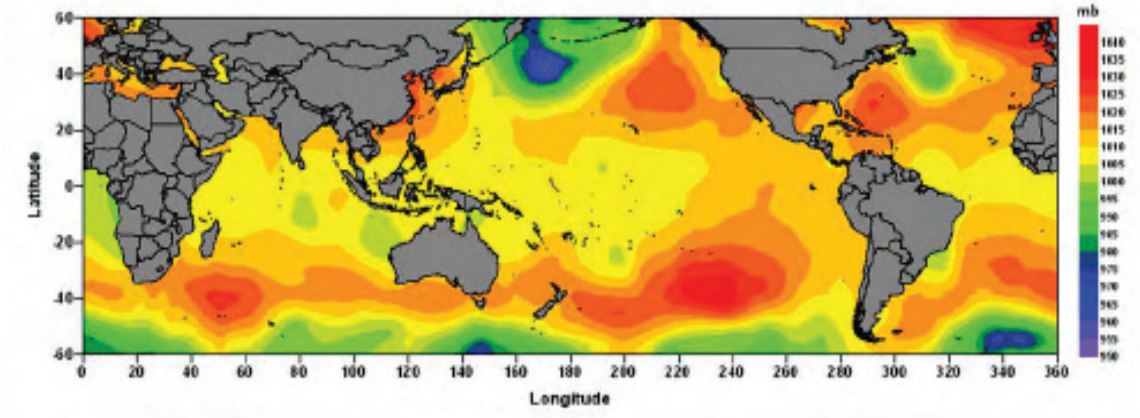
Large Aperture Scintillometer located at IARI Farm, New Delhi

The LAS was augmented with an Automatic Weather Station (AWS) having sensors of net radiometer, pyranometer, anemometer (2 levels), humidity and temperature probes (2 heights) and a soil heat flux plate at 10 cm depth. The 5 min fluxes of net radiation (Rn), sensible heat (H), latent heat (LE) and soil heat (G) fluxes were averaged at hourly intervals. All the fluxes were integrated over the day to analyse their seasonal pattern. Using H and LE daily integrated fluxes, daily values of evaporative fraction, EF = LE/ (H+LE) are calculated and analysed for their seasonal pattern.

Mapping, Modeling and Impact Assessment of Land Subsidence in Northern India: The basic objective is detection and mapping of land subsidence phenomena in selected cities of North India and Modeling of land subsidence in relation to groundwater withdrawal and tectonics; and Inter-comparison of land subsidence, groundwater extraction and gravity anomaly. L-band ALOS PALSAR and C-band RADARSAT-2 DInSAR data processing and analysis were carried out for land subsidence investigations in multiple test sites (Delhi, Gurgaon, Mohali, Chandigarh, Hissar and Mehsana). Spaceborne GRACE gravity anomaly study over Northern India is also completed. Predictive modeling for estimating land subsidence due to aquifer system compaction due to groundwater withdrawal was also tested.

Retrieval and Validation of Global Pressure Fields from OCSAT Winds: The daily global sea level pressure fields were generated from Oceansat-2 Scatterometer (OSCAT) winds using University of Washington Planetary Boundary Layer (UWPBL) model for the year 2011 and 2012. The Date Interpolating Vibrational Analysis (DIVA) technique was used to make global composite from along track pressure fields. These pressure fields were evaluated with the help of (~ 220818 co-located) pressure observations from Buoy measurements. The global sea level pressure fields are in good agreement with buoy measurements having correlation coefficient of 0.91, bias 0.31 mb, standard deviation ratio 0.40, and low scatter index of 0.0041. The validation results reveal that the global pressure products are useful for weather prediction studies such as El Nino and Southern Oscillation (ENSO), Indian Ocean Diople (IOD), Indian Summer Monsoon onset vortex and monsoon depressions in the Bay of Bengal.

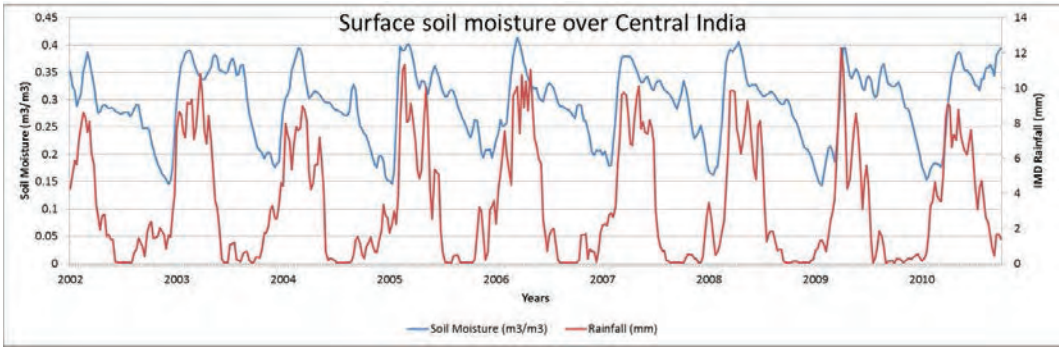
Latent Heat Flux (LHF) over North Indian Ocean: Latent Heat Flux / Evaporation rates over the ocean are essential for parameterising the ocean-atmospheric coupled predictive models. There are several methods in estimating evaporation rates/Latent Heat Flux over ocean. Among them, the prominent are (i) eddy correlation or direct method (ii) profiling or gradient method and (iii) Bulk aerodynamic method. Bulk-aerodynamic method is conceived as an integration of profile from the surface to the level of observation, as it is very difficult to get reliable small fluctuations using other



Sea Level Pressure fields of daily composite.

two methods. To calculate evaporation rates/Latent Heat Flux using bulk aerodynamic method the parameters required are wind speed, saturation vapour pressures (at sea surface and at the height of wind). Latent heat/evaporation rates were computed using TMI-SST, Wind field and Water vapour content for North Indian Ocean during 2001-2005 for monsoon periods.

Surface Soil Moisture Product on Bhuvan: Surface soil moisture is an important state variable in land surface hydrology and a key link between the land and the atmosphere. It is an important parameter for many weather forecasting and prediction models, since changes in soil moisture influences agricultural productivity, forestry and ecosystem health. The Land Parameter Retrieval Model (LPRM) was applied to data sets of AMSR2 brightness temperatures (Descending nodes) for the period July 2012 till date over the Indian subcontinent. Since the country is covered in two days, fully automated two days merged soil moisture products are made available on Bhuvan portal. Figure below depicts the Long term trends of soil moisture as derived from AMSR2 data and rainfall over Central India



Long term trends of soil moisture as derived from AMSR2 data & rainfall over Central India

Monitoring and Assessment of ecosystem process in North Western Himalayas: For sustainable environmental development, making disaster resilient society and improved livelihood in the North Western Himalayan (NWH) region, an interdisciplinary research project on "Monitoring and Assessment of Ecosystem Process in NWH" is being carried out at IIRS, Dehradun involving large number of research organisations with several sub-themes as given hereunder:

- Geodynamics and seismicity investigations
- Vulnerability assessment of forest ecosystems due to climate change
- Sustainable mountain agriculture
- Water resources status and availability
- Modeling temporal and spatial growth of cities and towns in NWH
- Rainfall retrieval using microwave remote sensing data and study of extreme rainfall events

Several instruments, namely, Continuously Operating Reference Stations (CORS)-2 Nos., Automated Weather Station (AWS) – 24 Nos., Seismometers – 2 Nos., Eddy Covariance System, Snow Pack Analyser, Snow depth Gauge, etc., were installed to quantify various ecosystem parameters of NWH region. L-band ALOS-2 PALSAR DInSAR based spatial terrain deformation due to Nepal earthquake (showing high relative deformation along the weak structural planes of south west of Mt. Everest) was studied using November 24, 2014 and April 27, 2015 data. Active fault mapping has been carried out in Doon valley and surrounding regions using Cartosat-1 data and confirmation done by field GPR and IP resistivity survey data. Ensemble model for forest species prediction for present and future climate change scenarios was developed and forest species distribution model was also established for west Himalaya. Climate change impacts on crop productivity and land suitability of crops in Himachal Pradesh were studied. Glacier velocity and depth using RISAT-1 and other SAR data were studied for Smudra Tapu, Chotta Shigri and Siachin glaciers. Long term (1901 to 2004) trend analysis of rainfall suggests that out of the three states of the Northwest Himalaya, Uttarakhand receives higher frequency of extreme rainfall events with greater intensity than Himachal Pradesh and Jammu & Kashmir.

NATIONAL INFORMATION SYSTEM FOR CLIMATE AND ENVIRONMENT STUDIES (NICES):

Realising the need for a comprehensive information base to build long term data records on various Essential Climate Variables (ECVs) for environmental and climate studies with inter and intra-departmental linkages, ISRO formulated the National Information System for Climate and Environment Studies (NICES). The mandate of NICES is to build an information base for climate change impact assessment and mitigation. 10 Geophysical products are already uploaded in Bhuvan portal and about 15 Geophysical Products are planned to be uploaded by March 2016. The number of Geophysical Products derived and uploaded in Bhuvan Portal of ISRO is depicted in the following table:

Domain	Geophysical Products on NICES Page/Bhuvan
Land	Eight Products - Soil Moisture (SM), Normalised Difference Vegetation Index (NDVI), Vegetation Fraction (VF), Albedo, Water Bodies Fraction (WBF), Landuse & Land Cover (LU & LC)
Ocean	Six Products - Tropical Cyclone Heat Potential (TCHP), Ocean Heat Content (OHC), Ocean Mean Temperature (OMT), Wind Curl, Velocity and Stress
Atmosphere	Two Products - Tropospheric Ozone, GPSRO Gridded profiles
Cryosphere	Two Products - SCF, Snow melt/Freeze
Model Outputs	Two Products - Modeled D26, Modeled TCHP
Total	20
Number of downloads > 30,000	

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 Post Graduate 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 & GIS training and 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 ranges from one-week to two-years.

The training and education programmes conducted by the Institute are – (1) Post-graduate Diploma courses of 10 months duration, (2) Certificate programmes of 8 weeks duration (including NNRMS-ISRO sponsored programme for University faculty), (3) Awareness programmes for Decision Makers for 1 week duration, (4) Special on-demand / tailor-made courses for 1-8 week duration. 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 and 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 10077 professionals (till November, 2015), including 944 professionals from abroad representing 95 countries from the Asia, Africa and South America. A total of 406 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 and demand for such tailor-made courses has increased significantly.

It is imperative to mention here that Institute organises its prestigious two training programmes each year of 8 week duration, in the category of Technical Course under ITEC/SCAAP; namely 'Short course in RS with emphasis on Digital Image Processing (SRS)' and 'Short course in Geoinformatics (SGI), wherein a total of 468 foreigners from 79 countries have been benefited from ITEC/SCAAP courses at IIRS. First-phase of ISRO-NCERT sponsored special course was coordinated by IIRS for conducting a special training at all India level from 25 centers, parallelly, targeting about 500 Post Graduate Teachers (PGT) of KVs, NVs and Pvt. CBSE affiliated schools. Similarly, other special courses were also undertaken like UAV Remote Sensing, ISPRS Summer School, etc. besides the regular mandates courses.

IIRS received the 'Education Leadership Award' from ABP News National Education Awards on July 23, 2015 at Mumbai. The award is in recognition of the leadership, development, marketing, and institute and industry interface.

In addition, IIRS has also trained 1484 professionals from 34 countries and 29 participants from 18 countries outside Asia pacific region in the last 19 years.

Further, 24799 graduate and post-graduate students from 310 universities spread across the country have also benefited through the distance learning programmes being offered by the Institute since 2007. In the present ongoing program, the number of universities registered is 310 with more than 5800 participants.

IIRS has received National Award for Excellence in Training on 'EDUSAT Program' and 'e-learning Program' for 2015 from DoPT and UNDP.

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

- Regular courses benefiting 505 participants on various courses, namely PG(41), Diploma (63), NNRMS (64), ITEC(33), Decision Maker (36), Certificate (9) and Special-courses (259).

- CSSTE-AP benefiting 112 participants on various courses conducted at IIRS, SAC and PRL, namely PG Course in RS & GIS (24), RS-Short Courses (19), International Training Course on Small Satellite Missions (25), PG Course on GNSS (9).

- Special/Tailor-made courses are being designed and conducted for Watershed Management (8), Indian Air Force (13), ISPRS Summer School (81), GB Pant Pantnagar (11): NCERT (18); Jammu University (10); Forest Department, West Bengal (11); Ministry of Environment and Forest

(20), India Meteorological Department (24); Indian Statistical Service Officers (20), Central Water Commission (25), National Institute of Veterinary Epidemiology UAV Remote Sensing (23).

- 95 summer trainees of various professional courses (e.g. B.Tech, M.Tech, MCA, etc.) from various Universities and affiliated Colleges have also benefited by completing Dissertation/Project-work at IIRS

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 416 persons by organising 18 courses (eleven Special, two 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 Geosphere Biosphere Programme (IGBP) has been mainly on measuring, modelling and monitoring in the biological, chemical and physical processes of the Earth system, thereby also understanding the regional factors influencing climate change. IGBP scientific activities on climate research are in existence for almost 20 years and an excellent in-situ measurement infrastructure has already been set up across the country through the various initiatives. The data collected under the projects like Aerosol Radiative Forcing over India (ARFI), Network of Observatories for Boundary Layer Experiments (NOBLE), National Carbon Project (NCP), Atmospheric Trace Gases Chemistry and Transport Modeling (ATCTM), Marine Carbon Nitrogen Cycles (MCNC), Energy and Mass Exchange in Vegetative Systems, etc., are of highly valuable inputs in the wake of pollution monitoring, weather and climate related studies.

Some of the salient finding/observations of Aerosol Radiative Forcing Over India & Integrated Campaign for Aerosols and Radiation Budget and Regional Aerosol Warming Experiment (ARFI, ICARB and RAWEX), include optical properties and Cloud Condensation Nuclei (CCN) activity of aerosols at Himalayan region; Enhancement in Black Carbon radiative forcing due to multiple scattering; Formation of ultra-fine particles and their varying growth rates at contrasting environment, etc.

As part of Network of Observatories for Boundary Layer Experiments (NOBLE) project, eight stations have been established so far and installation of a 32-m tower at Goa University, Goa, has been completed last year. Two major experimental campaigns were conducted during last year. The campaign conducted in Shillong, was aimed to investigate diurnal evolution of the vertical structure of ABL, its effect on mesoscale circulation and the role in controlling regional meteorology over a mountainous terrain during the per-monsoon season. The second campaign was conducted at the Indian Antarctic station at Bharati for investigating the ABL characteristics and vertical flux of energy and momentum.

As an outcome of the project 'Energy and Mass Exchange in Vegetative Systems', hot-spots of long-term change in evapotranspiration and net primary productivity over India have been diagnosed using satellite data and ground based observations.

Under the National Carbon Project (NCP), seven sub-projects were taken up aimed at the creation of remote sensing based spatial repository of terrestrial and oceanic Net Carbon balance estimates over India. They include Vegetation Carbon Pool, Soil Carbon Pool, Soil Vegetation Atmospheric Fluxes, Carbon Cycle Modelling and Simulation, Coastal Carbon Dynamics, Hydrogeochemistry of Cauvery Basin and Atmospheric CO^2 Retrieval and Monitoring.

Spatially explicit Carbon pool change assessment has been carried out and also permanent observatories were established for long term regional scale studies on terrestrial Carbon cycle under Vegetation Carbon Pools (VCP) project. Remote sensing based methods to upscale field specific/stand level measurements to large areas have been taken up.

As part of Soil Carbon Pools assessment, organic carbon stock of India has been estimated. The results show that total Carbon density was highest in Gujarat mainly due to contribution from higher Soil inorganic Carbon densities. Kerala and Assam have higher Soil organic Carbon densities due to luxurious vegetation growth. Under the theme soil and vegetation-atmosphere fluxes, six eddy flux towers have been established so far. The total Carbon sequestered and net ecosystem productivity has been estimated for these representative forest and agriculture ecosystems.

Cruises were conducted along Bay of Bengal and in Hooghly- Matla Estuarine system to understand the underwater optical parameters and the associated, biological, physical and chemical processes, as part of the studied on Coastal Carbon Dynamics.

Long-term (1981-2012) net primary productivity and net ecosystem productivity were simulated and its variability at different time scales was examined under the Carbon Cycle Modeling and Simulation activity. Regarding hydrogeochemistry study of Cauvery basin, samples were collected at 25 km distance for entire river from Talakavari to Point Calimer covering 725 km, for the analysis of water quality, sediment and surface Carbon profile parameters.

As part of Atmospheric CO^2 Retrieval and Monitoring, data collected during the year 2014-15 at the four stations using precision Greenhouse Gas Analyser (GGA), has been analysed for seasonal trends, diurnal variations and differences across the stations that are set in different geographical and environmental conditions.

Measurement and analysis of primary productivity and carbon uptake rates; source identification of Dissolved Inorganic Carbon (DIC) in the estuary and the Arabian Sea and N2 fixation rates measurements, etc., were carried out for Cochin Estuary and Coastal Arabian Sea, under the project Marine Carbon Nitrogen Cycles.

National Meet on "Promoting Space Technology based Tools and Applications in Governance and Development"

Use of Space Technology applications for governance and development has been on the constant rise since its inception about four decades back. Space based information and services, its visualisation

and analysis, combined with ICT tools have enabled or strengthened the decision making process in various disciplines. India has developed a sophisticated space technology system over the last few decades. India has been recognised as one of leaders in space technology applications that have a wide impact on society. The end-to-end capability in space for vital application in communications, navigation, meteorology and natural resource information, which are of direct relevance for national development, has secured India a unique place in the international community.

Today, space technology is being used for several diversified sectors, namely, agriculture, forestry and environment, water resources, urban planning, infrastructure development, asset mapping, mineral prospecting, ocean resources, meteorology, satellite communication, location based services, tele-education, tele-medicine, disaster management support and many more.

Considering the potential of Space Technology applications in governance and development activities of various Central Ministries/Departments and State Governments, the Prime Minister of India had urged Department of Space to pro-actively engage with all stakeholders to maximise the use of space technology applications.

Subsequently, assessment of current utilisation of Space technology-based tools in various Ministry/ Department was done and identification of new potential application areas which will benefit the country in governance and development was also carried out. In order to hold proactive interactions with the Central Ministries, 18 expert teams were constituted within ISRO. These teams conducted one-to-one interactions with the Ministries/ Departments and a joint action plan on “Effective Use of Space Technology” was prepared with 60 Central Ministries/Departments. About 160 projects across various Ministries/Departments have emerged in the areas of Natural Resources Management, Energy & Infrastructure, Disaster & Early Warning, Communication & Navigation, e-Governance & Geo-spatial Governance, Societal Services, and Support to flagship programmes.

A one-day National Meet was organised on September 07, 2015 at Vigyan Bhavan, New Delhi to deliberate on the action plans of various Ministries/Departments. The National Meet received an overwhelming response with the participation of more than 1200 delegates across 60 Central Ministries/ Departments, 28 States and 5 Union Territories. Secretaries, Additional Secretaries, Joint Secretaries to Government of India, Chief Secretaries, Principal Secretaries of the States and senior functionaries of Central and State Governments, officials from Prime Minister's Office and Cabinet Secretariat, young administrators as well as experts from academia and institutions actively participated in this Meet. The Prime Minister of India addressed during the concluding session of the National meet and emphasised the need for new initiatives in all areas of governance, using space technology applications.

Hon'ble Prime Minster addressing the Delegates during the National Meet

Subsequent to the National Meet, considering the large number of projects projected by the Ministries during the National meet and the importance of the frequent interaction and follow-up of these projects, enabling formation of space technology cells, wherever necessary, and exploring newer space based applications, ISRO/Department of Space has formed 22 dedicated working groups to interact with various Departments/Ministries.

Space Transportation System

The Indian Space Programme has made successful transition in terms of technology acquisition and launch vehicle development in the last year. PSLV went on to become a favoured carrier for satellites of various countries due to its reliability and cost efficiency, promoting unprecedented international collaboration. The Geosynchronous Satellite Launch Vehicle (GSLV) with indigenous Cryogenic stage, graduated to become an operational vehicle for communication satellites. Future readiness is the key to maintaining an edge in technology and ISRO endeavours to optimise, accelerate and enhance its technologies through establishment of facilities and forging partnership with industries. ISRO is moving forward with the development of heavy lift launchers, human spaceflight, reusable launch vehicles, semi-cryogenic engines, etc., to cater to different payloads and an array of missions.

