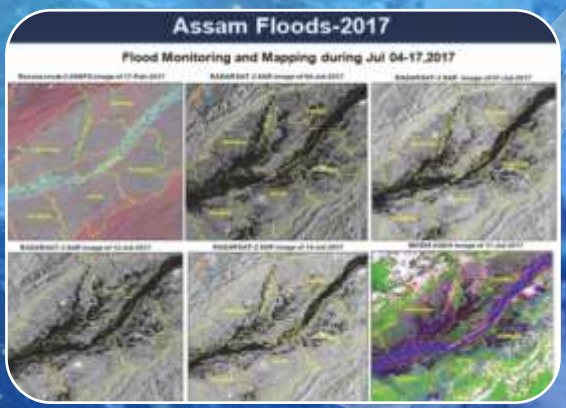
भारत सरकार
अन्तरिक्ष विभाग

सत्यमेव जयते

GOVERNMENT OF INDIA
DEPARTMENT OF SPACE



वार्षिक रिपोर्ट

Annual Report

2017 - 2018

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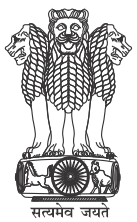


GOVERNMENT OF INDIA
DEPARTMENT OF SPACE

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 the management of natural resources and various developmental projects across the country using space based imagery
- Indigenous capability for the 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 2016–2020

MISSIONS	2016-17	2017-18	2018-19	2019-20
EARTH OBSERVATION SATELLITES	CARTOSAT-2 Series1 CARTOSAT-2 Series2 SCATSAT-1 RESOURCESAT-2A INSAT-3DR	CARTOSAT-2 Series3 CARTOSAT-2 Series4 **MICROSAT**	CARTOSAT-3 OCEANSAT-3 RISAT-1A RISAT-2 Series	RESOURCESAT-3S OCEANSAT-3A RESOURCESAT-3 CARTOSAT-3 Series HRSAT(3) GISAT-1 GISAT-Series
COMMUNICATION & NAVIGATION SATELLITES Procured Launch Service	IRNSS-1G GSAT-18	IRNSS-1H IRNSS-1I South Asia Satellite **GSAT-6A** **GSAT– 19** GSAT-17	**GSAT– 29** GSAT-7 Series GSAT-11	**GSAT– 22**
SPACE SCIENCE & PLANETARY EXPLORATION SATELLITES			Chandrayaan-2	
TECHNOLOGY DEVELOPMENT LAUNCH VEHICLES PSLV GSLV GSLV-MkIII	RLV-TD SCRAMJET 5 Missions 1 Mission	4 Missions 2 Missions **1 Mission**	Includes one Commercial 5 Missions 2 Missions **1 Mission**	Includes one Commercial 6 Missions 2 Missions **1 Mission**

Highlights

Department of Space has continued to provide its technological services to the country with the development and implementation of launch vehicles, satellites and applications, as envisaged. 2017 proved to be a busy year with many achievements that helped the country to not only showcase its capability in space technology, but also enabled it to reach newer heights with unique achievements.

During the period of reporting, country witnessed many significant achievements of the Indian Space Programme. Four launch vehicle missions were successfully accomplished during the year that included GSLV-MkIII D1 the maiden developmental flight of India's most powerful launch vehicle GSLV-MkIII, successful launch of GSLV-F09 and two PSLV launches from Satish Dhawan Space Centre SHAR, Sriharikota. Also, ISRO could place seven Indian satellites and 57 foreign satellites into the orbit. The seven Indian satellites included two earth observation satellites, three communication satellites and two experimental small satellites.

The successful launch of GSLV-MkIII D1 was one of the important highlights during the year, which could place a 3,136 kg high throughput communication satellite GSAT-19 into a Geosynchronous Transfer Orbit (GTO). Yet another important achievement, as part of this success, was the maiden flight of indigenously developed "C25 high thrust cryogenic engine and stage". GSAT-19 is the heaviest satellite to be launched from the Indian soil so far.

During the year, ISRO was also successful in launching GSLV-F09, that could successfully place the South Asia Satellite (GSAT-9) into GTO, which is a gift from India to SAARC nations. Polar Satellite Launch Vehicle (PSLV) had two successful launches during the year, (i) unique distinction of launching a record number of 104 satellites in a single mission during February 2017 and (ii) launch of 31 satellites during June 2017. The launch of GSAT-17, a communication satellite was accomplished from French Guiana during June 2017. However, the 41st flight of PSLV carrying India's eighth navigation satellite IRNSS-1H could not place the satellite in the designated orbit and hence was not successful.

In 2017, India's Mars Orbiter Mission (MOM) spacecraft completed three years in its orbit around Mars, while AstroSat, India's multi-wavelength observatory, successfully completed two years in orbit. Both these satellites are in good condition and performing satisfactorily.

Important events of the Indian space programme during 2017 are highlighted in a chronological order as follows:

- On February 15, 2017, PSLV-C37 successfully launched a total of 104 satellites into a 505 km polar Sun Synchronous Orbit (SSO). Besides Cartosat-2 series satellite and two ISRO Nanosatellites, 96 satellites from the US, one each from The Netherlands, Switzerland, Israel, Kazakhstan and UAE constituted the 104 satellites launched.
- GSLV-F09 successfully launched South Asia Satellite into GTO on May 05, 2017. This was the eleventh flight of GSLV.