Major Accomplishments

Polar Satellite Launch Vehicle

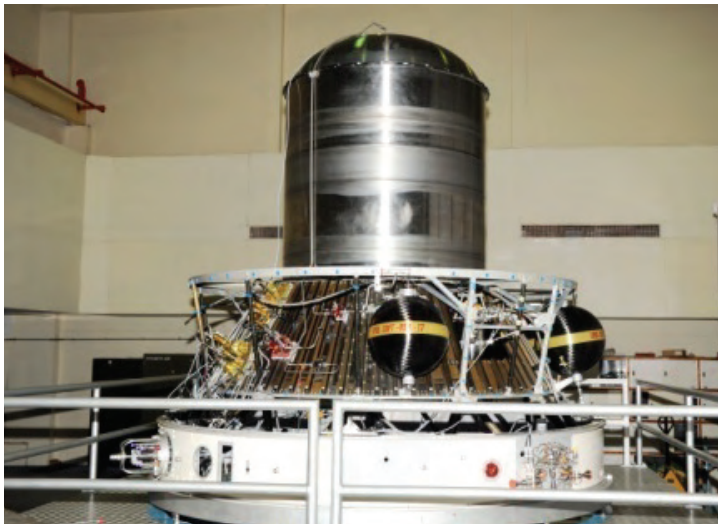
Polar Satellite Launch Vehicle (PSLV), the Indian operational launcher, completed its thirty second flight during the year. It was the thirty one consecutive successful mission, further proving the reliability and versatility of this medium lift vehicle developed by ISRO. Through these launches, PSLV has demonstrated a variety of missions such as Sun Synchronous Polar Orbit (SSPO), Geosynchronous Transfer Orbit (GTO) and Low Earth orbits (LEO) thereby emerging as the workhorse launch vehicle of India.

PSLV-C30 Lift-off

During the year, PSLV-C27 successfully launched IRNSS-1D, the fourth satellite in the Indian Regional Navigation Satellite System (IRNSS) on March 28, 2015 from Satish Dhawan Space Centre SHAR, Sriharikota. This was the 28th consecutively successful mission of the PSLV. The 'XL' configuration of PSLV was used for this mission. Previously, the same configuration of the vehicle was successfully used seven times. IRNSS-1D Satellite weighing 1425 kg was precisely injected to an elliptical orbit of 282.52 km X 20,644 km.

PSLV-C28 successfully launched five of United Kingdom's satellites from three DMC3 satellites,

CBNT-1 and Deorbit sail) on July 10, 2015 from Satish Dhawan Space Centre (SDSC) SHAR, Sriharikota. These five satellites were launched as part of the commercial agreement between DMC International Imaging, a wholly owned subsidiary of Surrey Satellite Technology Limited (SSTL), UK and Antrix Corporation Limited. This flight was unique since it was the heaviest Commercial Launch ever undertaken by ISRO with payload of 1440 Kg and for the first time, the 'XL' version of PSLV was used to launch commercial payloads exclusively.



PS4 Stage

PSLV-C30 in the 'XL' configuration successfully launched ASTROSAT, a Multi Wavelength Space Observatory into a 644.6 km X 651.5 km orbit at an inclination of 6 degree to the equator on September 28, 2015 from SDSC, SHAR Sriharikota. Six co-passenger satellites (LAPAN-A2, NLS-14 and four of LEMUR satellites) were also launched in this mission. The total weight of these seven satellites carried by PSLV-C30 was 1631 kg and this was the thirtieth consecutive success for PSLV.

PSLV-C29 in 'Core Alone' configuration carried TeLEOS-1 spacecraft in a dedicated commercial Mission for ST Electronics, Singapore on December 16, 2015. Besides the primary satellite TeLEOS-1 (401 kg), five more satellites from Singapore were flown as co-passengers in this Mission. The satellite were placed in 550km Circular orbit at 15° inclination.

PSLV-C31 in 'XL' configuration successfully launched IRNSS-1E, the fifth in the seven satellites IRNSS system into a GTO. Two more PSLV missions in 'XL' configuration i.e. PSLV-C31/IRNSS-1E, PSLV-C32/IRNSS-1F and PSLV-C33/IRNSS-1G Missions are targeted to launch by March 31, 2016 to complete the first phase of Indian Regional Navigation Satellite System constellation over Indian Region.

Productionisation of PSLV: It is planned to increase the production of PSLV Systems to cater to growing demands of national as well as commercial satellite launches.

GSLV-D6 Lift-off

Geosynchronous Satellite Launch Vehicle (GSLV)

Geosynchronous Satellite Launch Vehicle (GSLV) is a three-stage vehicle with solid, liquid and cryogenic upper stage, designed to place 2 ton class of communication satellite in the Geosynchronous Transfer Orbit (GTO).

GSLV-D6 with indigenous Cryogenic Upper Stage (CUS), successfully launched GSAT-6, an advanced communication satellite of 2117 kg, into GTO on August 27, 2015, from the Second Launch Pad of SDSC, SHAR, Sriharikota. The spacecraft was placed in its pre-determined GSO with great precision. GSLV-D6 mission further demonstrated the reliability of CUS developed by ISRO. This was the ninth flight of GSLV, the fifth developmental flight and third flight to carry the indigenous Cryogenic Upper Stage. This launch signified a major step in perfecting highly complex cryogenic propulsion technology and also achieving self-reliance in launching 2 Ton class communication satellites into GTO.

The realisation of subsystems/stages for the next flight GSLV-F05 has commenced. GSLV-F05 carrying INSAT-3DR satellite, is targeted for launch during the third quarter of 2016.

CUS 06 Stage assembly

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). It is a three stage vehicle with two solid motor strap-ons (S200), a liquid propellant core stage (L110) and a cryogenic stage (C25). The solid motors and liquid propellant core stages were successfully flight tested in the sub-orbital GSLV-Mk III X-mission during December 2014. This flight validated the vehicle design for the crucial and complex atmospheric flight regime and the stage separation systems. Post Flight Analysis (PFA) of GSLV-Mk III X-mission has proposed changes in vehicle configuration to improve robustness of GSLV-Mk III launch vehicle for all seasonal wind conditions. The changes in heat shield from bulbous to give and slanted nose cone for S200

S200 Motor Static Test

strap-ons are being implemented and will be validated in GSLV-Mk III-D1 flight. In addition to above changes, grain configuration of head end segment of S200 motor was modified to reduce the peak dynamic pressure on the launch vehicle during atmospheric flight regime. To validate the changes in S200 Head End Segment grain configuration, a static test of S200 (ST-03) was successfully conducted on June 14, 2015.

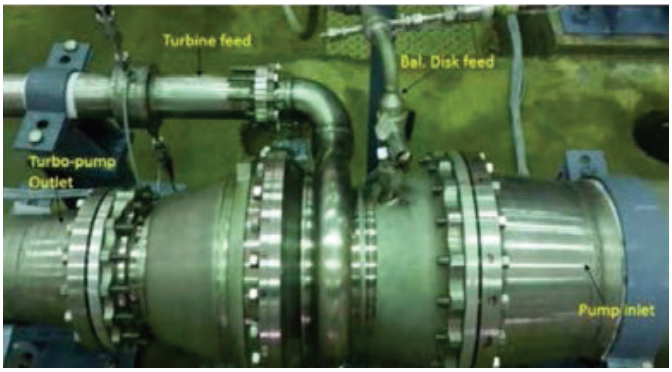
Significant achievements were also made in the development of high thrust cryogenic CE20 engine. Integrated Engine (E1) development test at sea level conditions were completed with the successful accomplishment of 12 tests, which validated the structural integrity of engine systems and demonstrated the repeatability of engine performance. Two cold flow tests and 10 hot tests including one flight duration hot test for 635 seconds and one extended duration hot test for 800 seconds were carried out. This engine will be used to power the C25 cryogenic stage for GSLV-Mk III launch vehicle. Realisation of C25 stage is in advanced stage. Propellant tanks are realised and engine & stage integration is in progress. The ground testing of C25 cryogenic stage is expected to be completed by the second half of 2016.

CE20 Engine Hot test

Propellant Casting of S200 middle segments for GSLV-Mk III-D1 had been completed. Structures and propellant tanks for L110 flight stage have been realised and stage assembly is in progress at IPRC, Mahendragiri. Sub assembly preparation activities are in progress for other systems. The launch of GSLV-Mk III-D1, the first developmental flight carrying GSAT-19E satellite of mass 3200 kg, is targeted during last quarter of 2016.

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). The semi-cryogenic engine uses a combination of Liquid Oxygen (LOX) and ISROSENE (propellant-grade kerosene), which are eco-friendly and cost-effective propellants.



Semi-Cryo LPOT Cold Flow Test

Integrated Technical Reviews of semi cryogenic Engine by the National Expert Panel has ratified the engine specifications, system configuration

and approach adopted for design of major engine sub-systems and the engine development/qualification plan. Fabrication of engine subsystems i.e., Thrust Chamber, Mixing head, Main Turbo pump, Booster Turbo pumps, Pre-burner and Heat Exchanger are in progress. Cold flow tests (five tests in non-cavitation mode) of Low Pressure Oxidiser Turbo Pump (LPOT) were conducted at newly established Cold Flow Test facility (CFT) at IPRC, Mahendragiri. Semi cryo pre burner single element injector hot tests (11 nos.) were also conducted demonstrating the ignition with hypergolic igniter and flame holding at very high mixture ratios.

Design of subscale Pre-Burner and Thrust Chamber is completed and realisation is in progress. Out of 21 types of engine control components, assembly and testing of 16 types have been completed. Assembly and testing of two types and fabrication of three types are in progress. Also, realisation of four types of control components for Hydraulic Actuation System (HAS) is in progress. Preliminary details of overall Stage configuration and stage engineering of Semi-cryo stage with 200 T propellant loading (SC 200) has been worked out.

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 Ground Resonance Test (GRT) and Structural Coupling Test (SCT) for both ascent and descent phases. Dynamic characterisation of Base shroud sub assembly through Acoustic test was conducted at NAL, Bengaluru. Dynamic characterisation for ascent and descent configurations and dynamic response analysis for HS9 ignition transient using GRT validated mathematical models were completed. NGC software simulation tests, wind measurement trials, tests pertaining to Telemetry were carried out. Qualification of components of actuation system such as actuators, accumulator and reservoir was successfully conducted and integrated into flight system.

Structural qualification test of sandwich composite movable fin, Nose cap, base shroud, actuator loop stiffness evaluation, wing pressurisation tests, structural qualification of fuselage-wing-interstage assembly, Structural and Thermo-Structural qualification tests of vertical tail, Nose cap thermal simulation and Rudder thermo-structural test cases have been carried out. Mechanical integration mock up was completed at First Launch Pad, SDSC SHAR.

Assembly and Integration of TDV

The Integrated airframe structure and inter stage have been realised. The flight components assembly in base shroud and Technology Demonstration Vehicle (TDV) is in progress. Avionics packages were integrated in Avionics Bay and tested. First phase of sign checks was completed. Mounting of Sensors, RCS integration, TPS bonding and Carbon-Carbon nose cap assembly, electrical harnessing of fuselage, base shroud and inter-stage have been completed. The HS9 motor segment is assembled and positioned at SDSC SHAR.

The first experimental mission, Hypersonic Experimental Flight (HEX-01) is targeted during the first quarter of 2016.

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 phases. The pre project activities are progressing with an aim of developing critical technologies that are needed to undertake human spaceflight mission. Significant progress was made in Crew Module (CM) System, Crew Escape System (CES) and Environmental Control and Life Support System (ECLSS). Post flight assessment of the Crew Module, recovered from sea after the successful GSLV-Mk III/CARE sub-orbital mission in December 2014, indicated that all the objectives of the mission were achieved satisfactorily.

The major developments in the area of critical technologies as part of pre-project phase are given below:

Crew Escape System (CES): The first major milestone in CES qualification is the Pad Abort Test (PAT) flight, to demonstrate the functioning of CES during any emergency condition occurring at launch pad. Design of structural elements, namely, Nose Cone, Pitch Motor Compartment, Inter-stage, Crew Module Fairing and Igniters for motors, have been completed. Fabrication activities are in progress for realisation of sub-systems.

Crew Module (CM) Systems: Crew Module for PAT flight has the same configuration as flown in CARE mission. Realisation of CM with metallic inner structure, CFRP panels and honeycomb avionics deck is in progress at work centres. Additional qualification tests have been planned on Parachute system to enhance its robustness. A high rate Inertial Navigation System is included in PAT flight for measuring CM attitude after separation from CES.

Environmental Control and Life Support Systems (ECLSS): Significant progress has been made in the functional modules of ECLSS like Carbon dioxide and Odour Removal System [CORS], Temperature and Humidity Control System [THCS] and Cabin Pressure Control System [CPCS]. As part of CORS development, comprehensive tests using Lithium Hydroxide (LiOH) pellets were carried out to evaluate pressure drop across canisters. Testing of THCS as an integrated unit comprising of the various types of heat exchangers is in progress. A thermo-vacuum chamber for testing space radiator and Gas bottle to store high pressure Oxygen were realised and successfully qualified.

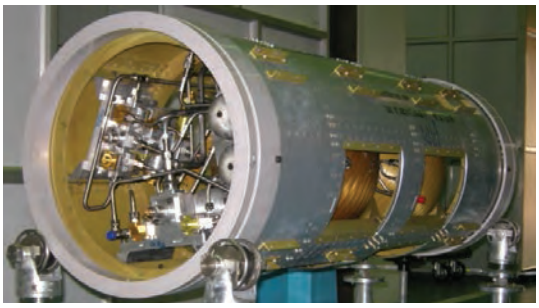
Air Breathing Propulsion Project (ABPP)

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 their associated technologies have been initiated, the present focus is on development of scramjet engine and flight testing the same in a cost effective method using Advanced Technology Vehicle (ATV).

The major highlights of development in this regard in the year include realisation of Avionics module and Energiser for Pilot Flame Ignition Unit, Qualification of Silicon Carbide coated Carbon/Carbon leading edges through hot tests at 6 MW Plasma Wind Tunnel Facility and commencement of Integration activities on scramjet engine frame and engine flow duct.

Engine Flow Duct

Rapid expulsion tests using gaseous hydrogen modules for the Titanium lined Carbon wrapped Gaseous Hydrogen bottles to be housed in Fuel Storage and Feed System was successfully conducted at IPRC, Mahendragiri. Acoustic characterisation test of Engine and Fuel Feed System as mounted to sustainer vehicle configuration was carried out at NAL, Bengaluru.



Fuel Storage and Feed System

Assembly and Integration of Air Breathing propulsion modules, namely. Scramjet Engines and Fuel Feed System for ATV-D02 flight, are in progress. The demonstration flight of advanced Technology Vehicle carrying active scramjet engine flight is targeted in 2016.

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 (ATV-D02) flight: ATV-D02 is the sounding rocket identified for carrying the twin scramjet air breathing engines for demonstrating supersonic combustion experiment scheduled during first quarter of 2016. The major activities completed towards this mission is Acoustic Test of

ATV-D02 sustainer vehicle configuration at National Aerospace Laboratories (NAL), Bengaluru, booster motor casting and spin test of Advanced Telemetry System with Sequencer. The Sustainer motor is ready for casting and the Aero dynamic and structural load studies have been completed.

Sounding Rockets

Totally nine RH-200 rockets were successfully launched during the year from TERLS range. A major milestone was achieved on July 15, 2015 when 100th successive successful launch of RH-200 rocket was conducted from TERLS, VSSC.


RH-200 Launch

Sounding Rockets Experiment (SOUREX) Programme: SOUREX is one of the pioneering experiments in ISRO to carry out in-situ measurements of wind and its composition, electron/ion density and electric field at various altitudes in the atmosphere. The programme will make use of 11 sounding rockets (3 RH-560, 4 RH-300 and 4 RH-200). The scientific payloads from Space Physics Laboratory (SPL) that are to be flown for conducting the SOUREX experiments are Electron Density and Neutral Wind Probe (ENWi), Langmuir Probe(LP), Earth's Atmospheric Composition Explorer Payload (EACE) and Tri Methyl Aluminum (TMA) payload. Realisation of RH-300 rocket is already completed and is ready for launch when the climatic conditions are conducive for TMA experiment. A RH 560 Mk III rocket is also under development towards this programme.

Infrastructure

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

VSSC: Iron Bird facility for Actuator-In-Loop, Simulation tests, Chemical Vapour Infiltration (CVI) Facility, Fluid Energy Mill (FEM) facility, Polydimethylsiloxane production plant, 35 kN Shaker system and Deep Space simulation system.

LPSC: Material characterisation laboratory, creep test facility, Integrated chemical cleaning facility, spin test facility, Stores for Engine materials.

SDSC-SHAR: Multi-Object Tracking Radar (MOTR) facility installed and is under testing. Facilities at SPP for PSOM-XL motor production.

IPRC: Semi-cryogenic Cold Flow Test facility (SCFT), New Control system for Main Engine and Stage Test Facility and Hydrazine Plant.

IISU: X-ray fluorescence (XRF) Analyser facility, Horizontal thermo vacuum chamber test facility for testing high power SADA drive electronics.

Space Sciences and Planetary Research

With the successful launch of the Indian multi-wavelength astronomy mission and completion of two years after the launch of Mars mission, the Indian space programme has gained impetus and skill sets to take up new projects in space science and planetary exploration.

Space science research activities are being pursued at Physical Research Laboratory (PRL), National Atmospheric Research Laboratory (NARL), Space Physics Laboratory (SPL) at VSSC, Space Astronomy Group (SAG) at ISAC and in other ISRO centres.

A number of research projects in the field of atmospheric science, astronomy and planetary exploration are supported and implemented at various universities and research Institutes based on the recommendations of Advisory Committee for Space Science (ADCOS) and approval from ISRO. Space science promotion and strengthening of space science in Universities is also being carried out. Scientists from various research institutes are encouraged to undertake space instrument/payload activities with ISRO funding support.

The major activities carried out under space science and planetary research during 2015-16 are summarised below.

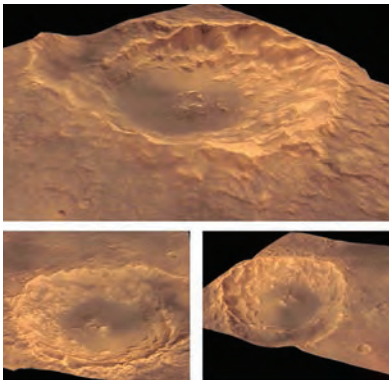
MARS ORBITER MISSION

Mars Orbiter Mission (MOM) completed two years after its launch on November 05, 2013 from Satish Dhawan Space Centre, Sriharikota. ISRO has been continuously monitoring the spacecraft using its Deep Space Network complemented by that of Jet Propulsion Laboratory (JPL) of NASA. MOM completed its design life duration of 6 months of orbiting around Mars on March 24, 2015. It has now outlived its expected life and has spent over an year (completed on September 24, 2015) orbiting Mars.

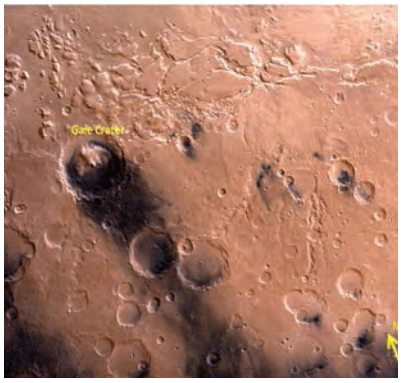
MOM went through a communication blackout as a result of solar conjunction from June 2, 2015 to July 2, 2015. Telemetry data was received even during most of the conjunction period except for 9 days from June 10 - 18, 2015, during superior conjunction. MOM was commanded with autonomy features starting May 18, 2015, which enabled the spacecraft to survive the communication blackout situation without any ground commands or intervention. The spacecraft could therefore successfully emerge out of blackout period with auto control of spacecraft systems.

The national and international scientific community accorded laurels on ISRO for successfully placing MOM in Mars orbit in the very first attempt, and MOM was awarded one of the 25 best inventions of 2014 as listed by American News magazine 'Time' and Space Pioneer award of 2015 instituted by National Space Society of USA. In view of attaining this significant achievement in space technology, ISRO was awarded with Indira Gandhi Prize for Peace, Disarmament and Development for the year 2014.

Mars Colour Camera (MCC) has acquired more than 440 images so far. By virtue of MOM's unique elliptical orbit, MCC could image the full Martian disc at single shot and also the Phobos and Deimos, the two moons of Mars from close distances. MOM is the only Martian artificial satellite which could image the far side of Deimos. Some of the images taken by MCC are shown below.