- On June 05, 2017, the first developmental flight of GSLV-MkIII vehicle was successfully accomplished when GSAT-19, the satellite carried onboard, was successfully placed in GTO.
- PSLV-C38 successfully launched 31 satellites in a single mission during June 2017. This included India's Cartosat-2 Series Satellite as primary payload and one university/academic institution satellite as well as 29 satellites from 14 countries with a total weight of 955 kg as co-passengers.
- During June 2017, the communication satellite GSAT-17 was successfully launched into the designated GTO by Ariane 5 vehicle.
- The launch of PSLV-C39, carrying IRNSS-1H satellite (1,425 kg) during August 2017, was unsuccessful.

Year 2018 started with successful launch of PSLV-C40 placing 31 satellites into intended orbits on January 12.

By January 2018, ISRO is successful in establishing a constellation of exclusive Meteorological, Earth Observation, Communication & Navigation Satellites, in addition to a multi-wavelength astronomical observatory and a spacecraft orbiting planet Mars.

During the reporting period (April 2017 - January 2018), ISRO could accomplish 11 missions.

Space Transportation System

There were three PSLV launches during the year 2017. The first of them launched 104 satellites and the other launched 31 satellites. But the third PSLV launch was unsuccessful.

GSLV-MkII, equipped with the indigenous Cryogenic Upper Stage (CUS), successfully launched South Asia Satellite on May 05, 2017. This mission (GSLV-F09) further demonstrated the reliability of CE7.5 cryogenic engine and stage developed by ISRO. This was the fourth consecutive successful flight of GSLV-MkII.

GSLV-MkIII D1 Mission could successfully launch GSAT-19 into GTO. This was the first full-fledged GSLV-MkIII mission with its C25 cryogenic engine and stage that proved to be successful in demonstrating the capability of putting 3.2 ton class of satellite into GTO.

PSLV-C40, in its forty second flight on January 12, 2018, proved its versatility by placing multiple satellites in to single orbit and a satellite into different orbit.

Besides, the developmental efforts on semi-cryogenic engine and realisation of critical technologies for human spaceflight were also pursued during the reporting period.

Space Infrastructure

Successful launch of three communication satellites and two earth observation satellites were the highlights pertaining to the Indian satellite programme in 2017. Besides, two ISRO nanosatellites were also launched during the year.

In 2017, two 715 kg Cartosat-2 series satellites with Panchromatic and Multispectral cameras for earth observation were launched by PSLV into a polar sun synchronous orbit. Two Nanosatellites were also launched as co-passengers during this time. In the communication satellite domain, three communication satellites, viz., South Asia Satellite, GSAT-19 and GSAT-17 were launched within a short span of less than two months. The 2,230 kg South Asia Satellite (GSAT-9) was launched by GSLV-F09 on May 05, followed by the GSAT-19, a month later. Three weeks after this launch, GSAT-17 equipped with C, extended C and S-band transponders as well as transponders for meteorological data relay and satellite aided search and rescue, was also launched into GTO through procured launch arrangement. These three communication satellites successfully reached their respective geostationary orbital slots and are operational. However, the eighth navigation satellite, IRNSS-1H, could not reach the intended orbit due to issues related to PSLV heat shield separation.

The Department continues to work on the scheduled missions to meet the country's future requirements with a series of planned missions in the coming months. GSAT-6A and GSAT-29 communication satellites will be launched by GSLV-MkII and GSLV-MkIII respectively, while GSAT-11 communication satellite is planned to be launched through procured launch. With regard to earth observation satellites, it is planned to initiate necessary processes of development of Cartosat-3, Oceansat-3 and RISAT-1A (Radar Imaging) in addition to the GISAT-1.

Space Applications

One of the unique characteristics of Indian space programme has been the application-oriented efforts and the benefits that have accrued to the country through these programmes. The societal services from INSAT / GSAT systems in various areas of communication in addition to tele-education and telemedicine were continued during the year. Remote Sensing applications projects at National, State and Local levels are made significant progress through a 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 providing vital inputs in Agricultural Crops Inventory, Agricultural Drought assessment, Forest Fire monitoring, effective use of groundwater prospects maps, and varieties of Governance applications.

The Disaster Management Support (DMS) Programme of ISRO is continuing to provide space based inputs for the effective management of disasters in the country. The Decision Support Centre (DMS-DSC), established at National Remote Sensing Centre (NRSC), is engaged in monitoring of natural disasters such as floods, cyclones, landslides, forest fires, etc. During 2017, India witnessed major floods during June to September affecting more than 104 districts in 8 states, namely, Assam, Gujarat, Manipur, Bihar, Uttar Pradesh, Arunachal Pradesh, Odisha and West Bengal. All the major flood

affected states were monitored using satellite data and about 100 maps were disseminated to the concerned states/departments.

During the fire season (February to June), daily near real time fire alerts were provided using satellite data. These inputs were provided in less than 30 minutes from the completion of satellite overpass. The activity was carried out in collaboration with the Forest Survey of India (FSI), covering the entire nation. During 2017, active fire locations information for about 32,546 forest fires were generated and made available to the respective forest departments of the States and FSI.

A massive landslide occurred on National Highway, NH154 (the road between Mandi and Pathankot) near the village of Kotropi, Mandi District, Himachal Pradesh on August 13, 2017. The event was monitored using Resourcesat-2 and Cartosat-2 data. Rainfall as the causative factor for the occurrence of such landslides was recognised.

National Database for Emergency Management (NDEM) continued to provide disaster related inputs for all 36 States/UTs with multi-scale geo-spatial database. In addition to these daily data, alerts/warnings from forecasting agencies were also provided as part of NDEM dashboard.