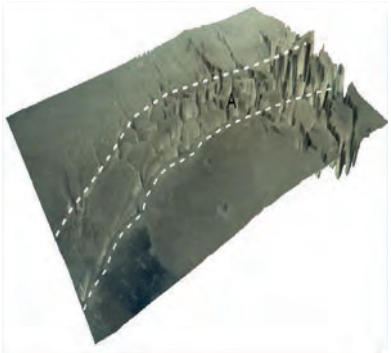
3D view of Impact Crater



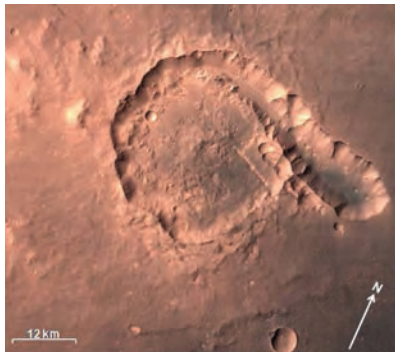
Gale Crater

Shield Volcano Tharsis Tholus

Mosaic created from MCC Images



3D View of Arcuate block-faulted graben



Pittal Crater

Mars Atlas was prepared and made available on ISRO website (www.isro.gov.in) for general public.

The Mars Exospheric Neutral Composition Analyser (MENCA) payload has observed several species in its neutral mass spectrum. Specific studies of altitude variation of these are made. Since Thermal Infrared Imaging Spectrometer (TIS) has an uncooled bolometer as detector, good sensitivity is obtained

only during higher temperatures and a few images are taken under appropriate observation conditions. The Lyman Alpha Photometer (LAP) payload has had 80 operations so far and hydrogen Lyman alpha intensity is estimated as a function of altitude and further studies are underway.

ISRO has made an announcement of opportunity for utilising the MOM data to encourage and expand the scientific community to access and analyse the data.

ASTROSAT Mission

ASTROSAT is the first dedicated Indian astronomy mission aimed at studying celestial sources in X-ray, optical and UV spectral bands simultaneously. The spacecraft was launched successfully on September 28, 2015 from SDSC Sriharikota into a 650 km near-equatorial orbit with an inclination 6 degree by PSLV-C30.

ASTROSAT Integration under progress in the Clean Room

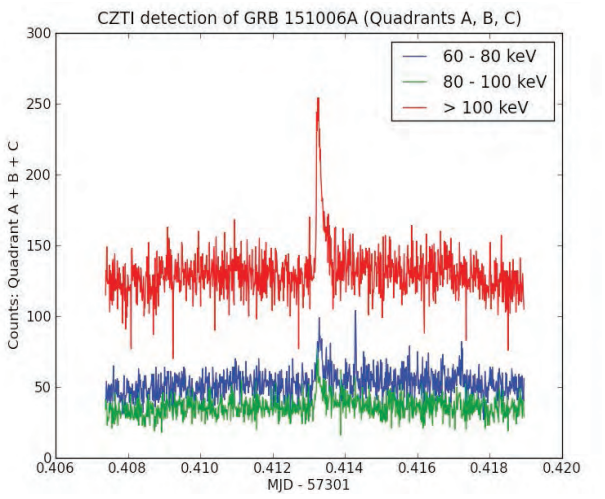
The payloads of ASTROSAT are:

- Ultra Violet Imaging Telescope (UVIT) consisting of two identical telescopes, one covering the FUV band (130 - 180 nm) and the second sensitive to NUV (200 - 300 nm) and the Visible (320 - 550 nm) bands.
- Soft X-ray Telescope (SXT) with CCD camera for timing and variability studies in the X-ray bandwidth of 0.3 to 8 keV.
- Three Large Area X-ray Proportional Counters (LAXPCs) operating in 3-80 keV band for timing and spectral studies.
- Cadmium Zinc Telluride Imager (CZTI) array with coded mask aperture for hard X-ray imaging and spectral studies in 10-100 keV.
- Scanning Sky Monitor (SSM) for X-ray transient & monitoring in the 2.5-10 keV band using proportional counter system.
- Charge Particle Monitor (CPM) an ancillary payload, to detect high-energy particles during the satellite orbital path and alert the instrumentation.

All these payloads are operational. The first sky observations and preliminary results were made available in the ISRO website. Some of the results are provided below.

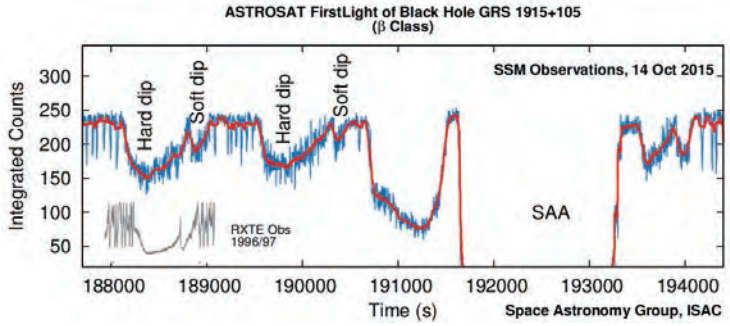
i) Detection of Gamma Ray Burst (GRB) 151006A by CZTI:

GRBs are bursts of gamma-rays, coming from apparently random directions in the sky. This GRB is reported by NASA's Swift satellite. CZTI detected the GRB and has seen significant and sharp jump in the counts above 100 keV during the time of GRB. CZTI has demonstrated its ability in detecting Compton scattering events. This information is flashed to the scientific community through GCN circular 18422. CZTI has the capability to estimate polarisation of the incoming events at hard energies. This is to be demonstrated in future observations.



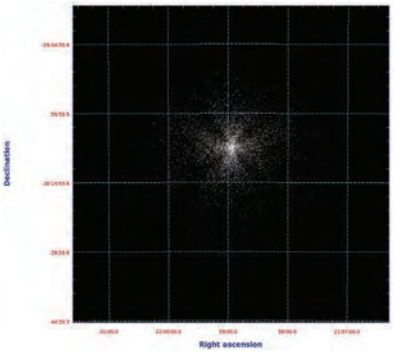
ii) GRS 1915+105 - a Galactic Black Hole source viewed by SSM:

SSM observed the black hole source, GRS 1915+105. On October 14, 2015, the source displayed 'structured' X-ray variability, the 'β class'. β class variability is associated with the ejection of material in the form of jets from the Black Hole system, accompanied by radio emission. Since this class of variability remains only for a few days and may be associated with radio flares, the observation is reported as an "Astronomers' Telegram" ATel #8185.

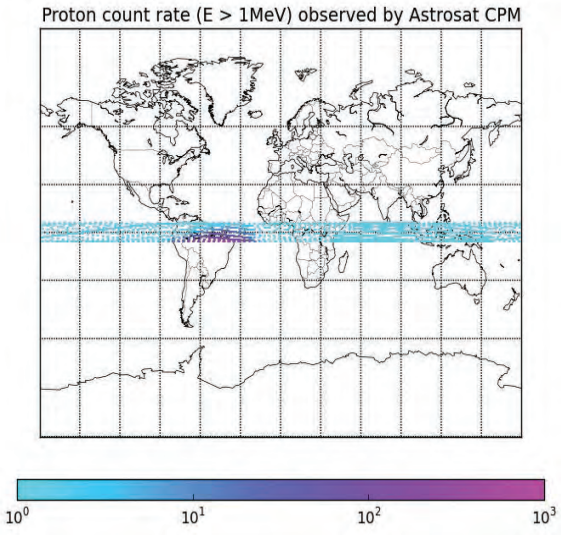


iii) Blazar viewed by SXT:

PKS2155-304 is a bright blazar (a special type of Quasar with a superluminal jet – a stream of particles accelerated to nearly the speed of light - pointing almost towards the telescope) about 1.5 billion light years away. The source is actually a point source. The wings and extensions are due to the special nature of grazing incidence optics and the way the 320 mirrors were assembled and held together to make the telescope optics.



iv) Charged particle counts monitored by CPM:



Low particle rates – Cyan colour

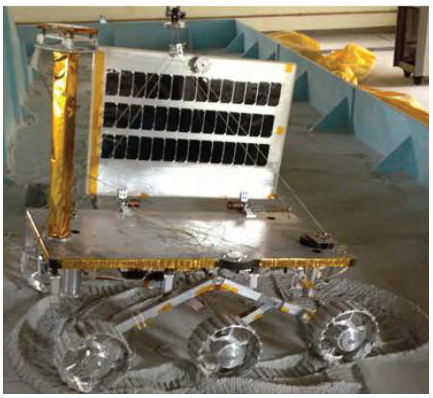
Location of the high background SAA region - Magenta patch

Satellites in the Low Earth Orbit (LEO) pass through the trapped radiation belts of the South Atlantic Anomaly (SAA) region which has high fluxes of protons and electrons. SAA at altitudes above ~600 km spans approx -50 deg to 10 deg latitude and -90 deg to +40 deg longitude. Particle rates can go very high when the satellite enters SAA region. CPM will measure the count of charge particles at the satellite location and will automatically provide a signal to other instruments.

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 the first quarter of 2018. A major milestone of the spacecraft level Preliminary Design Review (PDR) has been completed in the month of May 2015.

Open field test between lander and rover at HAL airport



Six Wheeled Rover (New Configuration)

Orbiter Craft: The primary structure has been realised and delivered to the integration team for the integration with other subsystems which will begin from Dec 2015. Some of the mainframe systems are realised and some are in the Test and Evaluation phase. The Payloads are being realised at various centres and few are in an advanced stage of development. The equipment panel layouts are in the final stage of release. Interfaces between Orbiter and GSLV-Mk II has been finalised.

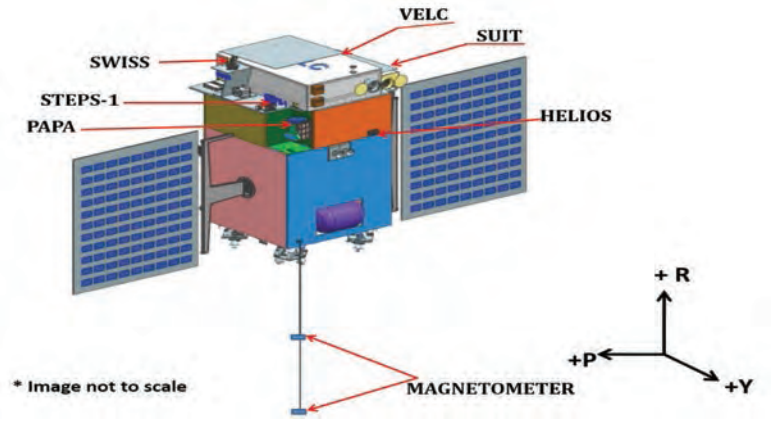
Lander Craft: The Lander Craft configuration has been finalised for a safe and soft landing at the identified site. The mission critical elements of sensors and actuators for a safe and soft landing are being developed at various centres. The development/qualification models are expected to be delivered in the middle of 2016. The special tests to verify the integral performance of all sensors, actuators and software in a closed loop are planned in the middle of 2016. Accommodation study of all elements has been completed. The 800 N Liquid Engines have undergone High Altitude Test (HAT) for a duration of 513 sec successfully. A Standing Technical Review committee (STRC) met and is overseeing the overall progress of the new Advanced technologies present in the lander.

Rover: The Engineering model of six wheeled rover is being realised. Navigation Camera, Inclinometer, Rover imager and mechanism hardware are ready for integration. The other systems are in the final stages of fabrication. The illumination setup for the lunar terrain test facility has been commissioned.

Aditya - L1 Mission

The Aditya mission has now been revised to Aditya-L1 mission which will be inserted in to the halo orbit around Lagrangian point 1 (L1) of the Sun-Earth system. The satellite carries additional payloads with enhanced science scope and objectives.

The primary objective is to study the solar corona and processes leading to changes in the solar corona and to understand what heats the corona. Observations of Sun's Photosphere (soft and hard X-ray), Chromosphere (UV) and corona (Visible and NIR) are possible. The project is approved and the satellite will be launched during 2019 – 2020 timeframe by PSLV-XL from Sriharikota.



Aditya spacecraft with magnetometer in deployed condition

The main payload, the Coronagraph, will study the solar corona in the visible the and Infrared bands, UV payload will observe the Chromosphere, X-ray payloads will study the solar flares, Particle payloads are to study the particle flux emanating from the Sun and reaching the L1 orbit, and the magnetometer payload is to measure the variation in the magnetic field strength due to this.

The selected payloads and their capability are provided in the table below:

Payloads	Science capability	Lead Institution
Visible Emission Line Coronagraph (VELC)	Corona Imaging, Spectroscopy and spectro-polarimetry	Indian Institute of Astrophysics (IIA)
Solar Ultraviolet Imaging Telescope (SUIT)	Photosphere and Chromosphere Imaging in near UV (200-400 nm)	Inter-University Centre for Astronomy and Astrophysics (IUCAA)
Aditya Solar wind Particle Experiment (ASPEX)	Solar wind/Particle Analyser	Physical Research Laboratory (PRL)
Plasma Analyser Package For Aditya (PAPA)	Solar wind/Energy distribution	Space Physics Laboratory (SPL), VSSC
Solar Low Energy X-ray Spectrometer (SoLEXS)	Soft X-ray Spectrometer (1-30 keV) to monitor X-ray flares	ISRO Satellite Centre (ISAC)
High Energy L1 Orbiting X-ray Spectrometer (HEL1OS)	Hard X-ray Spectrometer (10 keV to 150 keV) to study solar eruptive events.	ISAC and Udaipur Solar Observatory (USO)-PRL
Advanced Tri-axial High Resolution Digital Magnetometers	Measure Magnetic Field/In-situ measurement	Laboratory for Electro-Optics Systems (LEOS) and ISAC

Polarimeter Instrument in X-rays (POLIX) payload on X-ray Polarimeter Satellite (XPoSat)

Over the last four decades, several missions in X-ray astronomy have made significant advances in instrumentation to conduct imaging, timing and spectroscopic observations of several X-ray emitting sources. However, it has been increasingly realised that resolution of several very important and key scientific issues about cosmic X-ray sources require polarisation measurement.

The scientific objective of this satellite is to have a simple Polarimeter Instrument in X-rays (POLIX) to detect and measure low degree of X-ray polarisation at 2-3% level for about 50 bright X-ray sources in the 5-30 keV range by the process of Thomson scattering. The project proposal is submitted for necessary approvals.

The engineering model of POLIX is under development at Raman Research Institute (RRI), Bengaluru. Preparations for qualification tests will be done in the future.

RESEARCH ACTIVITIES IN SPACE SCIENCES

i) Astronomy and Astrophysics

Scanning Sky Monitor (SSM) payload developed by Space Astronomy Group (SAG) is successfully flown onboard ASTROSAT and is providing good results. SSM would survey the sky for brightening of X-ray intensity in any source viewed and alert the Astronomy community for follow up observations and studies.

The development of the Chandrayaan-2 Large Area Soft X-ray Spectrometer (CLASS) payload for Chandrayaan-2 and Solar Low Energy X-ray Spectrometer (SoLEXS) of Aditya-L1 missions are under progress.

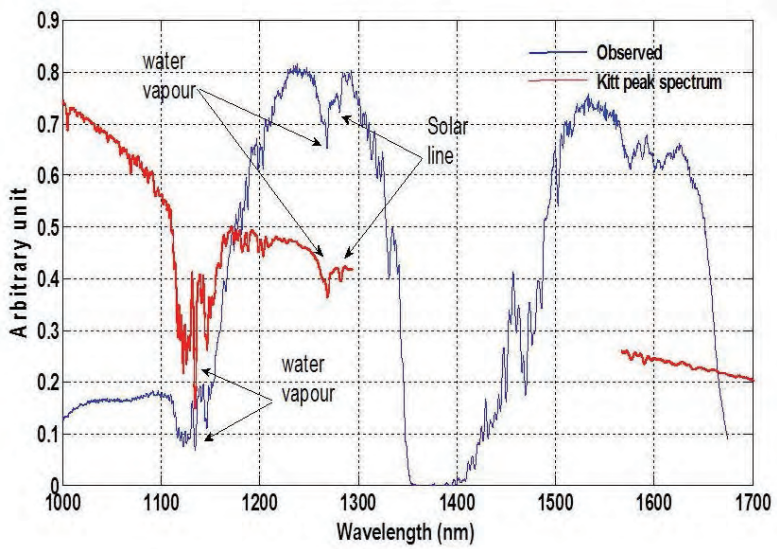
The group has also been involved in the following activities:

Developing a method to estimate mass of BH sources and investigated Cyclotron Resonant Scattering Feature (CRSF) in HMXB of Neutron stars.

Study of coronal spectra obtained at four different temperature lines for deriving the temperature, density, and emission measure.

Developing of a simulation code for radiative transfer in the Martian atmosphere in infra-red and its preliminary validation using archival data from Compact Reconnaissance Imaging Spectrometer for MARS (CRISM) payload of NASA's Mars Reconnaissance Orbiter (MRO) mission.

Gas Electron Multiplier (GEM) Based Soft X-ray Polarimeter, Charge Sensitive Pre-amplifier (CSPA), Probe for Infra-red Spectroscopy of Mars (PrISM) the technology development programs.



Observed spectrum with PrISM (blue) along with Solar spectral atlas from Kitt Peak Solar Observatory (Red). Solar lines are matched in these two spectra

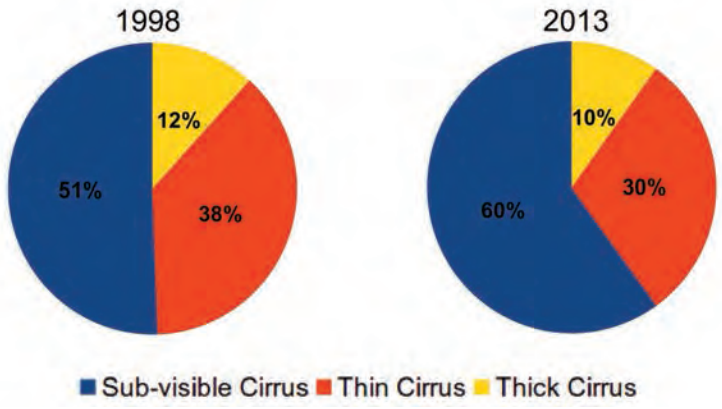
ii) Atmospheric Sciences

National Atmospheric Research Laboratory (NARL), DOS is involved in research on atmospheric sciences, indigenous technology development for atmospheric probing, weather and climate modeling.

The MST radar has been upgraded into a full-fledged active phased array system with transmitter and receiver modules made of solid state devices. An advanced mesosphere lower thermosphere photometer has been developed indigenously and installed at NARL in January 2015. The data is used for the study of the dynamic processes involved in the mesosphere-thermosphere coupling. The causative mechanisms of tropical mesopause variabilities are investigated. The mesopause temperature and ozone mixing ratios are positively correlated with the solar cycle due to changes in CO2 and O, respectively.

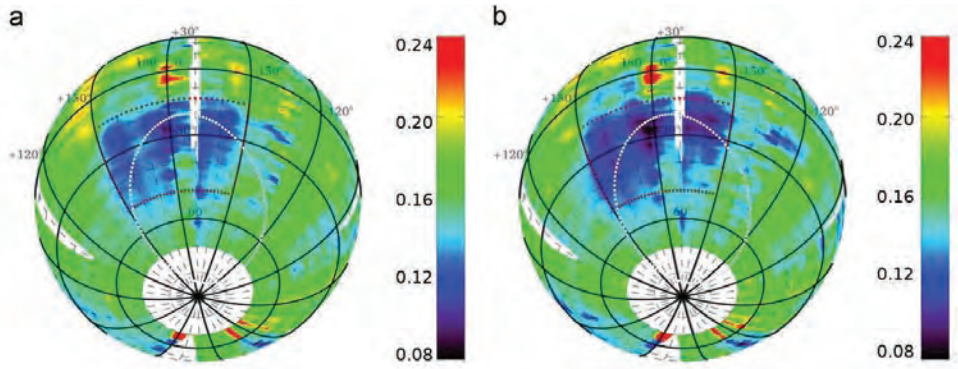
A study of 16-year (1998-2013) climatology of cirrus clouds and their macrophysical (base height, top height and geometrical thickness) and optical properties (cloud optical thickness) was observed using a ground-based lidar over Gadanki and outputs generated. The climatology obtained from the ground-based lidar was compared with the climatology obtained from seven and a half years (June 2006 – December 2013) of Cloud-Aerosol LIdar with Orthogonal Polarisation (CALIOP) observations onboard NASA's CALIPSO mission. A very good agreement is found between the two climatologies in spite of their opposite viewing geometries and difference in sampling frequencies. Nearly 50-55% of cirrus clouds were found to possess geometrical thickness of less than 2 km. Also, fraction of sub-visible cirrus clouds is found to be increasing during the last sixteen years (figure below) which has implications to the temperature and water vapour budget in the tropical tropopause layer.

Trend analyses reveal a statistically significant increase in the amount of sub-visible cirrus clouds increasing during the last sixteen years.



Space Physics Laboratory (SPL), VSSC is involved in the research on atmospheric, space and planetary sciences. Preliminary results from the analysis MENCA (Mars Exospheric Neutral Composition Analyser payload developed by SPL) data suggest significant variability in the atmosphere of Mars. The GMRT (Giant Meterwave Radio Telescope) observations of Venus at different frequencies were conducted, when Venus was close to Earth, for studying its sub-surface thermo-physical properties. The development of payloads for Chandrayaan-2 and Aditya-L1 missions are under progress.