ISRO is a signatory of the International Charter for 'Space and Major Disasters', which aims at providing a unified system of space data acquisition and delivery to users affected by disasters. Towards this, ISRO supports the charter and Sentinel Asia by planning satellite data acquisition from various Indian Remote Sensing Satellites and providing the same within a stipulated time period. In 2017, ISRO supported 29 disasters across 22 countries by providing around 140 sets of IRS data.

Space Science and Planetary Research

Mars Orbiter Mission (MOM), which is India's first inter-planetary spacecraft mission, has successfully completed three years in its orbit around Mars and still continues to provide vital information on Mars on regular basis. The health parameters of Mars Orbiter spacecraft are normal. Scientific analysis of the data being received from the Mars Orbiter spacecraft is being done on various aspects of the planet. Twenty scientific papers have been published so far in peer reviewed journals. The Mars Colour Camera has produced more than 900 images so far. During the year, an orbit maneuver was also successfully performed on the spacecraft, which removed the danger of long period eclipse till 2021. The spacecraft could also successfully came out of second blackout (superior solar conjunction) in July 2017.

A 'MOM Science Meet' was held at ISRO HQ, Bengaluru during September 2017, on the occasion of three-year completion of MOM in Mars orbit. The second year data of MOM (Sept 24, 2015 to Sept 23, 2016) was released to public through ISSDC website to encourage the researchers to download and use the data for scientific research.

AstroSat, India's first multi-wavelength observatory, completed two years in orbit on September 28, 2017. The satellite is now being operated as an "Observatory", in which observational time is allocated

based on the proposals received from interested researchers and scientists in the country, through ISRO's Announcement of Opportunity (AO). From October 2017, the observatory is open to Indian and International Astronomical Community.

The future space science missions of ISRO includes Chandrayaan-2, a follow-on mission to Chandrayaan-1, with an Orbiter, Lander and Rover as a next step in the exploration of the Moon, which is to be launched onboard GSLV flight during the first half of 2018. Aditya-L1, a scientific mission for solar studies, carrying seven payloads including a Coronagraph and the XPoSat mission (X-ray Polarimeter Satellite), a dedicated mission for polarisation studies, are also planned subsequently. Aditya-L1 is planned to be placed into a halo orbit around the L1 Legrangian point.

Capacity Building

The achievements of Indian space programme have been primarily due to the well-established mechanisms of taking up a task and achieving the same with commitment and dedication with professionalism. Recognising the importance of nurturing such unique talents and motivating principles, the department has always emphasised on the capacity building related aspects. Capacity building encompasses multiple areas of development to ensure that the department achieves its goals, as envisioned. Following are some of the key areas of capacity building.

Human Resources

The department has continued to lay stress on recruitment, training and career progression features. It continues to strive in providing its personnel with necessary facilities such as housing, medical, etc., to ensure smooth functioning of the organisation. Considering the amount of workload in ISRO with the increased number of missions and their frequency, necessary augmentation of manpower as well as involving academia and industry have been given specific focus. The total approved sanctioned strength of the department as on 01.03.2017 is 16,902, out of which 12,300 are in Scientific and Technical (S&T) category and 4,602 are under administrative category.

Enhanced Output Through Outsourcing

Involvement of Indian industry in the country's space programme continued during the year. In the past, it has made significant contribution towards the realisation of subsystems required for the Indian space programme. Department of Space has been associated with more than 500 small, medium and large-scale industries while implementing various programmes. So far, the department has transferred about 300 technologies to Indian Industries for commercialisation and undertaken technical consultancies in various fields. Need is felt to evolve newer strategies to involve Indian industries in a much larger way to enhance productivity.

International Cooperation

International cooperation in space related activities is an important consideration for ISRO which

continues to hold importance with regard to bilateral and multilateral relations with various space agencies and professional bodies. The main focus of international cooperation is taking up new scientific and technological challenges, defining international frameworks for exploitation and utilisation of outer space for peaceful purposes including refining space policies and building/ strengthening existing ties amongst other countries, etc,. During the year, ISRO signed cooperative agreements with Armenia, Australia, Bangladesh, Canada, Israel, Japan, The Netherlands, Portugal and USA, on specific areas of interest.

Outreach activities

During the year, ISRO organised many outreach events to propagate the advantages of space technology for the nation as a whole and to citizens in particular. Some of the key outreach programs were workshops and expert talks by reputed scientists, particularly the academia. In addition, many exhibitions, displays, visits to facilities, etc., were also organised with positive results. One of the main focus with regard to outreach has been on finding ways and means to involve academia in many activities of space technology to leap-frog on bringing the uses/applications to the common man.

On all launch occasions, media visits to SDSC SHAR-Sriharikota was ensured as part of public outreach. Besides, ISRO also organised many exhibitions at National and International Conferences, important public congregations like cultural festivals, trade fairs, major events and also at academic institutions. Exhibitions and other outreach events including APRSAF-24 water rocket event with the participation of 12 countries were also organised in various places for keeping the public abreast of the Indian space programme.

Space Commerce

Antrix Corporation Limited, the commercial arm of the Department of Space, is marketing the Indian space products and services in the global market. Antrix offers a wide range of services from the space based systems through specific commercial contracts with other agencies, including foreign customers. Under commercial contracts with Antrix, 237 international customer satellites have already been successfully launched by PSLV during the period 1999-2018. In 2017 alone, PSLV launched 130 foreign satellites. Another 28 foreign satellites were launched by PSLV on January 12, 2018. Proposals from other International Customers for the launch of their satellites onboard PSLV are under discussion and consideration.