Data from SARA payload on Chandrayaan-1 provided variations in backscattered Hydrogen Energetic Neutral Atoms (ENAs) over the South Pole Aitkin basin on Moon (fig. below).



ENA maps over the South Pole Aitken basin obtained from CENA/SARA aboard Chandrayaan-1.

(a) ENA in the low energy range (<30% of the incident solar wind energy), and (b) ENAs in the high energy range (>30% of the incident solar wind energy). The red polygon shows the approximate extension of the ENA feature and white ellipse shows the best fit to the topography data. [Ref: Planetary Space Science, 2015].

A new methodology has been developed to retrieve upper tropospheric humidity (UTH) from the Megha-Tropiques/SAPHIR microwave payload observations (Level 1 Tb data) data and the conversion coefficients are made available in the public domain. As a part of atmospheric chemistry studies, long term (2000-2014) trend in carbon monoxide (CO) obtained utilising the MOPITT measurements show decrease in lower tropospheric CO and column CO in spite of increasing anthropogenic activities. It is found that total Carbon and organic Carbon in the aerosol samples collected at Thumba contribute

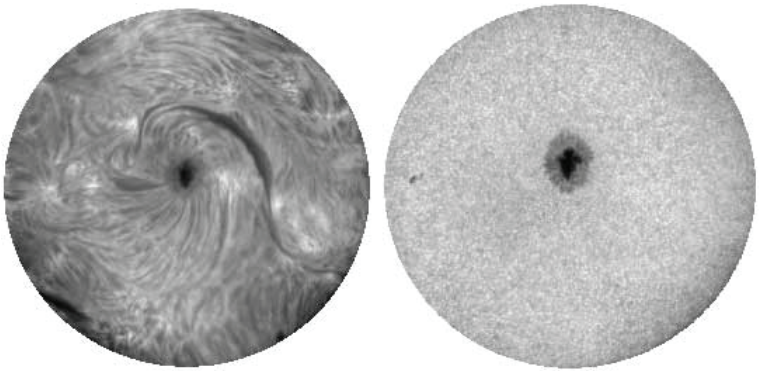
~22% and 18% respectively to the total aerosol mass. A year-long balloon-borne Frost-Point Hygrometer campaign for studying water vapour in the tropical upper troposphere and lower stratosphere is going on at Hyderabad and Thiruvananthapuram.

Planetary Sciences

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, Theoretical Physics, Atomic, Molecular & Optical Physics and Astrochemistry.

The Multi-Application Solar Telescope (MAST) at Udaipur Solar Observatory (USO) has been operationalised on June 16, 2015, and has started receiving data and found to be working as expected.

A View of USO; The collapsible dome enclosing the MAST is seen on the right side



Chromospheric (left) and Photospheric (right) images of a sunspot taken in H-alpha (656.3 nm) and G-band (430.5 nm) wavelengths. The sunspot is part of an active region NOAA# 12356, taken on June 2015, 05:13 UT.

The recurrent nova V745 Scorpii, in its third outburst on February 6, 2014 was monitored from the Infrared Observatory at Mt. Abu. This observation revealed the generation of a powerful blast wave by the high velocity (>4000 km/s) ejecta.

In the process of developing a modern polarimeter for the Multi-Application Solar Telescope, the Liquid Crystal Variable Retarders (LCVRs) used for the polarimetry were successfully characterised. Along with this experimental activity, a new Milne-Eddington inversion code was developed for the MAST polarimetry.

A significant clue about sunspot magnetic field was revealed for the first time by a study of the relative signs of chiral and shear components of the electric current in a sunspot.

Plans for establishing a 2.5 metre telescope facility at Mt. Abu are nearing completion.

PARAS Radial Velocity (RV) measurements suggested a transiting Jupiter like planet around a metal-rich red giant star.

Evidence of the effect of tropospheric cyclonic system on upper atmospheric dynamics has been obtained from Gurushikhar, Mt. Abu during the cyclonic storm Nilofar using optical airglow emissions and outgoing longwave radiation as the tracers for upper atmospheric and tropospheric wave activities, respectively.

The first ever pan-India seasonal and annual isotopic maps for precipitation across the country and the corresponding meteoric water lines are now available from IWIN Isotope Data and provide new insights about spatio-temporal variations in hydro meteorological processes operating in India.

A new chromatographic procedure for simultaneous extraction of Si and Mg has been established. This experimental development is a major step in facilitating the simultaneous study of silicon and magnesium isotope systematics of differentiated meteorites to understand core formation process and time scales for the formation of planetesimals and planets.

Planetary Science and Exploration Programme (PLANEX)

The PLANEX Program focuses towards enhancing research and development of instruments in the area of planetary science, in the country.

Two meteorites, Raghunathpura (IIAB) iron, a fall from Rajasthan, India and Nyaung (IIIAB) iron, a fall from Myanmar, were studied. Its shock thermal history. By studying its chemistry and its morphology is analysed. While extremely slow rate of cooling (4 C/Ma) followed by a strong late stage metal fractionation appears to explain the features of Raghunathpura, where as Rapid rate of cooling of Nyaung molten core may be explained in terms of fractional crystallisation of a small body of molten core insulated with a very thin silicate mantle, caused by a high degree of shock.

Using high resolution datasets from NASA's LRO, Kaguya of JAXA and ISRO's Chandrayan-1 missions, remote sensing investigations of the Lowell crater region (a ~198 x 198 km^2 area in the north western quadrant of Orientale basin) has been conducted. The analysis indicates that the Lowell crater formed due to an oblique impact (~30 deg -45 deg) in the Montes Rook from the S-SW direction ~370 Ma ago. The lithological assemblages of the various components of the Lowell crater indicate that it would have excavated a deep-seated pre-existing (pre/ post Orientale) mafic pluton. The region had witnessed volcanic eruptions as recently as ~2-10 Ma ago.

Development of the Alpha Particle X-ray Spectrometer (APXS), one of two instruments onboard Chandrayaan-2 rover to analyse several soil/rock samples with characteristic X-rays in 1 to 25 keV range, is in progress.

A lab model of a LaBr3:Ce based gamma ray spectrometer to conduct High energy (>100 keV) gamma ray spectroscopy is being developed. This can be used for remote sensing studies of chemical composition of planetary surfaces, for future missions.

Three new projects have been supported during the present year (2015-16) under PLANEX program. A total of 10 projects are being supported currently and 14 publications have resulted from the projects in the national and international journals during the year.

SPACE SCIENCE PROMOTION

ISRO's Space Science Promotion Scheme: ISRO-SSPS

ISRO-SSPS is an initiative by Advisory Committee on Space Sciences (ADCOS) 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. On completion of phase-1 activities, Phase-II activities (five years duration) of the scheme have already been initiated in five universities.

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 three gold and two silver medals at the International Olympiad in Astronomy and Astrophysics held at Indonesia during July 26 to August 3, 2015.

Nineteenth National Space Science Symposium – (NSSS-2016)

National Space Science Symposium (NSSS), sponsored by ISRO, is being conducted once in two years. NSSS provides a scientific forum for the presentation of new results and to discuss recent developments in space science, planetary exploration and space and ground-based astronomy programmes /projects being pursued at various research institutions and universities in India. During the symposium, best Oral and Poster Cash Prize Awards are being distributed to young scientists. The Nineteenth National Space Science Symposium (NSSS-2016) was held at VSSC, Thiruvananthapuram during February 9-12, 2016.

The symposium featured one popular lecture by along with invited lectures for the Special Plenary Sessions, interdisciplinary lectures and five parallel sessions (oral and poster presentations for contributory papers).

Sponsored Research

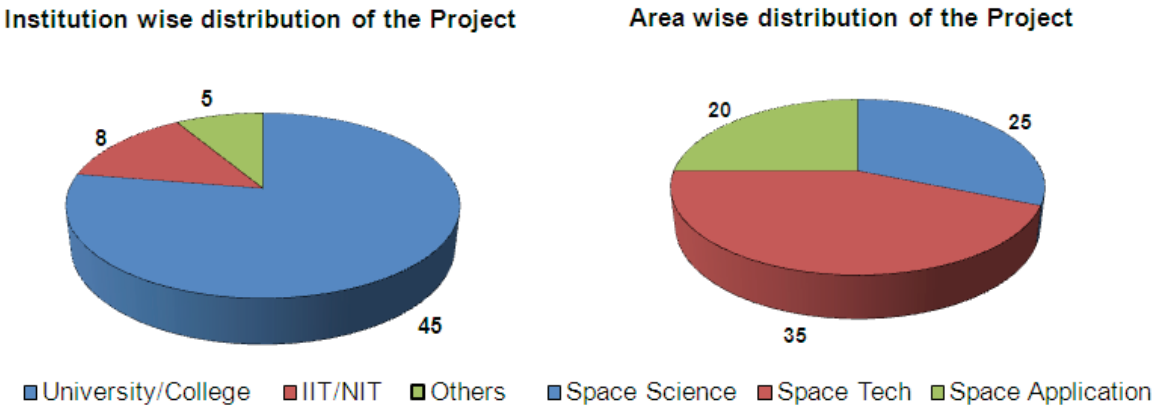
RESPOND (Research Sponsored) programme started in the 1970s, aims at encouraging academia to participate and contribute in various space related activities. Under RESPOND, projects are taken up by universities/academic institutions in the areas of relevance to Space Programme. Apart from this, ISRO has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

Activities

During the year, RESPOND supported 27 New Projects and 53 Ongoing Projects and five Space Technology Cells and Joint Research Programme with Savitribai Phule Pune University. In addition, ISRO Chairs and 45 conferences/symposia/ publications, and other scientific/promotional activities have been supported. During the year, 33 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 have interacted with various ISRO focal points/experts in realising the projects.

During the year, RESPOND has supported 45 Universities/Colleges, 8 IITs / National Institutes and 5 Research Centres to take up Projects both new and ongoing. Further, a good number of projects has been supported in all three broad areas, namely, Space Science (25), Space Applications (20) and Space Technology (35)



Projects at Space Technology Cells: During the year, RESPOND has supported 73 new projects and 115 ongoing projects of five Space Technology Cells and Joint Research Programme at Savitribai Phule Pune University, further 45 projects have been completed. Details are given in the table below:

Sl. No.	Name of STC/JRP	Number of Projects		
		New	Ongoing	Completed
1.	IISc Bengaluru	20	30	20
2.	IIT Madras	7	13	2
3.	IIT Bombay	11	5	4
4.	IIT Kanpur	13	16	3
5.	IIT Kharagpur	13	27	8
6	SP Pune University	9	24	8
Total		**73**	**115**	**45**

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 at Indian Institute of Science (IISc) Bengaluru, National Institute of Advanced Studies (NIAS) Bengaluru, IIT Kharagpur, SP Pune University and Bengaluru University.

Highlights of a few Major RESPOND Projects

- **Dual Blind detection Robust Watermarking for Multimedia Security:** A robust and secure technique is required to protect confidential data as it can be claimed by third party as their copy. Digital watermarking is used for Intellectual Property Rights protection and authentication. The project has successfully developed a watermarking scheme in JAVA with netBeans environment. Single Value Decomposition (SVD) was developed using Java Matrix Package. The retrieved image is highly correlated with the original watermark image in terms of normalised correlation and peak signal to noise ratio. The algorithm is robust under different attacks. The outcome of the research work can be used to watermark multi-media data (images) published from ISRO.

- **Study and optimisation of Microstrip Antenna System to receive satellite link from moving trains:** Under this project, an optimal microstrip based antenna system was developed to link GSAT-6/INSAT-4E satellites for railway mobile communication. The antenna was designed meeting specifications like gain, polarisation, radiation pattern, space constraints, etc., as well as ensuring dynamic stability. The proposed design for low gain antenna will be helpful in the development of ground terminal antennas.

- **Numerical simulation of suppression of residual flames and cooling of solid rocket motors using water injection:** Under this project, the numerical simulation of the residual flame quenching and further cooling of rocket motors using water jets by simulating the process using CFD (Computational Fluid Dynamics) codes was carried out. The injection of Nitrogen gas after the water injection is simulated numerically for S200 motor. An axisymmetric model with unstructured triangular grid is used for these simulations. The Study concluded that at 5 bar inlet pressure the nozzle is already chocked with Mach number 1 restricting the further increase in the mass flow rate. Further, the series of shock cells retract the jet further inwards, resulting in a smaller jet penetration. Hence, It is suggested that the quench nozzles are to be designed in such a way that they shall not get choked due to Nitrogen purging.

- **Evaluation of Ti-15-3 Beta Titanium Alloy for high Strength Fasteners for Space Applications:** Beta Titanium alloys are attractive materials for fastener applications. They can be heat treated to high strength levels and uniform mechanical properties can be realised over large cross sections. Further, Beta alloys have excellent cold formability coupled with other inherent attractive properties of Titanium alloys. The project aimed at evaluating Ti-15-3 alloy for fastener applications. The focus was on applications involving exposure to space atmospheres, an important design consideration of ISRO. Studies were carried out to evaluate the resistance of alloy to stress corrosion cracking, pitting corrosion and crevice corrosion. Slow strain rate test technique was adopted to conduct these studies. The studies were also carried out to characterise the resistance to general and localised corrosion, comparative evaluation of Ti-15-3-3 alloy was also conducted with Ti-6Al-4V alloy. Further, the effect of treatment and cold rolling on the electrochemical behavior of Ti-15-3 was studied. It has been established from the studies that Ti-15-3 is a candidate material for aerospace applications.

- **Development of Image Processing Method for assessing the Content of Trees outside Forest (TOF) using IRS high resolution satellite images:** The main aim of the project is to count the number of trees present in outside forests for a given Indian Remote Sensing Satellite Image. Trees outside the forests include tree in cities on farms along roads and in many other locations, which are by definition not a forest. Growing population, shrinking forests and degraded ecosystems all suggest that the trees outside forests are destined to play a larger local and global role in meeting the challenges of resource sustainability, poverty reduction and food security. Many algorithms were tested on Resourcesat-2, LISS-IV (5.8 m resolution) Images and are tested on 20 different Resourcesat-2 LISS-IV map zones of a single field. Out of the implemented algorithms, Hybrid model of K-Means and NDVI in laboratory color space gives good results for multispectral images and Principal Component Analysis for monochrome images.

- **Development of stable Pt and Ni doped nanostructured ternary semiconductor catalysts for solar hydrogen production by water splitting:** Cadmium Indium Sulphide is one of the potential materials for the applications in photoconductor, solar cell and light emitting diode. Under this project, the nano-structured CdIn2S4 was synthesised using direct hydrothermal method at 150°C for 30 hours. The reaction parameters such as concentration of precursor, temperature and time have been optimised to get different morphologies. All the

synthesised catalysts were used for photocatalytic water splitting using 2% ascorbic acid as hole scavenger. The hydrogen evolution obtained from photocatalytic water splitting of these catalysts proves candidature of CdIn2S4 as potential hydrogen generator.

- **Development of Prototype MPD Thruster:** The project has successfully developed a technology demonstrator prototype Magneto Plasma Dynamic Thruster (MPD) using Argon propellant with a specific impulse of 2500 s at a thrust of 25 mN. The development of MPD Thruster involved design using two methodologies, fabrication & testing and performance estimation. The first design methodology was based on the requirements of given mass flow rate, thrust, specific impulse, arc initiation and propellant ionisation and establishment of supersonic flow. The second design method was indirect and involved the calculation of radial and axial inductance of the thrusters for a given geometry followed by design estimate of performance using electromagnetic energy principles. The MPD thruster was successfully developed and was tested successfully in the vacuum facility in the laboratory. In order to obtain an estimate of its performance, optical methods have been used as the hostile conditions in the plasma exhaust made direct measurement difficult. Two optical techniques have been used to obtain plasma exhaust Mach number and Temperature. The developed thruster is a prototype Technology Demonstrator.

- **Investigation on Lithium ion cells for design parameters/failure modes on fresh/cycled cell using Destructive Physical and Chemical Analysis (DPA/ DCA) techniques:** Under this project, analytical procedures were developed for the destructive physical and chemical analysis of Lithium ion cells in general, Commercial-off-the-Shelf (COTS) technology cells in particular, for the materials of construction of the cell, to understand the modes and mechanisms of degradation under various simulated GEO, LEO operation conditions as well as abusive test conditions. A high quality methodology for the cell disassembly was evolved to preserve the state (operational or failed) of the cell for the purpose of post-disassembly analysis. Jigs and fixture were designed for the disassembly. The study observed and analysed the performance of cells from various manufacturers with respect to constructional details, active material ratio, composition of cathode, anode and nature and type of separator materials including heat resistant layer treatment to guide future R& D activities on space quality cells.

Indian Space Industry

India has come a long way in developing multi-dimensional operational remote sensing, satellite communication, navigation and planetary missions programme. INSAT and IRS programers are the mainstay of India's space program, which, from a modest beginning, now competes with the best in space community. The diverse role of space technology/ services in various fronts-social, commercial, economic and strategic have made the space systems an important component of our national infrastructure.

Indian space programme has been growing from strength to strength during the past four decades, attracting global attention for the rapid strides it has been making. ISRO executes the activities through its centres of excellence, each of which has been identified a lead role for carrying out research, development, manufacturing and application missions. Towards achieving shorter turnaround times for realising the missions, ISRO, right from the beginning, has been encouraging the participation of Indian Industry. ISRO has robust industry participation in the space program from public and private sector Indian industries. The strong involvement of Indian industry has not only helped ISRO in realising its programmatic goals but also given necessary impetus to successfully undertake complex and advanced interplanetary missions with ease.

The long-term policy envisioned for space industry partnership has contributed to the growth of Indian space program. 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, ten technologies are licensed to Indian industries for commercialisation and regular production. These include Barium Magnesium Tantalite (BMT) Ceramic, EPY-1061 Epoxy Resin, Benzoxazine Resin, 15 Watt C-band Solid State Power Amplifier (SSPA), EFA-4330 Film Adhesive, PC-10 Thermal Protection System, CSNM-0102 Adhesive, Polyimide Film, HESC/CSNM-29 Coating and SESCO-125 Flame Retardant.

Barium Magnesium Tantalite (BMT) is a typical ceramic, which is widely used in oscillators, multiplexers, filters, etc., in satellite and terrestrial microwave communication systems. Globally, only a few materials have been manufactured for use in specific range of microwave spectrum. Indigenous BMT ceramics are light weight, small size, are temperature stable, with the cost of manufacturing being quite low. EPY 1061 is an amidoamine modified epoxy based system specially developed to protect the metal surfaces from corrosion in aqueous strontium perchlorate medium. The technology for synthesising Benzoxazine resin was transferred to two industries. Benzoxazine is a matrix resin used for high density ablative composites and for light weight foam composites in aerospace applications. The resin has thermo-oxidative stability, chemical inertness, abrasion resistance and flame retardant properties. The resin may find potential

application as an encapsulant in electronic industry and as a resin for composites for structural and thermo-structural aerospace applications.

ISRO through its INSAT/GSAT satellites, is providing satellite based connectivity for broadcast, communication and networking applications. There is a demand for C-band SSPA for use in transponder onboard INSAT/GSAT satellites to be launched by ISRO. The 15 watt C band SSPA developed by ISRO is expected to be used in satellite payloads. EFA-4330 is a heat curable, toughened, light weight and high strength polymer film adhesive. It is suitable for achieving very high bond strength in honeycomb sandwich structures. PC-10 is a silicone polymer based thermal protection system having good thermal, chemical and ageing resistance apart from compatibility with a wide variety of substrates. PC-10, which is a room temperature curing system, can be applied on surface by brushing, spraying and putty blade. Adhesive CSNM-0102 is a special epoxy resin for cryogenic structural/thermocouple bonding. It is a high strength adhesive for metal/ceramics/composite bonding. Polyimide based films with their high temperature, ablative and vibration resistant properties find potential applications in aerospace and electrical industries as thermal and electrical insulation material for wiring, multilayer insulation for thermal control systems, insulation for electrical motors and transformers, etc. 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. 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.

The productionisation of technologies licensed to industries has been progressing satisfactorily. Six tonnes of various types of special chemicals, adhesives and resins are being supplied back to ISRO, for its various launch vehicle and satellite programs. Polyurethane based rigid and semi rigid foam products like jettisonable thermal pads, umbilical protection pads, cowling cones, half pipe sections and thermal insulation couplings, have been sourced through recipient industries. The advanced Digital Holography image processing software is fast gaining grounds in educational institutions. During the year, licenses were granted to three academic institutions. Licensees of BMT and DK-18 Ceramics and polymer products are planning to start commercialisation in the near future. The Photosynthesis Irradiance Incubator Box manufactured by licensee industry has been certified by ISRO. Attempts are being made by industries to customise the licensed technologies to suit the requirements of user community.