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. In the fulfillment of its primary objective of providing quality manpower to ISRO, 104 out of 151 were conferred degrees and offered placement in ISRO in 2017. Thus, a total of 775 B.Tech graduates, so far from the institute have been absorbed into ISRO.

Right to Information - Ensuring Transparency

Strict compliance with the requirements of Right To Information (RTI) Act 2005 is practiced in the department. The 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, the 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 2017 - December 2017, 1,163 applications were received and information was disseminated under the provisions of the RTI Act. 203 Appeals were received by the First Appellate Authority and 12 appellants approached the Second Appellate Authority, i.e., Central Information Commission.

Summary

The Indian space programme, during the year, made significant progress in its missions by achieving most of its targets with many unique accomplishments. While keeping focus on space technology, specific space-based applications were pursued with special emphasis on location based applications from NavIC. All programmatic activities related to satellites and launch vehicles were pursued. Necessary infrastructure for casting large boosters and building Semi-cryogenic stages for advanced heavier launchers and other missions was established. Varieties of space missions, encompassing remote sensing, communications / navigation and space science have been realised, while plans for future missions have been initiated successfully.

The continuation of space applications programmes including 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, the Indian Space Programme continues to pursue goals on several fronts in meeting its objectives.

Organisation

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

Space Commission formulates the policies and oversees the implementation of the Indian space programme to promote the development and application of space science and technology for the socio-economic benefit of the country. DOS implements these programmes through, mainly, ISRO, Physical Research Laboratory (PRL), National Atmospheric Research Laboratory (NARL), North Eastern-Space Applications Centre (NE-SAC) and Semi-Conductor Laboratory (SCL). Antrix Corporation Limited, 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, earth observation, navigation, launch vehicle, space science, disaster management support, sponsored research scheme, contracts management, international cooperation, system reliability and quality, safety, publications and public relations, budget and economic analysis and capacity building. 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 responsible for the design and development of launch vehicle technology. The Centre pursues active research and development in various disciplines including aeronautics, avionics, materials, mechanisms, vehicle integration, chemicals, propulsion, space ordnance, structures, space physics and systems reliability. The Centre undertakes crucial responsibilities of design, manufacturing, analysis, development and testing related to the realisation of subsystems for the different missions.

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.

VSSC Main Building at Veli Range Complex

The major programmes at VSSC include Polar Satellite Launch Vehicle (PSLV), Geosynchronous Satellite Launch Vehicle (GSLV) and Rohini Sounding Rockets. The Centre also focuses on developing capabilities towards advanced technology vehicles, air breathing propulsion, critical technologies for human spaceflight, low cost small satellite launch vehicles and modular heavy lift launch vehicles.

ISRO Satellite Centre (ISAC)

ISRO Satellite Centre (ISAC), Bengaluru is the lead centre for design, development and integration of satellites for communication, remote sensing, navigation, scientific studies and small satellites. ISAC is actively involved in research and development in the area of advanced state of art technologies, total management of all satellite missions, creation of a vibrant space industry for the realisation of space systems, technology transfer, academia interface, etc. ISAC is fully equipped with state-of-the-art facilities for fabrication and testing of mechanical and electronic hardware/subsystems and integrated satellite.

ISRO Satellite Integration and Test Establishment (ISITE) established in 2006 is equipped with facilities for the complete assembly and test sequence that can enable rolling out of a flight worthy spacecraft from the stage of a bare structure. It is a replete with integration and environmental test facilities under one roof, namely a large clean room for spacecraft assembly, integration and testing, a compact antenna test facility specific to communication satellites and antenna systems, a vacuum chamber, vibration facility and acoustic test facility. ISAC has realised the spacecrafts in the area of communication, meteorology, remote sensing and navigation 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 the 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 of 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 for satellites and launch vehicles.

The Centre is realising a Second Vehicle Assembly Building (SVAB) facility for the integration of launch vehicles for meeting the future requirements for the Indian Space Programme. The main objectives of the SVAB are a) to meet increased launch frequency, b) to provide full-fledged integration facility for GSLV-MkIII flights, c) to take care of future launch vehicles, d) to implement Auxiliary Umbilical Tower concept to reduce launch pad occupancy time and e) to serve as a prime integration facility for future Third Launch Pad.

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

Liquid Propulsion Systems Centre (LPSC)

Liquid Propulsion Systems Centre (LPSC) is the centre for design, development and realisation of liquid propulsion stages for ISRO's Launch Vehicles. Development of fluid control valves, transducers, propellant management devices for vacuum conditions and other key components of liquid propulsion systems are also under the purview of LPSC.

LPSC activities and facilities are spread across its two campuses, namely, LPSC, Valiamala, Thiruvananthapuram and LPSC, Bengaluru, Karnataka.

LPSC, Valaimala is responsible for R&D, System Design/Engineering and Project Management functions. The Fluid Control Components Entity and the Materials & Manufacturing Entities are located here apart from the Earth Storable & Cryogenic Propulsion Entities as well as handling the core tasks of the Centre.

LPSC, Bengaluru is responsible for design and realisation of propulsion systems for remote sensing and communication satellites and other scientific missions. Development and production of transducers and sensors are undertaken here.