There are a number of technologies identified for know-how transfer from ISRO. These include various types of adhesives and polymers, speciality materials, sensors, plating and thermal control coating techniques, etc. Industries have been identified for the technology transfer of Silica Fibre and Silica Granules which have high temperature insulation properties and for SSF P-70, a low density silicone syntactic foam insulation coating for cryogenic applications. The technologies which are in the active pipeline for transfer to industries include PF-106 and PF-108 phenolic resins, RWPC-03 waterproofing compound, NRCM-204 corrosion resistant coating, EPY PEEKTOH film adhesive, MEMS acoustic sensor and a ceramic based flame proof coating compound.

As part of indigenisation process and to build competency in the areas of computational numerical simulation for aerospace applications in ISRO, development of finite element based structural analysis software, FEAST (Finite Element Analysis of STructures) was initiated. Over the years, the software has attained a greater level of maturity in the area of structural engineering analysis and catered to the requirements of ISRO. The software can run on a range of platforms from personal computers to parallel processing systems with scaled performance. Indigenous structural analysis software FEASTSMT has scope for a wide range of applications both in industrial and educational sectors. Licenses are being awarded to selected agencies for marketing FEASTSMT.

Intellectual Property Rights

Patents and Copyrights

In today's electronic world, an organisation's intellectual property is its biggest asset. The advent of the e-communication has revolutionised the way of information exchange between stakeholders. IPR are valuable assets of the organisation and realising this, efforts are on to create a strong Intellectual Property Right (IPR) portfolio. ISRO scientists are sensitised about the importance of obtaining IPRs for the novel development arising out of their activities. The IPRs are expected to act as a cradle for potential technology transfer to industries.

Seventeen new patents were granted during the year including a UHF miniature microstrip patch antenna, universal test suite for field programmable gate arrays, systems for testing electronic devices by real time simulation and acquisitions, method of coating substrate with temperature resistant ceramic coating composition with high emissivity and a test structure for testing electronic sub assemblies under thermo vacuum conditions, etc. Patents for sixteen new products and processes developed by ISRO were filed during the year in diverse areas like valve system, thermal barrier coating, carbide composites, adhesive compositions etc.

Copyright protection for five software developed by ISRO for space and non space applications has been undertaken during the year. This includes Finite Element Structural Analysis Software (FEAST) and Software for Mission Design and Analysis for Interplanetary Trajectories with Multiple Planets Swing by Capability (SMILE). Copyright was registered for six works including message driven method for optimal management of dynamic production workflows and ground station workflow manager software.

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 have been finalised for development and implementation of satellite communication and navigation based system for a premier Government organisation. Technical assistance is being provided to a major public sector industry for development of multi band and composite feed system for earth stations. Private sector industry is being provided consultancy for the development of radar level transmitter. Industry personnel are being trained for

fabrication, assembly and testing of a critical components required for spacecraft and launch vehicle projects. Under the technical consultancy scheme of ISRO, best practices and expertise of ISRO are shared with industry.

Technology Utilisation and Vendor Development

There has been a steady increase in the number and complexity of missions accomplished by Indian space program. In recent years, the throughput in terms of the number of satellites and launch vehicles realised have seen an upward trend. ISRO is constantly encouraging and envisaging increased participation from domestic industry in India's space program. ISRO has forged a strong relationship with a large number of industrial enterprises, both in public and private sector to implement its projects.

Indian industry is today on the threshold of entering into a new era where it is poised to assume greater responsibility in making the nation self-reliant. The Indian space industry is internationally competitive with quality standards, efficiency and manufacturing facilities on par with its peers elsewhere. India is fast developing into a manufacturing hub for world corporations wanting to leverage the aerospace sectors proven skills in product design, reconfiguration and customisation with creativity, assured quality and value addition.

As part of its vendor development efforts, ISRO/DOS has been placing considerable effort towards development and qualification of new vendors for undertaking a multitude of tasks. Industry involvement in space program has not only been through the supply of hardware for satellites and launch vehicles, but also for creating required ground infrastructure, development, testing and utilisation of space hardware, either independently or through a consortium.

In the launch vehicle area, ISRO is not only meeting the national requirements but also emerging as a global player for launching international customer satellites. The magnitude of industry contribution has grown apace to meet the needs of PSLV, GSLV and GSLV-MkIII. ISRO has embarked on a host of productionisation initiatives at external work centres to meet the ever increasing needs of its projects, keeping in view the quality, redundancy, reliability and shorter lead times required for space systems.

The industry consortium partners continued their contribution towards realising L40, PS2, GS2 and L110 stage VIKAS engines. The public sector industry based at Thiruvananthapuram supplied L40 conical version VIKAS engine. The integration of L40 stage for GSLV mission is being carried out at a Bengaluru based public sector industry. An alternate source for VIKAS engine contour nozzle is being developed.

The cryogenic engine fabrication is a technologically complex task. The initiative of involving industry from early stages of the project has started yielding results. During the year, Cryogenic Upper Stage (CUS), Cryogenic Engine-CE20 and C25 engine realisation was carried out at two private sector industries. The major hardware realised by industry include CE20 engine gas generator assembly, CUS main turbo pump, CE20 liquid oxygen and liquid hydrogen turbo pumps, CUS and C25 thrusting device assembly and interface elements for CE20 engine. In order to gear up for meeting the future

requirement, efforts have been initiated to set up an integrated cryogenic engine manufacturing facility at Bengaluru based public sector industry. This facility is expected to cater to the exclusive requirements of CUS, CE20 and semi-cryo engine sub system. The specification of major equipment of the facility has been finalised.

The approach adopted for cryogenic engine fabrication is being replicated for semi-cryo engine sub system production. The semi-cryo engine fabrication consisting of six major packages, namely, booster pump, pre burner, heat exchanger, main turbo pump, mixing head and thrust chamber, has been entrusted to industry.

During the year, progress has been made towards establishment of a dedicated assembly and test facility at an ISRO Centre for carrying out sub assembly preparation, inspection, assembly and testing of cryogenic components and modules under the aegis of the proposed Integrated Cryo Components and Modules Assembly and Test Facility (ICMAT). The assembly activities will be carried out by industry professionals under the supervision of ISRO.

The integrated production approach adopted at industry for propulsion components has been yielding rich dividends. Fully assembled and tested modules for various propulsion systems used in PSLV, GSLV and GEOSAT program is being supplied under this scheme. Private sector industry is carrying out end-to-end production of components and modules involving raw material procurement, fabrication, assembly and testing for meeting the requirements of 2 PSLV, 2 GSLV and 3 GEOSAT satellites. Private sector industry at Coimbatore has established the infrastructure for carrying out fabrication, assembly and testing for Integrated Production of Control System Components and Modules (IPCS) for catering to the requirements of 4 PSLVs and 2 GSLVs per annum. Under IPCS, the components for PS0 and PS1 Secondary Injection Thrust Vector Control (SITVC), PS1 Reaction Control System (RCS) and modules for 4 PSLV missions were delivered.

Tankages and structure fabrication has been progressing well at ISRO's work centre at public sector aerospace industry located at Bengaluru. PS2, PS4, GS2, L40 and L110 stage propellant tanks, feed lines and water tanks were fabricated by the industry. The above industry is also involved in realising the propellant tanks and structures for CUS and C25 projects. Public sector aerospace industry at Thiruvanathapuram realised the L40 propellant tanks, L40 water tank, PS2 clams, RFDS tubes, L40 feed lines and stage and tibia, PS1 SITVC tanks. The augmentation of GSLV Mk-III tankage production facility is progressing well.

The production of pressure fed engine has been streamlined at Industry. Hyderabad based industry has stabilised the integrated production at 26 PS1 Reaction Control Thrusters (RCT) and PS4 engines. The production of various satellite thrusters and Liquid Apogee Motor (LAM) engines is carried out at three private sector industries.

Industry has been developed as a dedicated work centre for the end-to-end production of 21NA and differential pressure transducers. The throughput of 21 NA transducers has stabilised at 1420 numbers per annum. 100 sets of differential pressure transducer realisation is in progress. During the year, more

than 1000 transducers were delivered by private and public sector industry.

Long term strategic planning is essential for successfully meeting the requirements of increased launches. In line with ISRO's policy of maximal industry participation, new initiatives are being implemented in various industries. In this direction, industries are being identified for assembly and testing of injection valves as well as gear box assembly actuators for PS0 and PS1 SITVC and PS1 RCS propulsion system for six PSLVs per year. Currently, PS4 propellant tank is fabricated with Titanium alloy. In order to meet future requirements, an alternate public sector industry has been identified for fabrication of PS4 propellant tanks using Aluminium alloy. Similarly, a new vendor has also been identified for PS2 propellant tanks.

ISRO satellites have become the mainstay of various projects of national importance. The demands of space assets are growing for meeting the country's requirement in communication/ broadcasting, remote sensing, meteorological and navigation areas. It is systematically planned to roll out more satellites and towards this, the capability at industry is also being strengthened.

The public sector aerospace industry based at Bengaluru has supplied spacecraft structures, catering to the requirement of ISRO satellites. In the area of satellite thermal control engineering, private sector industry has supplied more than 500 heat pipes. Heat pipe is used in communication satellites for the thermal equilibration of satellite transponders. Pondicherry based industry supplied 24000 Optical Solar Reflectors (OSR). More than 100 flux heaters were delivered by a Pune based industry.

In the area of spacecraft mechanisms, eight sets of Solar Array Deployment Mechanism (SADM) for IRS and INSAT satellites were supplied by private industry. Shell type Reflector Deployment Mechanism is being realised by industry.

In the area of power systems, industry contributed in the fabrication and testing of solar panels for both communication and remote sensing satellites. During the year, fabrication activity for supply of 31 square meter of space-qualified solar panel has been successfully completed for catering to the requirement of IRNSS-1F, IRNSS-1G, GSAT-18 and GSAT-19 spacecraft. Industry has augmented facility to cater to the increased requirement of space-qualified batteries. With industry participation, eight batteries of various capacities were realised. Work is in progress at industry for the realisation of six more spacecraft batteries. Inspection of 7200 ATJ solar cells was also carried out by the industry. Core power, distribution and shunt packages for SCATSAT and IRNSS-1G satellites were fabricated and tested by industry.

With the augmentation of existing systems and newer forays into domain like satellite navigation, the prospects of industry involvement in the payload development area is encouraging. Space grade TCXO, OCXO, Ku-band receivers and frequency converters, C-band receivers, Ku-band LNA and driver amplifiers are few of the components where industry support is being utilised. Joint development of 60W C band SSPA with public sector electronics industry has resulted in two flight models being delivered. The development activity for micro power module for 140W Ku-band TWTA is in progress.

The industrial partners are also supporting routine activities like the supply of PCBs for onboard and ground applications, Hi-Reliability fabrication and assembly, etc.

In the inertial systems area, the services of industries were utilised in the realisation of miniature dynamically tuned gyroscope hardware, mini Redundant Strapdown Inertial Navigation System (RESINS) hardware, IRS Solar Array Drive Assembly (SADA) hardware and in the fabrication of momentum wheel and reaction wheel hardware.

The fabrication and testing of Telemetry, Telecommand (TMTC), control electronic packages, OSRs, anodizing and inorganic black colouring on aluminium on various spacecraft components, etc., is being carried out by industry. Surface treatment processes as per ISRO standards have been qualified at small-scale industry for Gold plating on Aluminium 6061, Invar and Kovar, Silver plating and chromating on Aluminium 6061.

The end-to-end production of spacecraft propulsion system components at industry for 14 types of components for 42 spacecraft (24 GEOSAT and 18 IRS) is on track with the assembly and testing of components for 7 spacecraft in progress. A long term arrangement has been established with leading public sector industry for production of 63 sets of pressure vessel parts over five years. Three sets of 390 L satellite propellant tanks hemispheres were delivered and further, 8 sets of satellite propellant tanks hemispheres (390 L, 769 L, 870 L) are in the final stage of realization.

In the electro-optics area, sensor systems and optics elements for IRNSS-1E/1F/1G, GSAT-6, ASTROSAT, Resourcesat-2A and GSAT-15 were developed with cooperation from public and private sector industries. The sensors and optics for Scatsat, GSAT-18, GSAT-11, Aditiya-1 and Chandrayaan-2 are under realisation. Over the years, multiple vendors have been developed for supplying high performance optics elements. Private sector industry based at Pondicherry completed the fabrication of 20 Corner Cube Retro Reflector (CCRR) optical components. Small scale industry has been qualified for supply of Whiffle Tree type support system for testing medium to large size mirror optics. Industry continues to support high performance coating requirements by supplying large numbers of coated stainless steel vanes for star sensors and black chrome coated plates for the development of photo masks for application in precision sun sensors for IRS and INSAT. Industry is supplying ion implanted/diffused Silicon (Si) wafers for production of Si photo detectors and processed wafers for the development of large area Si photo detector arrays required for the current IRS/INSAT projects. Mechanical components for sensors and optics, carrying out HMC design, fabrication and packaging of different categories of MEMS devices, namely, accelerometers, micro bolometer, RF switches and Si photodiode array is also being carried out by various industries.

Development and maintenance of infrastructure at spaceport is essential for shorter turnaround times resulting in increased number of launches. The development of Multi Object Tracking Radar (MOTR) has been completed at the spaceport and the facility commissioned for tracking long range multiple targets in space to meet the future mission requirements. MOTR has been realised with complete indigenous efforts with the participation of Indian Industry. The fabrication, installation, testing and commissioning

of mobile MOTR on similar lines has been entrusted to industry. At the spaceport, industry engagement is increasing with industral partners commissioning the indigenously designed and developed PS4 control system and 200 kg vertical mixer. Progress is being made in a host of other areas including 450 tonne EOT crane, curing oven at propellant plant etc.


Multi Object Tracking Radar

Industry is engaged through the joint development of systems for meeting the requirements of ground based solutions including multi channel video and audio broadcast receivers and IRNSS receivers. A 6.3m L/S band antenna system was installed and commissioned by industry. Seven industries have been identified for miniaturisation, packaging and production of high power MSS terminals based on ISRO design.

Indigenisation efforts lead to self-reliance in hi-technology areas. ISRO along with Indian industry, is constantly exploring avenues for the indigenisation activities in materials and alloys used for space program. During the year, 18X2H4MA material and Grade 300 maraging steel was indigenised by public sector industry for meeting the requirements of semi cryo project. Satellite propellant tank with Cassini Dome indigenisation is nearing completion. Z30C13 APD forgings and AS7G03Y23 Aluminium alloy castings have been indigenously developed at public sector steel industry based at Salem for meeting the requirements of CE20 engines.

There is no doubt that in the coming days, our space programme is going to achieve greater heights with increased industry involvement in realising technologically complex and challenging missions.

Space Commerce

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

The global marketing of IRS data is being pursued in collaboration with its international partners. Upgradation of stations for customer from Germany for reception of OCM data from Oceansat-2 satellite has been completed. Efforts are on for enabling direct reception of OCM data at United Kingdom. Currently, Antrix markets IRS data and services from RISAT-1, Resourcesat-2, Cartosat-1 and Oceansat-2 satellites. The currently operational IRS Ground Stations (IGS) are Svalbard/Tromso, Norway for RISAT-1, Iran and Algeria for Cartosat-1 and Germany for Resourcesat-2 and Oceansat-2 satellites. Antrix is in the process of expanding the IRS ground segment market outreach with plans for setting up of more stations outside India.

The outlook for commercial launches on PSLV is promising with many proposals from international customers under active discussion and consideration. Under a commercial contract with Antrix, in the year, three identical DMC3 optical earth observation satellites built by Surrey Satellite Technology Limited (SSTL), United Kingdom (UK) were launched onboard PSLV-C28 flight. In addition to the three DMC3 satellites, two auxiliary satellites from UK, namely, CBNT-1, a technology demonstrator earth observation micro satellite built by SSTL, and De-OrbitSail, a technology demonstrator nano satellite built by Surrey Space Centre, were also launched. With the overall lift-off mass of the five satellites amounting to about 1440 kg, this mission was the heaviest commercial mission undertaken by Antrix till date.

In addition, under a commercial contract with Antrix, in the PSLV-C30 mission, six international co-passenger satellites, LAPAN-A2, NLS-14 (Ev9) and four LEMUR satellites were launched. LAPAN-A2 is a microsatellite from National Institute of Aeronautics and Space-LAPAN, Indonesia. NLS-14 (Ev9), is a nanosatellite from Space Flight Laboratory, University of Toronto Institute for Advanced Studies (SFL, UTIAS), Canada. The four LEMUR nanosatellites were from Spire Global, Inc. (San Francisco, CA), USA.

TeLEOS-1, an optical earth observation satellite of Singapore, was launched by PSLV on December 16, 2015. As part of the commercial agreement with ST Electronics, Singapore, TeLEOS-1, VELOX-C1, KR-1, VELOX-II, ATHENOXAT-1 and GALASSIA satellites from Singapore were launched on board PSLV-C29.

Till date, 57 foreign satellites from 20 countries have been launched using PSLV. During the year, six commercial launch contracts have been signed for launching 13 satellites on PSLV. These include one satellite from Japan, three satellites from Algeria and nine satellites from USA.

Antrix enables satellite communications service providers with the necessary space segment capacity, predominantly covering the Indian region. Currently, a large number of transponders from INSAT/ GSAT fleet are provisioned to Indian users for Television Broadcasting (TV), Direct To Home (DTH), Digital Satellite News Gathering (DSNG), Very Small Aperture Terminal (VSAT) and Telephony services. The services realised in the process address a wide range of social and business needs. Provisions are being made towards meeting the demand of new and existing customers.

In the mission support services area, business initiatives for TTC support have progressed well. The capabilities in providing TTC support are well established and there is a steady enquiry from international customers for using our network of ground stations for meeting various mission requirements. As part of the long term framework agreement with an international customer, Antrix supported the Ka-band Transfer Orbit Support Service (TOSS) mission of international satellite from MCF, Hassan. Requests have been received from national and international customers for utilising our expertise for the establishment and operation of ground stations.

The Committee on Public Undertakings (COPU) and Committee on Papers Laid on the Table (COPLOT), Rajya Sabha reviewed Antrix activities during their visit to Bengaluru. Industry delegations and high level officials from leading global space companies visited Antrix to discuss commercial projects of mutual interest.

As part of its Corporate Social Responsibility (CSR) efforts, Antrix has undertaken activities related to re-habilitation of physically challenged (orthopedically, visually and hearing impaired) personnel in Arasikere and Channarayapattana Taluks of Hassan District, Karnataka, in association with Artificial Limbs Manufacturing Corporation of India (ALIMCO), a PSU under Government of India, Ministry of Social Justice and Empowerment. In addition, Antrix has undertaken efforts to build a sanitation facility in twenty Government Schools located in Malur Taluk, Kolar District, Karnataka, utilising the services of M/s. Sulabh International and with the involvement of Government of Karnataka. Water purification systems for drinking water are also being provided in these schools.

Systems Reliability and Safety

Directorate of Systems Reliability and Quality (DSRQ) as an apex body and for Quality and Reliability in ISRO, continued its active role in supporting various ISRO Centres and Units towards improving the Quality standards in their practices. Through its various delivery mechanisms, DSRQ addressed many systemic issues in this area across major activities of ISRO.

ISRO Reliability standards in the area of Aerospace fasteners and Contamination control were brought out with the help of ISRO experts. Task teams were also identified for bringing out new ISRO Reliability standards in the areas of launch vehicle Rain proofing and Pyro devices. Detailed discussions were held among the Quality community across ISRO in the Integrated Product Assurance Board (IPAB) meetings on sharing of lessons learnt and best practices. These discussions resulted in bringing common practices in Configuration Control Management, database management software for lessons learnt, Software Quality Assurance, etc. To unearth any inherent Quality issues and also to give confidence on the missions, Comprehensive Quality Analysis and Audit of PSLV C28, C30 and GSLV-D6 systems were conducted.

To propagate the Zero Defect delivery Programme (ZeeDP), a meet with the technical workforce from external vendors was organised at M/s HAL and also at ISAC. More than 1000 technical workforce personnel were benefited from this meet. Also, a Quality awareness programme for fresh SR professional was held at Headquarters with the participation of young engineers in the area of Quality and Reliability drawn across ISRO. Most of the centre Quality teams have continued their efforts in propagating Quality culture within their organisation. In this context, they have held several awareness programmes including annual Quality day, zero defect delivery events, etc.

The Systems Reliability (SR) agencies at ISRO centres contributed very significantly for the success of all the missions it has embarked upon, in this year too. The consecutive successes demonstrated in PSLV and GSLV missions followed by various satellite missions strongly bring out the effectiveness of the unstinted efforts from the Quality agencies across ISRO. They played a vital role in all phases of development including parts selection, screening, extensive design review of circuits and systems and mechanical assemblies, process verification, Quality audits and subjecting the systems to rigorous cycles of T&E including life testing. Software QA was also carried out for on-board, mission simulation, checkout and all ground applications software. Independent analysis on non-conformances and also the post flight data analysis for every launch were carried out meticulously. The teams have also given thrust in spreading the message of learning from the past experience in the form of lessons learnt document, highlighting all the issues experienced.