ISRO Propulsion Complex (IPRC)

ISRO Propulsion Complex (IPRC), Mahendragiri is equipped with state-of-the-art facilities necessary for realising the cutting edge propulsion technology products for Indian space program. The centre is responsible for assembly, integration and testing of liquid propulsion systems for operational and developmental launch systems. IPRC conducts flight testing of spacecraft engines and thrusters, and simulation trials for interplanetary modules.

IPRC is responsible for the supply of Storable Liquid Propellants for 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 the Indian space programme.

Space Applications Centre (SAC)

Space Applications Centre (SAC), Ahmedabad is a major Research and Development Centre of ISRO. The core competence of the Centre lies in development of space borne and air borne instruments / payloads and their applications for national development and societal benefits. Besides these, the Centre also contributes significantly in scientific and planetary missions of ISRO like Chandrayaan-1, Mars Orbiter Mission, etc. The communication transponders developed at this Centre for the Indian National Satellite (INSAT) and Geosynchronous Satellite (GSAT) series of satellites are used by government and private sector for VSAT, DTH, Internet, broadcasting, telephony services, etc.

Thaltej Campus, Ahmedabad

SAC designs and develops the optical and microware sensors for the satellites, signal and image processing software, GIS software and many applications for Earth Observation (EO) programme of ISRO. These applications are in diverse areas of Geosciences, Agriculture, Environment and Climate Change, Physical Oceanography, Biological Oceanography, Atmosphere, Cryosphere, Hydrosphere, etc. The facilities at SAC includes 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 active collaborations with industry, academia, national and international institutes for Research and Development. The Centre also conducts nine-month post graduate diploma courses for students from the Asia Pacific region under the aegis of the Centre for Space Science and Technology Education – Asia Pacific (CSSTE-AP) in satellite meteorology and communication.

Development and Educational Communication Unit (DECU)

Established in 1983, the Development and Educational Communication Unit (DECU) at Ahmedabad is dedicated for realising satellite-based societal applications. DECU is involved in ideating, conceptualising, designing, implementing, evaluating, invigorating, sustaining and upgrading SATCOM based societal applications along with producing video programmes incorporating multimedia elements as a medium of interaction and conducting social science and communication research studies for national development. It works with user agencies to experiment with innovative configurations to meet their requirements and facilitates in covering the 'last mile' in space applications. The unit has been responsible for conceptualisation and demonstration of many societal applications of satellite communications in the past decades.

ISRO Telemetry, Tracking and Command Network (ISTRAC)

ISRO Telemetry, Tracking and Command Network (ISTRAC), Bengaluru is entrusted with the primary responsibility of providing TTC and mission control services to major Launch Vehicle and Spacecraft missions of ISRO. In order to realise these objectives, ISTRAC has established a network of ground stations at Bengaluru (BL-1, BL-2 & BL-3 and BL-4), Lucknow (LCK-I & LCK-II), Mauritius (MAU-I & MAU-II), Sriharikota (SHAR-I & SHAR-II), Port Blair, Thiruvananthapuram, Brunei, Biak, Indonesia (BK-1 & BK-2) and the Deep Space Network Stations DSN-32 and DSN-18. The Mission Operations Complex located at Bengaluru carries out round-the-clock mission operations for all remote sensing, science and planetary missions. All network stations of ISTRAC are connected to the Mission Operations Complex through dedicated high-performance satellite communication links and / or terrestrial communication links.

ISTRAC has established a network of stations to support IRNSS satellites consisting of 4 IRCDR stations (Hassan, Bhopal, Jodhpur and Shillong), 16 IRIMS stations (Bengaluru, Hassan, Bhopal, Jodhpur, Shillong, Dehradun, Port Blair, Mahendragiri, Lucknow, Kolkata, Udaipur, Shadnagar, Pune and Mauritius). ISTRAC has also established ISRO Navigation Centre-1, including an IRNWT facility at Bengaluru and ISRO Navigation Centre-2, including an IRNWT facility at Lucknow.

ISTRAC is also undertaking the development of radar systems for launch vehicle tracking and meteorological applications, establishing and operationalising the ground segment for Indian Regional Navigational Satellite System, providing Search & Rescue and Disaster Management Services and supporting space based services like telemedicine, Village Resource Centres 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.

At present, MCF monitors and controls twenty-five satellites belonging to GSAT, INSAT, IRNSS series and Kalpana satellite. Currently, MCF Hassan is controlling 19 satellites and MCF Bhopal is controlling 6 satellites. To carry out these operations effectively, MCF Hassan is having an integrated facility consisting of nine Satellite Control Earth Stations.

Satellite Control Centre - MCF Bhopal

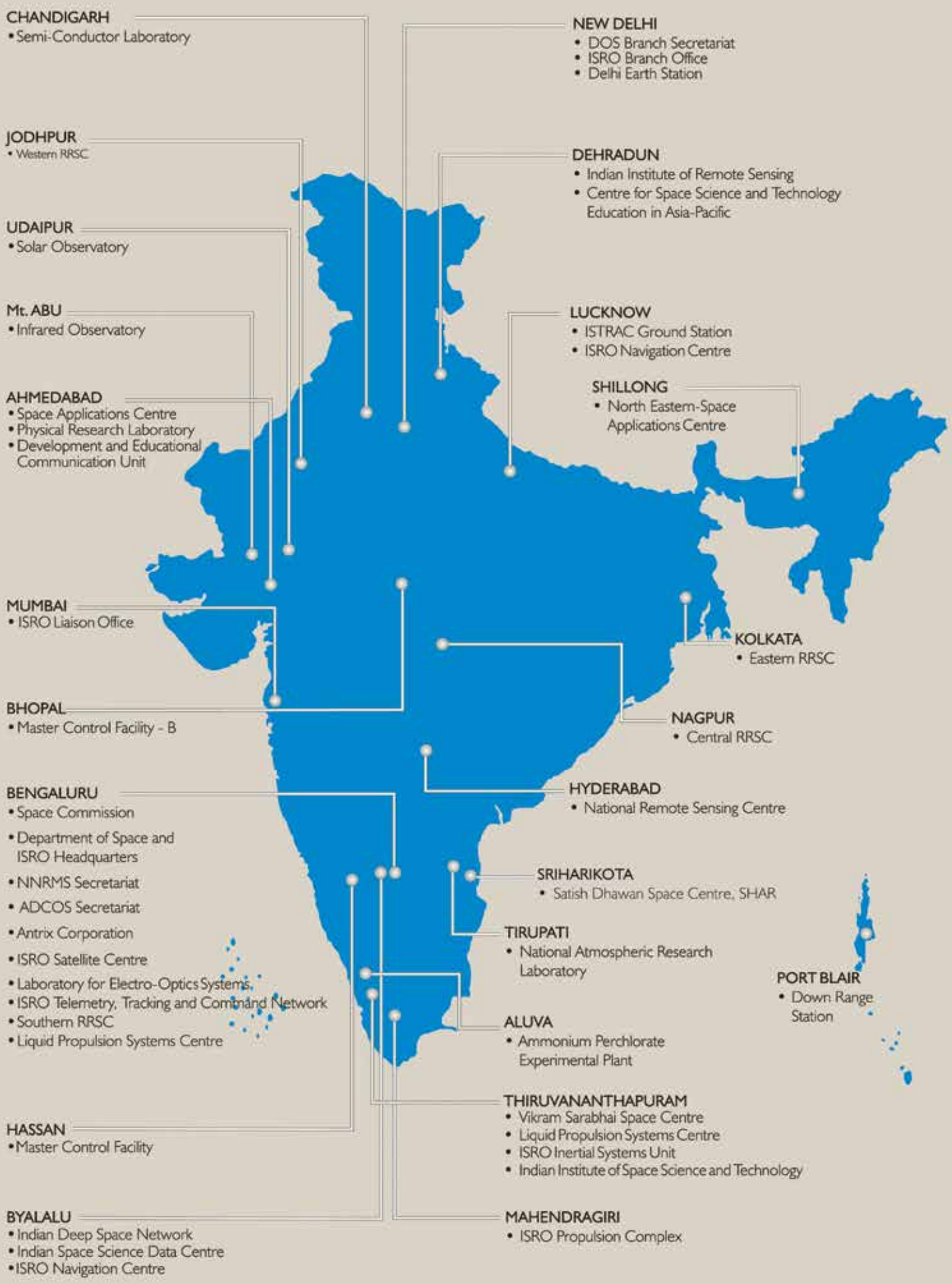
ISRO Inertial Systems Unit (IISU)

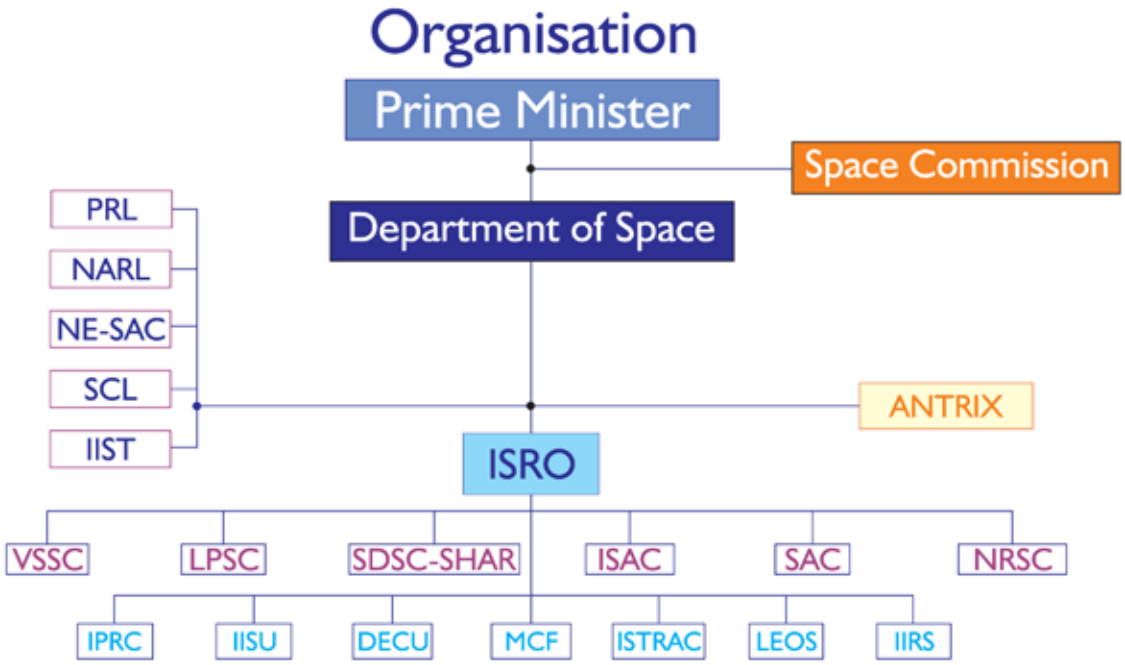
ISRO Inertial Systems Unit (IISU), Thiruvananthapuram is responsible for the design and development of Inertial Systems for Launch Vehicles and Satellites. Major systems like Inertial Navigation Systems based on mechanical gyros and optical gyros, Attitude Reference Systems, Rate Gyro Packages, Accelerometer Packages are developed indigenously and used in various missions of ISRO. IISU also designs and develops Actuators and Mechanisms, namely, Reaction Wheel, Momentum Wheel, Solar Array Drive and Scan Mechanisms for spacecraft and allied applications. Presently, IISU is engaged in the process of consolidation and productionisation of the Sensors, Systems, Actuators and Mechanisms for a variety of launch vehicle and spacecraft applications.