To ensure the Quality at external work centres, Quality system audit has been carried out in 40 external work centres related to launch vehicle activities by VSSC SR teams. Efforts have been put in capacity building in specific areas relevant to Systems Reliability activity. They include Advanced Thermo Vacuum Facility (ATVF) installation, Polyimide pipe testing and Ultrasonic testing of Cryo

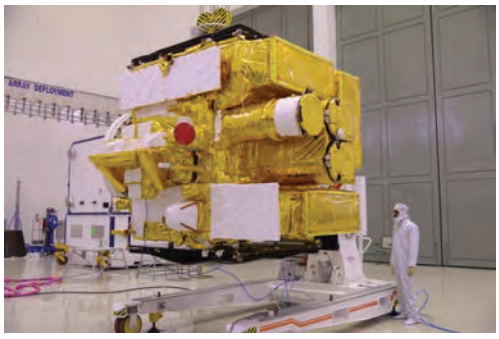
bimetallics. Towards Software Quality Assurance, apart from code inspection and extensive independent module level testing, the Quality team has also brought out Software Fault Injection testing concept which further improves the overall reliability of on-board software considerably.

ATVF

Systems Reliability and Quality Assurance team at Liquid Propulsion System Centre (LPSC) had certified three numbers each of PS2 and PS4 stages and booster stage control systems for PSLV C27, 28 and 30 missions. The Quality of four L40 stages, the GS2 and CUS stages for GSLV D6 mission was assured and certified. On similar lines, the propulsion system of IRNSS-1D, ASTROSAT, GSAT-6 and GSAT-15 were also certified by the team. As part of generating Quality Awareness, the team has held several training programs at external work centres. The outsourcing attempt of inspection activities in the mechanical area initiated by SR team is working satisfactorily,

Systems Reliability Group of Space Application Centre (SAC) played a key role in assuring the Quality of 24 different payloads for Communication, Optical and microwave remote sensing applications. Nineteen new processes at both in-house as well as vendors' facilities were qualified catering to various critical areas. The team has also successfully completed the qualification of the Rover Imager camera module for Chandrayaan-2 mission, extended efforts in capacity building in the areas of automation and software development. The Quality team has conducted a detailed study to evaluate alternate failure rate prediction methodologies for complex and new technology devices from the generic practice using MIL-HDBK-217F.

The on-board performance of IRNSS-1D, GSAT-6, ASTROSAT and GSAT-15 satellites was meticulously ensured by executing stringent Quality Assurance tasks during various stages by the Quality team at ISRO Satellite Centre (ISAC). Specifically, the ASTROSAT being contamination sensitive, the team addressed both particulate and molecular contamination by enforcing strict control over material selection and following clean room protocol up to the launch base. The team also played a very significant role in the conduct of Qualification and acceptance tests for the 6 m Unfurlable Antenna used in GSAT-6, for the first time. Qualification of new processes and materials for 30 W DC-DC converter (HMC based) was successfully carried out. Also Improvements were brought in through "Integrated Component Service Data Base Management System (ICSDBS)" towards better configuration control.



ASTROSAT in Clean room

The Systems Reliability team at SDSC, SHAR has ensured high degree of Reliability and Availability of various critical facilities used for launch support. They include facilities related to Vehicle integration, ground support systems like liquid propellant charging, radars, mission computers, real time systems

and range instrumentation. Successful qualification of PSOM-XL Motor processing facility and its static testing, carrying out FMECA of the new Mobile Launch Pedestal Traction control system, etc., are a few of the major achievements of this team during the current year.

The Quality team at ISRO Inertial Systems Unit (IISU) evaluated and cleared various subsystems such as Inertial Reference Unit (IRU), Reaction Wheel Assembly (RWA), Payload Steering Mechanism, Inertial Navigation Systems, Scatterometer Scan mechanism and Control Electronics, etc., for various satellite and launch vehicle projects. As part of ensuring Quality at external work centres, the team has audited 14 work centres. Towards capacity build up, the R&QA team at IISU has validated and deployed Particle Impact Noise Detection (PIND) test facility.

Reliability and Quality Assurance team at ISTRAC has ensured the in-house calibration and maintenance of 150 RF and Microwave Test Equipment as per the ground system requirement. The team also performed Test and Evaluation of both Hardware and Software elements and ensured the ground Systems Reliability and availability to meet the mission requirement of PSLV and GSLV missions. Effective configuration control was ensured by SR Team for PSLV, GSLV and Spacecraft supporting systems, which resulted in error free operations at ISTRAC.

The Quality Assurance team at Laboratory for Electro Optics Systems (LEOS) provided excellent support during the development and qualification of Mark-II Star sensor, APS Sun sensor, Miniature conical sensor, indigenous bolometer, Color camera and image storage unit for SRE-II, Navigation Camera for Lunar rower, etc. Also, the team extended the necessary support in the development of various detectors and MEMS based devices for space applications including the Micro Sun sensor. The team has also played a very vital role in commissioning 3-axis Motion Simulator, 3.5-ton vibration shaker, vendor development and certification for the production of sensors and electronics.

Safety Services

Space programme continued to be free from any major incidents during this year. All activities were completed without any reportable injuries and there was no major incident reported in any of the Centre/ Unit of ISRO/DOS. The launches of PSLV-C27/IRNSS-1D, PSLV-C30/ASTROSAT, PSLV-C28/DMC-3 and PSLV-C29/TELEOS, GSLV-D6/GSAT-6 with indigenous cryogenic upper stage were the major milestones of this year and were successfully completed without any safety related non-conformance. As in the case of previous launches, well established safety procedures, standards and emergency preparedness plan were implemented to prevent unforeseen incidence. Safety surveillances were available round the clock during the launch campaign activities. Critical activities like production of solid propellants, pyrotechnic materials, storage and transport of solid propellants, earth storable propellants and cryogenic propellants were carried out under the control of a well co-ordinated safety team.

The most significant achievement of this year is the endurance hot test of indigenously developed high thrust cryogenic rocket engine CE-20 and the third static test of S-200 solid motor with modified head end segment grain configuration. Both were successfully completed without any safety implications.

Process safety clearance was issued for propellant mixing, casting, curing, bowl cleaning and decoring of S200 solid propellant segments of GSLV MKIII. Safety clearance were also issued for activities like CE20 integrated turbo pump (TP) test, Cryogenic upper stage steering engine flight acceptance test at Steering engine test (SET) facility, CE20 thrust chamber hot test at Thrust chamber test (TCT) facility, Semi-cryogenic single element injector hot test at Spacecraft propulsion test facility (SPTF), etc.;

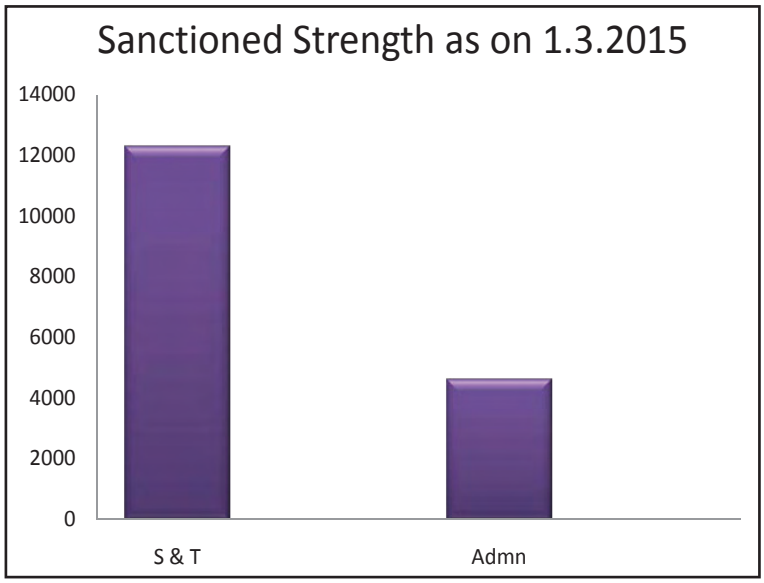
Safety surveillance was in place during fabrication, integration, thermovac test, vibration test and high-pressure tests of IRNSS-1E, ASTROSAT and GSAT-15. Safety clearance was issued for pressure hold test and dynamic tests of GSAT-15 satellite, vibration test of GSAT-9 propellant tank, vibration test of GSAT-6 satellite. Also safety review of radiation sources in ASTROSAT was completed without any safety waivers.

Rigorous safety inspections and audits, drills at various hazardous areas, preparation of safety manuals and emergency guide and review of facilities before critical operations were carried out by safety department. Safety committees at various ISRO/DOS establishments reviewed and cleared locations for the construction and commissioning of new facilities. Safety team provided safety awareness about personal protective equipment and safety related items for all employees and organised safety and fire fighting training programmes to all employees. Safety promotional activities have continued through the celebration of National safety day, Fire service day, issuing posters, organising safety seminar, etc.,

Human Resources

The total approved sanctioned strength of the department as on 1.3.2015 is 16902 out of which 12300 are in scientific and technical Categories and 4602 are in administrative categories. Welfare measures like housing, medical, canteen and 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.

The competencies, commitment and dedication of ISRO/DOS personnel have played a key role in various achievements of the 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 the successful completion of their B,Tech programme with a certain level of benchmark. The fifth batch of students, who were admitted to B.Tech Programme during September 2011 at the Indian Institute of Space Science and Technology (IIST), Thiruvananthapuram, have graduated during June 2015. A total of 99 students, who have passed out fulfilling the quality benchmark, have been inducted in all DOS/ISRO Centres.

Training

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 where in they are introduced to various rules, regulations, systems and processes that are in vogue in the organisation.

All the Officers from Purchase and Stores area, have been sponsored for specialised training programme at National Institute of Financial Management, Faridabad for programme on public procurement policies.

Space Studies Programme (SSP) 2015 for young Scientists/Engineers organised by International Space University at Ohio University, USA, during June-August 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 and technical personnel was organised at Administrative Staff College of India in three batches and a total of 60 employees were sponsored.

I APPRENTICE TRAINING

Under the Apprentices Act, 1961, training has been imparted to 3553 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 appointed 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)

3361 persons belonging to Other Backward Classes are existing at present. Out of the 3361 OBCs, 96 were appointed during the year.

v) WOMEN EMPLOYEES:

There are 1820 Women Employees in the Scientific and Technical categories and 1232 Women Employees in Administrative categories in the Department as per details in Table IV. They represent 20.23% of personnel in the Department.

vi) JOINT CONSULTATIVE MACHINERY (JCM)

The scheme of Joint Consultative Machinery (JCM) of the Department continued to function satisfactorily.

vii) CONFERENCES AND WORKSHOPS:

(a) National Conference for ISRO Women Employees

National Conference for ISRO Women Employees was organised at Laboratory for Electro Optics Systems (LEOS) with the support from ISAC and ISTRAC at Bengaluru on April 10, 2015. The main theme of the National Conference for ISRO women employees was "WE Made it Happen". Women employees from various DOS/ISRO establishments participated in the Conference as delegates and presented papers.

(b) International Day of Yoga

The United Nations has declared June 21 as the 'International Day of Yoga' on the topic of 'Yoga for Mind, Body and Soul'. As part of the celebrations, a mass yoga practice/demonstration was organised in DOS/ISRO establishments.

(c) Dr. B. R. Ambedkar's Birth Anniversary Celebrations

124th Birth Anniversary of Bharat Ratna Dr. Bhimrao Ramji Ambedkar was celebrated in DOS/ISRO establishments in 2015.

Table - I: Status of Scheduled Caste/Scheduled Tribe Personnel in DOS/ISRO (2015-16)				
Sl No	**Centre/Unit**	**Total Strength of Employees**	**Strength of SC Employees**	**Strength of ST Employees**
1	DOS/ISRO HQ	419	79	22
2	VSSC	4443	350	70
3	ISAC	2377	283	89
4	SDSC-SHAR	1958	301	120
5	SAC & DECU	1798	186	94
6	LPSC	1187	135	28
7	NRSC	857	103	32
8	ISTRAC	447	70	17
9	MCF	312	33	15
10	ADRIN	166	22	5
11	IIRS	89	14	4
12	PRL	209	8	1
13	SCL	567	107	4
14	NARL	64	10	1
15	NESAC	32	2	4
16	IIST	92	3	0
17	IPRC	639	130	11
TOTAL		**15656**	**1836**	**517**

Table - II: Status of Persons with Disabilities in DOS/ISRO (2015-16)							
Sl No	**Centre/Unit**	**Total Strength of Employees**	**Strength of Persons with Disabilities**	**Classification of Employees with Disabilities**			
				Deaf & Dumb	**Blind**	**Partially Blind**	**Orthopedically Handicapped**
1	DOS/ISRO HQ	419	5	0	0	0	5
2	VSSC	4443	93	18	15	0	60
3	ISAC	2377	57	13	4	0	40
4	SDSC-SHAR	1958	51	3	1	0	47
5	SAC & DECU	1798	35	4	2	0	29
6	LPSC	1187	26	5	0	0	21
7	NRSC	857	15	2	0	0	13
8	ISTRAC	447	9	2	0	0	7
9	MCF	312	4	1	0	0	3
10	ADRIN	166	3	0	0	0	3
11	IIRS	89	3	0	1	0	2
12	PRL	209	4	1	0	0	3
13	SCL	567	3	0	0	0	3
14	NARL	64	1	0	0	0	1
15	NESAC	32	0	0	0	0	0
16	IIST	92	1	0	0	0	1
17	IPRC	639	15	0	0	0	15
TOTAL		**15656**	**325**	**49**	**23**	**0**	**253**

Table - III: Status of Representation of Ex-Servicemen in DOS/ISRO (2015-2016)			
Sl No	**Centre/Unit**	**Total Number of Employees in Group - C**	**Total Number of Ex-Servicemen in Group - C**
1	DOS/ISRO HQ	89	11
2	VSSC	949	97
3	ISAC	306	7
4	SDSC-SHAR	574	17
5	SAC & DECU	57	4
6	LPSC	174	38
7	NRSC	82	0
8	ISTRAC	48	2
9	MCF	46	2
10	ADRIN	30	3
11	IIRS	7	1
12	PRL	34	0
13	SCL	62	0
14	NARL	5	0
15	NESAC	0	0
16	IIST	5	0
17	IPRC	105	20
TOTAL		**2573**	**202**

Table - IV: Women Employees in DOS/ISRO (2015-2016)				
Sl No	**Centre/Unit**	**Total Number of Employees**	**Number of Women Employees**	
			Scientific & Technical Staff	**Administrative Staff**
1	DOS/ISRO HQ	419	24	116
2	VSSC	4443	519	467
3	ISAC	2377	489	145
4	SDSC-SHAR	1958	128	132
5	SAC & DECU	1798	189	58
6	LPSC	1187	77	99
7	NRSC	857	134	59
8	ISTRAC	447	73	40
9	MCF	312	26	11
10	ADRIN	166	29	10
11	IIRS	89	17	5
12	PRL	209	9	18
13	SCL	567	29	16
14	NARL	64	5	7
15	NESAC	32	7	2
16	IIST	92	18	6
17	IPRC	639	47	41
TOTAL		**15656**	**1820**	**1232**

Vigilance

Vigilance Awareness Week was observed commencing with administering of pledge to the employees on October 26, 2015 to October 31, 2015.

The theme of observing the Vigilance Awareness Week for this year was “Preventive Vigilance as a tool of Good Governance”.

The activities carried out during Vigilance Awareness Week includes:

a) Display of Banners with the caption “Vigilance Awareness Week October 26, 2015 to October 31, 2015" at prominent places in ISRO Hqrs, Bengaluru

b) Display of cartoons of Late Shri. R.K Lakshman

c) Hon’ble Justice Shri Santhosh Hedge, former Judge of Supreme Court of India and former Lokayukta of Karnataka addressed the ISRO Community on the topic “Consequence of fall in Societal Values”.

d) Elocution competition for employees of Bengaluru Bond Units (BBU) (ISRO Hqrs, ISAC, ISTRAC,LEOS, LPSC(B) and MCF, Hassan) on “Preventive Vigilance as a tool of Good Governance” was also conducted and prizes were distributed to the winners of the competition.

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

Category of Employees	Type of cases	Cases pending as on 01.10.2014	Cases received during the period 01.10.2014 to 30.09.2015	Total (Col. 3+4)	Disposed during 01.10.2014 to 30.09.2015	Pending (Col. 5-6)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Group - A & Group-B (Gazetted)	Disciplinary (non-vigilance)	11	1	12	2	10
	Vigilance	7	1	8	2	6
Group - B (non-gazetted) Groups C & D	Disciplinary (non-vigilance)	11	6	17	11	6
	Vigilance	3	-	3	-	3
	Total	**32**	**8**	**40**	**15**	**25**

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.
- The first meeting of reorganised Joint Hindi Salahkar Samiti (JHSS) for DOS and DAE was organised in New Delhi under the Chairmanship of MOS, PMO on October 26, 2015.
- The Second Sub Committee of the Committee of Parliament on Official Language inspects various Centres/Units of the Department regularly. This year the Committee visited ISTRAC Port Blair on February 10, 2015, NARL, Gadanki on April 07, 2015 and DOS/ISRO HQ on September 03, 2015 with regard to the progress made in the Implementation of Official language.
- The Central OLIC meeting under the chairmanship of Secretary, DOL was organised on January 08, 2016 at New Delhi. The meeting was attended by the Joint Director (OL), DOS.
- All the centre/units of the Department in 'A', 'B' and 'C' region have achieved the target fixed for correspondence by the Department of Official Language.
- During the year an amount of ₹3,34,035 has been spent for the purchase of Hindi books for Library, which is in accordance with the target set up by DOL.
- During the year 2014-15, the department has spent ₹77,36,000 for the publication of hindi advertisement in the news papers.
- In order to implement Hindi in more meaningful and effective manner and to evaluate the progressive use of Hindi in DOS/ISRO Centers/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 Centers/Units to review the progressive use of Hindi.
- Internal inspections of Section of DOS/ISRO and also other Centres/Units were carried out to increase use of Hindi in day-to-day work.
- The training programmes in Hindi through Hindi Teaching Scheme, Correspondence course 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 Centers/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. Hindi Stenography training classes are conducted through video conferencing weekly thrice for those who have not yet completed the Hindi Stenography training. Out of the total strength of 16,651 in the department, 13,310 have the working knowledge of Hindi and 2,521 are proficient in Hindi and 170 employees are undergoing training.
- Three level Translation Training of Central Translation Bureau under the auspices of Town OLIC Central Translation Bureau, Bengaluru was conducted by the Department of Space for Hindi Translators of ISRO Centres/Units and TOLIC offices.

- With a view to refresh and update the knowledge of Official Language personnel an 'Official Language Orientation Programme' was organized in PRL, Ahmedabad during 28-29 January, 2016.
- Hindi Day, Hindi Week, Hindi Fortnight/Hindi Month and Hindi Workshops have been organised, in all DOS/ISRO Centers/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 Joint Hindi Salahkar Samithi regarding propaganda of Hindi from house-to-house, the family members of the employees were included during Hindi Fortnight celebrations in all Centers/Units of the Department and there was a very good response.
- The children of the employees who secured highest marks in Hindi in class X & XII were awarded.
- World Hindi Day was celebrated on 12th January in all Centers/Units of the Department by conducting various programmes. Hindi Bhashan Competition on "Swacch Bharat" & "Nari Suraksha" was organised in Antariksh Bhavan for all BBUs.
- Department plays an active role in the activities of Town OLIC. It conducts various programmes under the auspices of Town OLIC. A one day orientation programme for the heads of office of all member offices of Town OLIC was conducted in CPRI. Many officers of the Department took part in this programme. The Department also conducted the Hindi Shabd Sampada competition for all the members offices of the TOLIC on the occasion of the Joint Hindi Diwas.
- During the year 2014-15, seven Books in Hindi on Scientific subjects have been written by the Scientists of Space Application Centre, Ahmedabad and ADRIN. All these seven books are published. Publication of Technical Articles by the Scientists of the Department in leading magazines continued during the year. About eight articles were sent to the Department of Official Language, New Delhi to be considered for award.
- DOS/ISRO HQ in house magazine "Disha", a compendium of technical articles "Antariksh Gyan Sarita" and compendium of orders related to official language were also published during the year for the first time.
- Several pamphlets and stickers/posters on Indian Space Programme and Booklets on Glimpses of Indian Space Programme, PSLV-C23, 24, 26, 27, 28 and PSLV-C30, IRNSS-1D, 1E, GSLV-D6, Mars Orbiter Mission, etc, were brought out in Hindi. "Antariksh Bharat", a biannual technical magazine was also brought out tment in Hindi. A book specially written for school children named "Mars Orbiter Mission India's Triumphant Odyssey to the Red Planet" was also translated. In-house Hindi magazines are brought out by various Centres/Units of the Department. Space Odyssey, Glimpses of Indian Space Programme were updated.
- ISRO conducts several outreach programmes also to reach out the space activities to the common man and the student community. Exhibition in Hindi on Space were organised in schools during the year. SAC, Ahmedabad organised a space exhibition in Jhilia village of Bharuch district in Gujarat, where 5000 school students participated.

- The website of the department has been revamped. Hence the Hindi Website is being updated. In addition to Departments own Website, SAC, PRL, NRSC and NARL also have their own Websites. ISAC, VSSC, LPSC and 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. The new incentive scheme of the Department "SOLIS" has been introduced.
- A New Incentive Scheme "Vikram Sarabhai Maulik Lekhan Yojana" has been introduced to encourage the Scientists of the Department to Write Books on Scientific Subjects in Hindi.
- During the year various centres/units of the department conducted technical seminars in Hindi on various subjects. 13 technical seminars were organised. All the centres also organised a session on official language during their technical seminars. 12 official language seminars were conducted.
- The employees of DOS/ISRO Centres/Units have also participated in the activities on the progressive use of Hindi organised by various voluntary organisations and also by Town OLIC.
- Hindi Implementation introduced as part of Induction Programme in all the major Centers of DOS/ISRO continued during the year.
- During the year, the updation of space Science Glossary has also been undertaken by the Department in collaboration with CSTT, New Delhi. The first meeting regarding this was organised during April 15-17, 2015 at New Delhi. The second meeting was organised in Bengaluru during June 01-04, 2015 and the third meeting was organised in Udaipur during August 24-27, 2015. The last meeting in this regard was organized during January 01-04, 2016 at New Delhi and the e-version of the Glossary was released during the Orientation programme on January 28, 2016 at PRL, Ahmedabad.
- The Department also organised a training programme in Antariksh Bhavan on August 12, 2015 on the inclusion of Hindi in Accounts and Purchase area in COWAA for the various centre and units. Scientist from SAC and PRL, who have developed the software, were invited as faculty for this training programme.

Awards:

– Various Centres/Units of the Department have been awarded prizes under their respective Town OLICs during the year 2014-15 for the best Hindi Implementation work. VSSC, Thiruvananthpuram, MCF, Hassan, SCL, Chandigarh, IPRC, Mahendragiri and DECU, Ahmadabad got First Prize, ISRO Liasion Cell, Mumbai, SAC, Ahmadabad, LPSC, Bengaluru and PRL, Ahmadabad got Second Prize, VSSC's In-house Magazine "GAGAN" got Third Prize and NARL, Tirupathi got Special Prize..

– Scientists of the Department have been awarded for writing Books in Hindi: Rajbhasha Gaurav Purashkar 2015 for "Chandrayan-1: Ek Safal Bharatiya Prayas" – by Shri P.P. Sinha, retired scientist from VSSC; "C.V. Raman Vigyan Sanchar Purashkar" presented by Science and Technology Department to Shri Rakesh Shukla of ADRIN for his scientific writings in Hindi.

International Cooperation

International Cooperation on peaceful uses of outer space has been an integral part of Indian space programme. Indian Space Research Organisation (ISRO) of the Department of Space (DOS) carried out many activities in 2015-16, not only to strengthen the existing cooperation with space agencies of other countries and international bodies, but also to expand the cooperation with other space faring nations in promoting the development and use of space technology for various applications. ISRO works with other space agencies in pursing programmes of mutual interest; participates in international events dealing with space; and also shares its expertise with others in the applications of space technology.

Space cooperative documents were signed with space agencies of 36 countries and 4 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, Kuwait, Mauritius, Mexico, Mongolia, Myanmar, Norway, Peru, Republic of Korea, Russia, Saudi Arabia, South Asian Association for Regional Cooperation (SAARC), Spain, Sweden, Syria, Thailand, The Netherlands, Ukraine, United Kingdom, United States of America and Venezuela.

The cooperative agreements signed during this year are: (i) Programme between ISRO and French National Space Agency (CNES) for a reinforced cooperation in space activities; (ii) MoU between ISRO, CNES and French National Centre for Aerospace Research (ONERA) regarding their cooperation for Ka-band propagation experiment over the Indian tropical region; (iii) MoU between ISRO and Canadian Space Agency (CSA) concerning cooperation in the field of outer space; (iv) Letter of cooperation between ISRO and United States Geological Survey (USGS) for sharing of earth observation (Landsat satellite) data; (v) 2015-2020 Space Cooperation Outline between ISRO and China National Space Administration (CNSA); (vi) MoU between ISRO and Russian Federal Space Agency (ROSCOSMOS) on the expansion of cooperation in the field of exploration and use of outer space for peaceful purposes; (vii) Implementing Arrangement between ISRO and National Aeronautics and Space Administration (NASA) for cooperation on the Airborne Visible/Infrared Imaging Spectrometer Next Generation Airborne Campaign; (viii) MoU between ISRO and Kuwait Institute for Scientific Research (KISR) on cooperation in the exploration and use of outer space for peaceful purposes; (ix) Technical Assistance Agreement between ISRO and California Institute of Technology (Caltech)/ Jet Propulsion Laboratory (JPL) to share technical information to collaborate on a dual frequency scatterometer and wind data products generation.

Space cooperation between India and USA has been growing steadily and the increased interactions among the scientists paved the way for working together not only for earth observation but also for planetary exploration and space education. ISRO and NASA have achieved significant advancements in realising the microwave remote sensing satellite named “NASA-ISRO Synthetic Aperture Radar (NISAR)” and crossed various joint and agency-specific milestones including finalisation of Cooperation Project

Plan. The ISRO-NASA Mars Working Group, constituted in September 2014, had two meetings and discussed on initial results on analysis of data from respective Mars missions (MOM and MAVEN); possibilities for coordinated observations, cross calibration of scientific instruments and exchange of data/results from specific instruments. The fifth meeting of India-USA Civil Space Joint Working Group was organised at Bengaluru in September 2015 to review the ongoing cooperation and to identify newer areas of working together in earth observation, space exploration and satellite navigation.

India-Russia space cooperation made significant progress in 2015, the year of 40th Anniversary of launch of the first Indian satellite 'Aryabhata' by USSR launch vehicle. ISRO and ROSCOSMOS established a new Joint Working Group and the outcome of its deliberations are formalised through signing of a 'MoU on expansion of cooperation in the field of exploration and use of outer space for peaceful purposes' in June 2015. Both sides have identified 42 cooperative proposals under five major themes, viz., Satellite navigation; Launch vehicle development; Critical technologies for human spaceflight programme; Remote sensing of the Earth; and Space science and planetary exploration, for implementation.

As part of ongoing successful space cooperation between India and France, ISRO and CNES are discussing on the possibility of realising the third joint satellite mission with Thermal Infrared instrument for ecosystem studies. The "Programme for a reinforced cooperation in space activities" signed in April 2015, includes 'Earth Observation mission' as one of the potential cooperative activities for the near future. ISRO and CNES are also discussing the possibility of accommodating ARGOS instrument from CNES in ISRO's OCEANSAT-3 satellite, targeted for launch in 2018. The data from earlier two joint satellite missions, viz., Megha-Tropiques and SARAL, are used by global scientific community for studying tropical atmosphere and sea surface heights. Data from SAPHIR (Humidity profiler) in Megha-Tropiques is integrated into the Numerical Weather Prediction models, which has helped in substantially improving the weather forecasting. Data from ALTIKA (Ka-band Altimeter) is currently made available to global scientific community within 180 minutes of data acquisition.

As part of the on-going bilateral cooperation, the following meetings were organised: (i) the first meeting of ISRO-NARSS (National Authority for Remote Sensing and Space Science of Egypt) Joint Working Group at Bengaluru in March 2015; (ii) ISRO-KARI (Korea Aerospace Research Institute) Joint Workshop at Seoul and Daejeon, Korea in March 2015; (iii) the first Meeting of ISRO-CNSA Joint Committee on Space Cooperation at Beijing, China in May 2015; (iv) the first meeting between officials of ISRO and National Space Agency of Kazakhstan (KAZCOSMOS) over videoconference in June 2015; (v) the second ISRO-DLR (German Aerospace Centre) Workshop at Oberpfaffenhofen, Germany in October 2015.

Towards establishing new relations, ISRO hosted meetings with delegations from (i) Kenya, led by Principal Secretary, Ministry of Defence in March 2015; (ii) Tunisia, led by Tunisian Minister for Communication Technology and Digital Economy in July 2015; (iii) Colombia, consisting of University Professors, Industry leaders, Government officials and students in July 2015; (iv) United Arab Emirates (UAE) led by Chairman of UAE Space Agency in September 2015; (v) Ethiopia, led by Board Chairman of Entoto Observatory and Research Centre in November 2015; and (vi) Afghanistan, consisting of officials from the Ministry of Communication and Information Technology in November 2015. Comprehensive

notes on Space cooperation possibilities with Sudan, Peru, Central Asian Republics, and Pacific Island Countries were prepared and shared with Ministry of External Affairs (MEA) for further perusal.

Prominent visitors to ISRO Centres in 2015-16 include CNSA Administrator, CNES President, JPL Director, Chair of Missile Technology Control Regime (MTCR), Ambassador of Egypt to India and Ambassador of Republic of Korea to India.

India is in the process of building a 'Satellite for SAARC region' to provide satellite communication services to individual SAARC nations and also across the SAARC region. Towards this, ISRO/ DOS with active support from MEA hosted a Conference on "Satellite for the SAARC region and Space Technology Applications" on June 22, 2015 at New Delhi. The Conference deliberated on the configuration and ground Infrastructure requirements for the proposed satellite as well as other space technology applications. Representatives from all SAARC member countries have participated.

India has taken up a project with the Association of South East Asian Nations (ASEAN) comprising Brunei, Cambodia, Indonesia, Laos PDR, Malaysia, Myanmar, the Philippines, Singapore, Thailand and Vietnam, to 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.

ISRO has been included as a new member of Coordination Group on Meteorological Satellites (CGMS) in May 2015, in view of its contribution to its satellite programmes of the World Meteorological Organisation (WMO) Global Observing System.

In the field of capacity building, ISRO continues to share its facilities, expertise in the application of space science and technology by conducting short-term and long-term courses through Indian Institute of Remote Sensing (IIRS) and the United Nations (UN) affiliated Centre for Space Science and Technology Education in Asia and the Pacific (CSSTE-AP) at Dehradun. As of now, there are more than 1500 beneficiaries from 52 countries. Apart from the regular courses, these centres organised special courses on disaster risk reduction and emergency management in association with international centres for the benefit of officials from Asia Pacific region.

India participates in international disaster management mechanisms including International Charter "Space and Major Disasters", Sentinel Asia programme of Asia Pacific Regional Space Agency Forum (APRSAF), UN Economic and Social Commission for Asia and the Pacific (ESCAP) and UN Platform for Space based Information for Disaster management and Emergency Response (UNSPIDER). ISRO led the International Charter activities in 2015 and organised the 33rd Executive Secretariat and Board meeting at Hyderabad in April 2015 with the participation of representatives from ten countries. India, as a member of the International COSPAS-SARSAT system for search and rescue operations, provides search and rescue support to India and seven neighbouring countries, namely Bangladesh, Bhutan, Maldives, Nepal, Seychelles, Sri Lanka and Tanzania. Under Regional Cooperative Mechanism of UNESCAP, India offered technical support to Sri Lanka on agricultural drought monitoring. Dedicated software called 'Drought Monitoring System-Sri Lanka' was conceptualised, developed and operationalised in Sri Lanka along with required training.

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 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), 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) and Inter-Agency Space Debris Coordination Committee (IADC).

Space Pioneer award for the year 2015 was presented to ISRO by National Space Society (NSS) of USA in the Science and Engineering category at the 34th Annual International Space Development Conference held at Toronto in Canada in May 2015.

'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 2015 as shown below:-

Questions	Budget Session		Monsoon Session		Total	
	4th session- 16th of Lok sabha	234th session of Rajya Sabha	5th Session- 16th Lok Sabha	236th Session of Rajya Sabha	L.S.	R.S.
Starred Questions	03	01	02	00	05	01
Unstarred Questions	24	14	28	16	52	30
Total	27	15	30	16	57	31

The Questions were related to GSLV, GSLV-Mk III and Cryogenic Technology, Satellite Technology, Remote Sensing Applications, Space Technologies, Manned Space Mission, Chandrayaan–II, Mars Orbiter Mission, Mars-2 Mission, SAARC Satellite, Aditya Satellite, EDUSAT, Regional Positioning System/IRNSS, Reusable Launch Vehicle, Funds for Research, Satellites launched by India and accruals from Sending Satellites to Space, Pricing of transponders, Space Cooperation and Joint declaration in Space Sector, Satellite Launch Pad in the Country, Interplanetary Exploration, DTH services, Hacking of Website, NISAR mission, 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, webcasting of launches, organisation of exhibitions, educational activities like lectures, interactive sessions with students, quiz programmes, water rocket making and launching events, publications, video documentaries, SAKAAR – an Augmented Reality Application for Android devices, 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.

ISRO pavilion at 'Make in India Week' Exhibition

Publicity Through Media

Print and Electronic Media

Doordarshan and many private TV channels provided prominent live coverage to the launch of PSLV-C27/IRNSS-1D on March 28, 2015, PSLV-C28/DMC3 on June 10, 2015, GSLV-D6/GSAT-6 on August 27, 2015, PSLV-C30/Astrosat on September 28, 2015, PSLV-C29/TeLeos-1 on December 16, 2015, and PSLV-C31/IRNSS-1E on January 20, 2016, 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. Additionally, Doordarhan (DD) covered the launch of India's latest communication satellite GSAT-15 by European Ariane 5 VA227 Live. But, the event for which local, national and even international media continued to provide conspicuous coverage was the successful Mars Orbiter Mission (MOM). In 2015, National Geographic channel telecast a special one hour documentary on MOM. Foreign media also covered the two PSLV commercial launches (PSLV-C28 and PSLV-C29) as well as PSLV-C30 that carried six satellites from abroad besides ASTROSAT.

Special video capsules on the Indian space programme including those on MOM, GSLV-D6, IRNSS, ASTROSAT, GSAT-15 and PSLV commercial missions, 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 MOM. 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 MOM progress.

During 2015, media was invited to ISRO Satellite centre for 'GNSS User Meet 2015' as well as to MOX/ISTRAC on the second anniversary of the launch of MOM. Print and electronic media provided good coverage for ASTROSAT, which is India's first multi-wavelength Astronomical observatory, during its launch.

'SAKAAR', an Augmented Reality application for Android devices that helps the users, especially students, to better visualise ISRO launch vehicle, satellite and applications programmes, was launched in 2015.

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 Website also provides DOS Annual Report, Space India, press releases, special publications, SAKAAR, employment opportunities, RTI related information, etc.

Large number of students watching the Launch of a Sounding Rocket at Thumba during World Space Week celebrations – 2015 at VSSC

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 and many other outreach programmes were organised by ISRO Centres on important occasions like National Science Day and World Space Week in which thousands of students actively participated. Exhibitions and various other outreach events were also organised in association with Non-Governmental Organisations in various places and at prestigious events. A total of 30 exhibitions were organised during 2015-16. A large number of scientists, academicians and students from India as well as delegates from abroad visited many of these exhibitions. A mobile Tableau on Mars Orbiter Mission was conspicuously presented during the International Fleet Review- 2016 (IFR-16) at Visakhapatnam on February 07, 2016.

ISRO Tableau on Mars Orbiter Mission being paraded during 'International Fleet Review – 2016' at Visakhapatnam

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 (CPIO) for receiving applications and dissemination of information, Assistant Public Information Officers (APIOs for receiving applications), First Appellate Authority for the disposal of stage one appeals and Transparency Officer. As required under the Act, DOS has published the requisite information on the web page http://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 2015 to December, 2015, 807 applications were received and information were disseminated under the provisions of the RTI Act. 120 appeals were received by the First Appellate Authority and 25 appellants approached the Second Appellate Authority, i.e., Central Information Commission.

Audit Observations

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

Sl. No	Year	No. of Paras/ PA reports on which ATNs have been submitted to PAC after vetting by Audit	Details of the Paras/PA reports on which ATNs are pending			
			No. of ATNs not sent by the Ministry even for the 1st time	No. of ATNs sent by the Ministry and awaiting vetting by Audit	No. of ATNs sent but returned with observations and Audit is awaiting their resubmission by the Ministry	No. of ATNs which have been finally vetted by audit but have not been submitted by the Ministry to PAC
1	2	3	4	5	6	7
1.	Chapter V of Report No.9 of 2006 Non-Tax Receipts-Issues relating to receipts of DOS	NIL	NIL	NIL	ONE	NIL
2.	Report No.16 of 2011-12 (Para No19.1) Idle investment on development of a linac tube)	Nil	Nil	Nil	One	Nil
3.	Report No. 1 of 2010-11 Review of Selected Grants	Nil	Nil	Nil	One	Nil
4.	Report No. 4 of 2012-2013 Hybrid satellite digital multimedia broadcasting service agreement with Devas	NIL	NIL	NIL	ONE	NIL
5.	Report No. 13 of 2012-13 Avoidable payment of demand charges	Nil	Nil	One	Nil	Nil

Sl. No	Year	No. of Paras/ PA reports on which ATNs have been submitted to PAC after vetting by Audit	Details of the Paras/PA reports on which ATNs are pending			
			No. of ATNs not sent by the Ministry even for the 1st time	No. of ATNs sent by the Ministry and awaiting vetting by Audit	No. of ATNs sent but returned with observations and Audit is awaiting their resubmission by the Ministry	No. of ATNs which have been finally vetted by audit but have not been submitted by the Ministry to PAC
1	2	3	4	5	6	7
6.	Report No. 1 of 2013 Accounts for the year 2011-12 of the Union Government	Nil	Nil	One	Nil	Nil
7.	Report No. 22 of 2013 (Para No. 3.1) Edusat Utilisation Programme	Nil	Nil	Nil	One	Nil
8	Report No. 22 of 2013 (Para No. 3.2) Parking of foreign Satellite in Indian Administration coordinated orbital slot.	Nil	Nil	Nil	One	Nil
9	Report No. 22 of 2013 (Para No. 3.3) Loss due to unsafe transport and belated insurance of consignment	Nil	Nil	Nil	One	Nil
10	Report No. 1 of 2014 Appropriation Accounts	Nil	Nil	Nil	One	Nil
11	Report No. 22 of 2014 Management of satellite capacity for DTH service by Department of Space	Nil	Nil	Nil	One	Nil

Sl. No	Year	No. of Paras/ PA reports on which ATNs have been submitted to PAC after vetting by Audit	Details of the Paras/PA reports on which ATNs are pending			
			No. of ATNs not sent by the Ministry even for the 1st time	No. of ATNs sent by the Ministry and awaiting vetting by Audit	No. of ATNs sent but returned with observations and Audit is awaiting their resubmission by the Ministry	No. of ATNs which have been finally vetted by audit but have not been submitted by the Ministry to PAC
1	2	3	4	5	6	7
12	Report No. 22 of 2014 (Para No. 4.1) Inordinate delay in realisation of SRE-2 mission	Nil	Nil	Nil	One	Nil
13	Report No. 22 of 2014 (Para No.4.2) Loss in allocation of satellite Capacity	Nil	Nil	Nil	One	Nil
14	Report No. 22 of 2014 (Para No. 4.3) Avoidable expenditure due to improper contract management	Nil	Nil	One	Nil	Nil
15	Report No. 27 of 2014 (Para No. 4.4) Infructuous expenditure on procurement of components	Nil	Nil	One	Nil	Nil
16	Report No.30 of 2015 (Para No. 5.1) Implementation incentive scheme	Nil	One	Nil	Nil	Nil
17	Report No.30 of 2015 (Para No. 5.2) Irregular payment of service tax	Nil	One	Nil	Nil	Nil
18	Report No.30 of 2015 (Para No. 5.3) Avoidable payment of electricity charges	Nil	One	Nil	Nil	Nil

(B) Summary of important audit observations during 2015

(a) Para 5.1 titled "Implementation of incentive schemes":

"The policy framework of Indian Space Programme has provision for grant of various rewards and incentives to employees of Department of Space (DOS)/Indian Space Research Organisation (ISRO) and its Centres. Governmet of India approved Performance Related Incentive Scheme (PRIS) for individual/group performance based on the recommendation of Sixth Central Pay Commission. DOS implemented PRIS for all employees and continued to grant additionally, other special allowances resulting in multiple benefits to its employees. A structured monitoring and evaluation mechanism for PRIS was not instituted. There were instances of violation of DOS guidelines on grant of PRIS."