IISU is engaged in continuous Research and Development too. IISU has initiated advanced technology development programmes in niche areas with a focus on miniaturisation, low power & cost and industry producible sensors and systems.

IISU Main Buiding

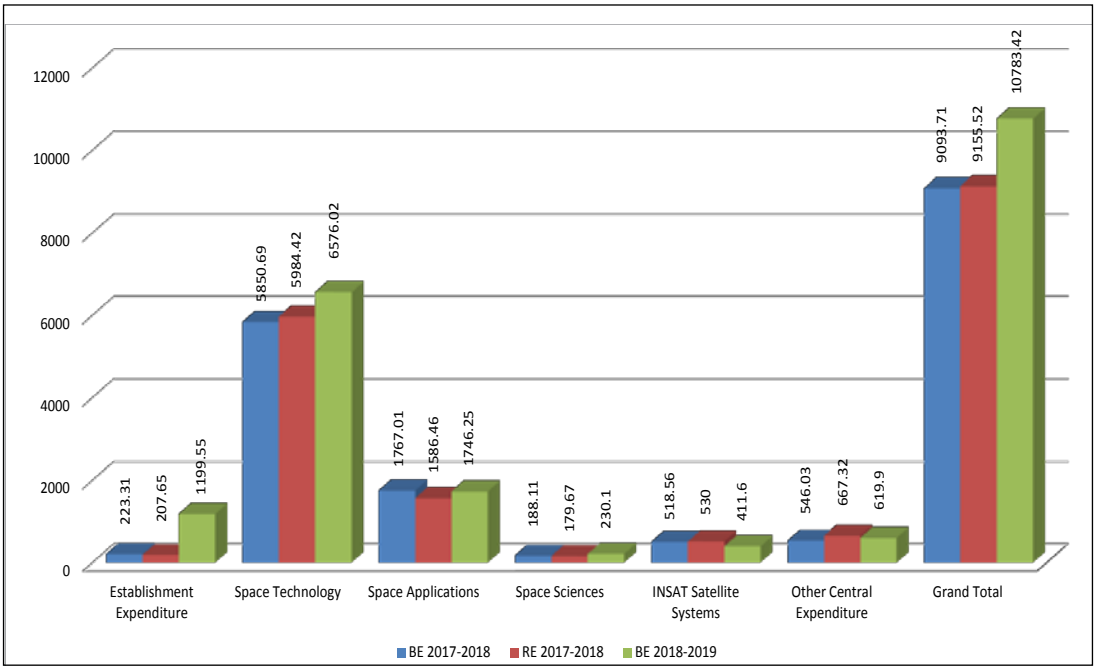
The Centres of Indian Space Programme





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-optics Systems **IIRS:** Indian Institute of Remote Sensing

Budget Profile (Rs. in Crores)



Laboratory for Electro-Optics Systems (LEOS)

The Laboratory for Electro-Optics Systems (LEOS), Bengaluru, which celebrated Silver Jubilee on December 18, 2017, is responsible for design, development and production of electro-optic sensors and optics for spacecraft use. Sensor system includes earth sensors, star sensors, sun sensors, magnetic sensors, fiber optic gyro, temperature sensors and processing electronics. Optics system includes optics for remote sensing cameras, radiometers, star sensor optics, optical filter, optical masks, optical coatings, Infrared detectors and MEMS based inclinometer. Research & development program by LEOS includes development of miniature sensors, high accuracy Active Pixel Sensor, Miniature star tracker, Vision Sensors, Detectors, MEMS devices, Segmented Mirror Telescope optics and advanced optics for future spacecraft use.

LEOS Main Building

National Remote Sensing Centre (NRSC)

National Remote Sensing Centre (NRSC), Hyderabad is responsible for Remote Sensing Satellite data acquisition, processing and dissemination, Applications, Aerial Services, Capacity Building and Outreach. NRSC's headquarters is at Balanagar, Hyderabad having its campuses at Shadnagar and Jeedimetla in Hyderabad. It is having Regional Remote Sensing Centres (RRSCs) in Bengaluru, Jodhpur, Kolkata, Nagpur and Delhi to cater to regional needs. Bhuvan is the flagship programme of NRSC for dissemination of Geo-spatial products and services in the country.

NRSC Ground station at Shadnagar acquires Earth Observation data from Indian remote-sensing satellites as well as from foreign satellites. Presently, data acquired at AGEOS and SVALBARD stations is also being transferred to IMGEOS for level-0 processing, product generation, archival and dissemination. IRS data acquired at International Ground Stations (IGS) are also transferred to NRSC, Shadnagar for archival.

NRSC is also engaged in executing remote sensing application projects in collaboration with the users. The Aerial Services and 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.