(b) Para 5.2 titled "Irregular payment of Service Tax":

"Master Control Facility, Hassan paid ₹1.33 crore during the period of July 2012 to June 2014 towards Service Tax on the cost of security services provided by Central Industrial Security Force, which was not required under rules. Of this, refund of ₹44.68 lakh was secured after the matter was raised by Audit. The remaining amount of ₹88.05 lakh stood forfeited as it became time barred"

(c) Para 5.3 titled "Avoidable payment of electricity charges":

Regional Remote Sensing Centre-East, Kolkata incurred avoidable expenditure of ₹55.37 lakh towards payment of electricity charges.

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)
- Successful launch of GSLV-D2, the second developmental test flight of GSLV with GSAT-2 on-board from SDSC SHAR (May 8, 2003)
- Successful launch of INSAT-3E by Ariane from Kourou, French Guyana (September 28, 2003)
- Successful launch of Resourcesat-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 GSLV-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
- GSLV-F06, the seventh launch of GSLV 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 GSLV-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-Franch 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 navigation 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-D5 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 eighth 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 suborbital 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. CARE module carried on-board to a height of 126 km successfully recovered later

2015

- PSLV-C27 Successfully Launches India's Fourth Navigation Satellite IRNSS-1D on March 28, 2015 from Satish Dhawan Space Centre SHAR, Sriharikota.
- PSLV-C28 successfully launches three identical DMC3 commercial Earth Observation Satellites, along with two smaller satellites from United Kingdom, into a polar Sun Synchronous Orbit on July 10, 2015 from Satish Dhawan Space Centre SHAR, Sriharikota.
- Geo-Synchronous Satellite Launch Vehicle (GSLV-D6), equipped with the indigenous Cryogenic Upper Stage (CUS), successfully launches 2117 kg GSAT-6, into a GTO on August 27, 2015 from Satish Dhawan Space Centre SHAR, Sriharikota.
- ASTROSAT, India's first dedicated astronomy satellite successfully launched by PSLV-C30 on September 28, 2015 from Satish Dhawan Space Centre SHAR, Sriharikota. Along with ASTROSAT, six satellites from international customers - LAPAN-A2 of Indonesia, NLS-14 (Ev9) of Canada and four identical LEMUR satellites of USA – were also launched by this PSLV flight
- The 3164 kg GSAT-15 carrying Ku-band transponders and GAGAN payload launched successfully by the European Ariane-5 VA-227 from Kourou, French Guiana on November 11, 2015
- In its thirty second flight conducted from SDSC SHAR, Sriharikota on December 16, 2015, PSLV-C29 successfully launches six satellites from Singapore (400 kg TeLEOS-1 as primary satellite and other Five co-passenger payloads).

Acronyms

AAI	:	Airports Authority of India
AAR	:	Accumulation Area Ratio
ABPP	:	Air Breathing Propulsion Project
ACL	:	Antrix Corporation Limited
ADCOS	:	Advisory Committee for Space Science
ADPS	:	Ancillary Data Products Generation Software
AEB	:	Brazilian Space Agency
AEM	:	Mexican Space Agency
AFTN	:	Aeronautical Fixed Telecommunications Network
AHRMX	:	Advanced High Resolution Multispectral Camera
AHRPAN	:	Advanced High Resolution Panchromatic Camera
AIR	:	All India Radio
ALIMCO	:	Artificial Limbs Manufacturing Corporation of India
ANSSIRD	:	Abdul Nazir Saab State Institute of Rural Development
APEP	:	Ammonium Perchlorate Experimental Plant
APIOs	:	Assistant Public Information Officers
APLD	:	Advanced Propulsion and Laser Diagnostics
APRSAF	:	Asia Pacific Regional Space Agency Forum
APXS	:	Alpha Particle X-ray Spectrometer
ARG	:	Automatic Rain Gauge
AS&DM	:	Aerial Services & Digital Mapping
ASEAN	:	Association of South East Asian Nations
ASPEX	:	Aditya Solar wind Particle Experiment
ATV	:	Advanced Technology Vehicle
ATVF	:	Advanced Thermo Vacuum Facility
ATVP	:	Advanced Technology Vehicles & Sounding Rockets
AWiFS	:	Advanced Wide Field Sensor
AWS	:	Automatic Weather Station

BMT	:	Barium Magnesium Tantalite
CALIOP	:	Cloud-Aerosol LIdar with Orthogonal Polarisation
CAM	:	Community Atmosphere Model
CARE	:	Crew Module Atmospheric Re-entry Experiment
CCD	:	Charge Coupled Device
CCE	:	Crop Cutting Experiments
CCRR	:	Corner Cube Retro Reflector
CEOS	:	Committee on Earth Observation Satellites
CES	:	Crew Escape System
CFD	:	Computational Fluid Dynamics
CFTF	:	Cold Flow Test Facility
CGMS	:	Coordinating Group on Meteorological Satellites
CGWB	:	Central Ground Water Board
CHAMAN	:	Coordinated programme on Horticulture Assessment and Management using Geoinformatics
CICR	:	Central Institute for Cotton Research
CM	:	Crew Module
CME	:	Continuing Medical Education
CNSA	:	China National Space Administration
COPLOT	:	Committee on Papers Laid on the Table
COPU	:	Committee on Public Undertakings
CORS	:	Carbon dioxide and Odour Removal System
CORS	:	Continuously Operating Reference Stations
COSPAR	:	Committee on Space Research
COTs	:	Commercial-off-the-Shelf
CPCS	:	Cabin Pressure Control System
CPIO	:	Central Public Information Officers
CPM	:	Charge Particle Monitor
CRISM	:	Compact Reconnaissance Imaging Spectrometer for Mars
CRSF	:	Cyclotron Resonant Scattering Feature
CSA	:	Canadian Space Agency

CSPA	:	Charge Sensitive Pre-amplifier
CSR	:	Corporate Social Responsibility
CSSTEAP	:	Centre for Space Science and Technology Education in Asia and the Pacific
CUS	:	Cryogenic Upper Stage
CVI	:	Chemical Vapour Infiltration
CWC	:	Central Water Commission
CZTI	:	Cadmium Zinc Telluride Imager
DCA	:	Destructive Chemical Analysis
DECU	:	Development and Educational Communication Unit
DEM	:	Digital Elevation Model
DES	:	Delhi Earth Station
DGCA	:	Directorate General of Civil Aviation
DIVA	:	Date Interpolating Vibrational Analysis
DMS	:	Disaster Management Support
DMSP	:	Disaster Management Support Programme
DOS	:	Department of Space
DPA	:	Destructive Physical Analysis
DRT	:	Data Relay Transponder
DSM	:	Digital Surface Model
DSNG	:	Digital Satellite News Gathering
DSPTs	:	Digital Satellite Phone Terminal
DSRQ	:	Directorate of Systems Reliability and Quality
DTH	:	Direct-to-Home
E1	:	Integrated Engine
EACE	:	Earth's Atmospheric Composition Explorer Payload
ECLSS	:	Environmental Control and Life Support System
ECMWF	:	European Centre for Medium Range Weather Forecasts
ECVs	:	Essential Climate Variables
ELAs	:	Equilibrium Line Altitudes
ENAs	:	Energetic Neutral Atoms
ENSO	:	El Nino and Southern Oscillation

ENWi	:	Electron Density and Neutral Wind Probe
EO	:	Earth Observation
ESA	:	European Space Agency
EUMETSAT	:	European Organisation for Exploitation of Meteorological Satellites
EVI	:	Enhanced Vegetation Index
FEAST	:	Finite Element Analysis of Structures
FEM	:	Fluid Energy Mill
FIR	:	Flight Information Region
FLEWS	:	Flood Early Warning System
GAC	:	Global Area Coverage
GAGAN	:	GPS Aided GEO Augmented Navigation
GAIL	:	Gas Authority of India Ltd
GCP	:	Ground Control Points
GEM	:	Gas Electron Multiplier
GEO	:	Geostationary Earth Orbit
GEO LUT	:	GEOSAR Local User Terminal
GIS	:	Geographical Information System
GISAT	:	Geo Imaging Satellite
GLDAS	:	Global Land Data Assimilation system
GMRT	:	Giant Meter-wave Radio Telescope
GPR	:	Ground Penetrating Radar
GRACE	:	Gravity Recovery and Climate Experiment
GRASP	:	Geostationary Radiation Spectrometer
GRT	:	Ground Resonance Test
GSLV	:	Geosynchronous Satellite Launch Vehicle
GSLV Mk-III	:	Geosynchronous Satellite Launch Vehicle Mark-III
GTO	:	Geosynchronous Transfer Orbit
HAS	:	Hydraulic Actuation System
HAT	:	High Altitude Test
HBCSE	:	Homi Bhabha Centre for Science Education
HCS	:	Humidity Control System

HEL1OS	:	High Energy L1 Orbiting X-ray Spectrometer
HEX-01	:	Hypersonic Experimental Flight
HSP	:	Human Spaceflight Programme
IAA	:	International Academy of Astronautics
IADC	:	Inter Agency Debris Coordination Committee
IAF	:	International Astronautical Federation
IAOP	:	Indian Astronomy Olympiad Programme
IARI	:	Indian Agricultural Research Institute
ICC	:	Coordination Committee
ICG	:	International Committee for Global Navigation Satellite Systems
ICMAT	:	Integrated Cryo Components and Modules Assembly and Test Facility
ICSDBS	:	Integrated Component Service Data Base Management System
IGS	:	International Ground Stations
IGS	:	IRS Ground Stations
IIA	:	Indian Institute of Astrophysics
IIRS	:	Indian Institute of Remote Sensing
IIS	:	Island Information System
IISc	:	Indian Institute of Science
IISL	:	International Institute of Space Law
IIST	:	Indian Institute of Space Science and Technology
IISU	:	ISRO Inertial Systems Unit
IITs	:	Indian Institute of Technology
IMDPS	:	INSAT Meteorological Data Processing System
INC	:	ISRO Navigation Centre
INCOIS	:	Indian National Centre for Ocean Information Services
INCOSPAR	:	Indian National Committee for Space Research
InFCCAS	:	Indian Forest Cover Change Alert System
INFFRAS	:	Indian Forest Fire Response and Assessment System
INLUS	:	Indian Lank Uplink stations
INMCC	:	Indian Master Control Centre
INRES	:	Indian Reference Stations

INSAT	:	Indian National Satellite
IOT	:	In Orbit Tests
IPAB	:	Integrated Product Assurance Board
IPCS	:	Integrated Production of Control System Components and Modules
IPR	:	Intellectual Property Right
IPRC	:	ISRO Propulsion Complex
IPU	:	Irrigation Potential Utilisation
IRCDR	:	IRNSS CDMA Ranging Stations
IRDCN	:	IRNSS Data Communication Network
IRIMS	:	IRNSS Range and Integrity Monitoring Stations
IRNSS	:	Indian Regional Navigation Satellite System
IRNWT	:	IRNSS Network Timing Facility
IRSCF	:	IRNSS Spacecraft Control Facility
IRU	:	Inertial Reference Unit
ISAC	:	ISRO Satellite Centre
ISECG	:	International Space Exploration Coordination Group
ISITE	:	ISRO Satellite Integration and Test Establishment
ISPRS	:	International Society for Photogrammetry and Remote Sensing
ISRO	:	Indian Space Research Organisation
ISTRAC	:	ISRO Telemetry, Tracking and Command Network
ITC	:	Integrated Test Complex
IUCAA	:	Inter-University Centre for Astronomy and Astrophysics
IWMP	:	Integrated Watershed Management Programme
JHSS	:	Joint Hindi Salahkar Samiti
JPL	:	Jet Propulsion Laboratory
JWG-CSC	:	Joint Working Group on Civil Space Cooperation
KARI	:	Korea Aerospace Research Institute
KSAT	:	Kongsberg Satellite Services
L1	:	Lagrangian point 1
LAC	:	Local Area Coverage
LAM	:	Liquid Apogee Motor

LAP	:	Lyman Alpha Photometer
LAXPCs	:	Large Area X-ray Proportional Counters
LCVRs	:	Liquid Crystal Variable Retarders
LEO	:	Low Earth Orbits
LEOS	:	Laboratory for Electro-Optic Systems
LEOP	:	Launch and Early Orbit Phase
LEOSAR	:	Low Earth Orbit Search And Rescue
LFDC	:	Large Format Digital Camera
LHF	:	Latent Heat Flux
LiOH	:	Lithium Hydroxide
LOX	:	Liquid Oxygen
LPOT	:	Low Pressure Oxidiser Turbo Pump
LPRM	:	Land Parameter Retrieval Model
LPSC	:	Liquid Propulsion System Centre
LST	:	Land Surface Temperature
LUTs	:	Local User Terminals
MADRAS	:	Microwave Analysis and Detection of Rain and Atmospheric Structures
MAST	:	Multi-Application Solar Telescope
MCC	:	Mars Colour Camera
MCC	:	Mission Control Centres
MCF	:	Master Control Facility
MENCA	:	The Mars Exospheric Neutral Composition Analyser
MFDC	:	Medium Format Digital Camera
MGDI	:	MODIS Global Disturbance Index
MHA	:	Ministry of Home Affairs
MNCFC	:	Mahalanobis National Crop Forecast Centre
MoHFW	:	Ministry of Health and Family Welfare
MOM	:	Mars Orbiter Mission
MOTR	:	Multi Object Tracking Radar
MOX	:	Mission Operations Complex
MPD	:	Magneto Plasma Dynamic Thruster

MRCCs	:	Maritime Rescue Coordination Centres
NAL	:	National Aeronspace Laboratories
NARL	:	National Atmopheric Research Laboratory
NASA	:	National Aeronautics and Space Administration
NCSM	:	National Council of Science Museums
NDC	:	NRSC Data centre
NDMA	:	National Disaster Management Authority
NDRF	:	National Disaster response Force
NDVI	:	Normalised Difference Vegetation Index
NEC	:	North Eastern Council
NEOC	:	National Emergency Operations Centre
NER	:	North Eastern Region
NE-SAC	:	North Eastern-Space Applications Centre
NGOs	:	Non-Government Organisations
NHAI	:	National Highway Authority of India
NIAS	:	National Institute of Advanced Studies
NICES	:	National Information System For Climate and Environment Studies
NISAR	:	NASA-ISRO Synthetic Aperture Radar
NNRMS	:	National Natural Resources Management System
NRC	:	Natural Resource Census
NRDB	:	Natural Resources Database
NRSC	:	National Remote Sensing Centre
NSDI	:	National Spatial Data Infrastructure
NSSS	:	National Space Science Symposium
NWH	:	North Western Himalayas
OCM	:	Ocean Colour Monitor
OLICs	:	The Official Language Implementation Committees
OLR	:	Outgoing Long Wave Radiation
OSCAT	:	Oceansat-2 Scatterometer
OSR	:	Optical Solar Reflectors
PAPA	:	Plasma Analyser Package For Aditya

PAT	:	Pad Abort Test
PC-NNRMS	:	Planning Committee on National Natural Resources Management System
PESEP	:	Professional Engineer and Scientist Exchange Programme
PFA	:	Post Flight Analysis
PIND	:	Particle Impact Noise Detection
PLANEX	:	Planetary Exploration
POLIX	:	Polarimeter Instrument in X-rays
PRI	:	Panchayath Raj Institutions
PrISM	:	Probe for Infra-red Spectroscopy of Mars
PRL	:	Physical Research Laboratory
PSLV	:	Polar Satellite Launch Vehicle
PSP	:	Pre-Signal Points
RCCs	:	Rescue Coordination Centres
RCS	:	Reaction Control System
RCT	:	Reaction Control Thruster
RESINS	:	Redundant Strap-down Inertial Navigation System
RESPOND	:	Research Sponsored
RISAT	:	Radar Imaging Satellite
RLV-TD	:	Reusable Launch Vehicle – Technology Demonstrator
RN	:	Radio Networking
RNP0.1	:	Required Navigation Performance, 0.1 Nautical Mile
ROSA	:	Radio Occultation Sounder for Atmospheric studies
ROTs	:	Receive Only Terminals
ROU	:	Right of Usage
RRI	:	Raman Research Institute
RRSCs	:	Regional Remote Sensing Centres
RS	:	Restricted Service
RTI	:	Right To Information
RWA	:	Reaction Wheel Assembly
SAC	:	Space Applications Centre
SADA	:	Solar Array Drive Assembly

SADM	:	Solar Array Deployment Mechanism
SAG	:	Space Astronomy Group
SAR	:	Synthetic Aperture Radar
SARAL	:	Satellite with ARGOS and ALTIKA
SAS&R	:	Satellite Aided Search and Rescue
SATNAV	:	Satellite Navigation
SBAS	:	Satellite Based Augmentation System
SCES	:	Satellite Control Earth Station
SCFT	:	Semi-cryogenic Cold Flow Test facility
SCL	:	Semi-Conductor Laboratory
SCNP	:	Satellite Communication and Navigation Programme
SCORPIO	:	Satellite based Cyclone Observation for Real-time Prediction over Indian Ocean
SCT	:	Structural Coupling Test
SDSC	:	Satish Dhawan Space Centre
SFCG	:	Space Frequency Coordination Group
SFL	:	Space Flight Laboratory
SIS-DP	:	Space-based Information Support for Decentralised Planning
SITs	:	Satellite Interactive Terminals
SITVC	:	Secondary Injection Thrust Vector Control
S-MSS	:	S-band Mobile Satellite Service
SoLEXS	:	Solar Low Energy X-ray Spectrometer
SOUREX	:	Sounding Rocket Experiment
SPL	:	Space Physics Laboratory
SPPU	:	Savitribai Phule Pune University
SPS	:	Standard Positioning Service
SR	:	Systems Reliability
SRSAC	:	State Remote Sensing Applications Centres
SSM	:	Scanning Sky Monitor
SSP	:	Space Studies Programme
SSPA	:	Solid State Power Amplifier

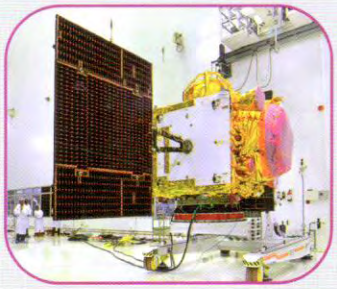
SSTL	:	Surrey Satellite Technology Limited
STC	:	Space Technology Cells
STFS	:	Standard Time and Frequency Signal
STRC	:	Standing Technical Review committee
SUIT	:	Solar Ultraviolet Imaging Telescope
SVAB	:	Second Vehicle Assembly Building
SVD	:	Single Value Decomposition
SXT	:	Soft X-ray Telescope
TDI	:	Time Delay Integration
TDMA	:	Time Division Multiple Access
TDP	:	Technology Development Programmes
TDV	:	Technology Demonstration Vehicle
TERLS	:	Thumba Equatorial Rocket Launching Station
TIS	:	Thermal Infrared Imaging Spectrometer
TMA	:	Tri Methyl Aluminum
TMTC	:	Telemetry Telecommand
TOF	:	Trees outside Forest
TOSS	:	Transfer Orbit Support Service
TSTO	:	Two Stage to Orbit
TWS	:	Total Water Storage
ULV	:	Unified Launch Vehicle
UN-COPUOS	:	United Nations Committee on Peaceful Uses of Outer Space
UN-ESCAP	:	United Nations Economic and Social Commission for Asia and the Pacific
UNSPIDER	:	UN Platform for Space based Information for Disaster management and Emergency Response
USO	:	Udaipur Solar Observatory
UT	:	University of Twente
UTH	:	Upper Tropospheric Humidity
UTIAS	:	University of Toronto Institute for Advanced Studies
UVIT	:	Ultra Violet Imaging Telescope
VAB	:	Vehicle Assembly Building

VELC	:	Visible Emission Line Coronagraph
VHI	:	Vegetation Health Index
VHRR	:	Very High Resolution Radiometer
VPN	:	Virtual Private Network
VPT	:	Video Picture Transmission
VRC	:	Village Resource Centre
VSATs	:	Very Small Aperture Terminals
VSSC	:	Vikram Sarabhai Space Centre
WMS	:	Web Map Service
XRF	:	X-Ray Fluorescence
ZeeDP	:	Zero Defect delivery Programme

PSLV-C28

PSLV-C29

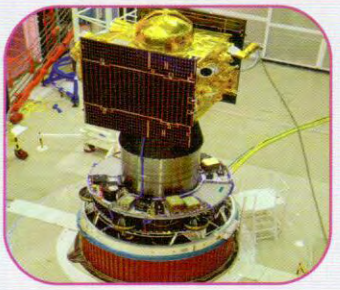
IRNSS-1D



GSAT-6

ASTROSAT

IRNSS-1E



PSLV-C27

GSLV-D6

PSLV-C30

PSLV-C31

GSAT-15