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 Geographical Information System (GIS) applications.

Indian Institute of Remote Sensing (IIRS)

Indian Institute of Remote Sensing (IIRS), 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 capacity building activities of the Institute are primarily grouped into three domains namely, Training & Education, Research and Outreach. The Institute also hosts and provides support to the Centre for Space Science and Technology Education in Asia and the Pacific (CSSTE-AP), affiliated to the United Nations. The training and education programmes of the Institute are designed to meet the requirements of various target/user groups, i.e., for professionals at working, middle and supervisory levels, fresh graduates, researchers, academia, and decision makers. The duration of courses ranges from one week to two years.

Indian Institute of Remote Sensing Main Building

Physical Research Laboratory (PRL)

The Physical Research Laboratory (PRL), 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 Astro-chemistry.

The primary mandate of the PRL is to carry out research, publish scientific papers and develop appropriate instrumentation to enable their specific science goals. PRL has published nearly two hundred research papers in peer-reviewed journals. Twelve Ph.D. theses were submitted during the year and PRL faculty members have published nearly 120 papers in peer-reviewed journals.

National Atmospheric Research Laboratory (NARL)

National Atmospheric Research Laboratory (NARL) at Gadanki near Tirupati, an autonomous society supported by DOS, is a centre for atmospheric research in the country. Started as a major national facility with a huge MST radar 25 years ago to cater to the scientific needs of the middle atmospheric research community, NARL has now grown into a premier national laboratory carrying out frontline research in atmospheric sciences, technology development and improved weather forecasting. NARL

has been serving the nation by facilitating scientists and engineers a unique opportunity to test and improve various atmospheric probing techniques, innovative ideas and algorithms, besides capacity building in lower, middle and upper atmospheric research and technology.

NARL Main Building

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.

North Eastern-Space Applications Centre (NE-SAC)

North Eastern-Space Applications Centre (NE-SAC), 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 play the catalytic role in holistic development of NER of India by providing space science and technology support. The centre also coordinates with the State Remote Sensing Application Centres of NER and acts as a nodal centre for implementation of major national and regional programmes on natural resource management, infrastructure planning, healthcare, education, emergency communication, early warnings for disaster management support and atmospheric science research. 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.

Aerial View of NE-SAC

The Centre has provided more than 16 years of dedicated service to the eight states of North Eastern Region (NER) of India using space science and technology.

Antrix Corporation Limited

Antrix Corporation Limited, Bengaluru is a wholly owned Government of India Company under Department of Space. ACL was incorporated as a private limited company owned by Government of India in September 1992, thus completing 25 years of service. So far, ISRO has launched 237 foreign satellites from 28 countries as part of the commercial arrangements between ACL and the International customers.

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 the operational launch vehicles (PSLV and GSLV); Mission support services; and a host of consultancy and training services.

Antrix is engaged in marketing and sale of products and services from ISRO and Indian Industries to the national and international customers. Antrix makes use of the expertise and infrastructure of ISRO as well as Indian industry for its business. For execution of each of the customer order, Antrix enters into a formal arrangement with the concerned ISRO Centre/ Unit, specifying the scope of work, time schedule and cost.

Semi-Conductor Laboratory (SCL)

Semi-Conductor Laboratory (SCL) at Chandigarh, an autonomous body under DOS, is engaged in providing end-to-end solutions for Development of Application Specific Integrated Circuits (ASICs), Opto-electronics Devices and Micro Electro Mechanical System (MEMS) Devices encompassing Design, Fabrication, Assembly, Packaging, Testing and Reliability Assurance. SCL has 180nm CMOS Technology on 8" Wafer Fab Line as per international standards and has a 6" Wafer Fab Line with CMOS/MEMS process capability.

The efforts at SCL are directed towards creating a strong microelectronics base with activities focused on realisation of critical and high reliability device requirements of DOS / ISRO Centres / Units and other users. SCL is also engaged in fabrication of Hi-Rel Boards, Radio Sonde Systems and indigenisation of electronic sub systems.

Indian Institute of Space Science and Technology (IIST)

Indian Institute of Space Science and Technology (IIST), Asia's first Space University, was established at Thiruvananthapuram in 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 undergraduate, postgraduate, doctoral and post-doctoral programmes in broad areas of space science, technology and applications. The institute is committed to excellence in teaching, learning and research. IIST fosters state-of-the-art research and development in space studies and provides a think-tank to explore new directions for the Indian Space Programme. 104 out of 151 conferred degrees were offered placement in ISRO in 2017. Thus, a total of 775 B.Tech graduates from the institute have been absorbed in ISRO.

IIST Building

1.0 Space Transportation System

The country has achieved self-reliance in space transportation capability through the operationalisation of Polar Satellite Launch Vehicle (PSLV) and Geosynchronous Satellite Launch Vehicle (GSLV) for launching satellites for earth observation, communication, navigation and space exploration. PSLV proved its reliability and cost efficiency by successfully launching satellites from different countries promoting international collaboration. The 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, reusable launch vehicles, semi-cryogenic engines, etc., to cater to different payloads and an array of missions.

During the reporting year, all the launch complex facilities were activated and utilised to their full capacity to ensure timely supply of production deliverables and precise accomplishment of activities to match with the varying needs of ISRO's Launch Vehicle and Satellite communities and also the foreign satellite customers. GSLV-MkIII D1, the First developmental flight with the high thrust indigenous Cryogenic Engine, was successfully launched. This is a major step towards enhancing the launch capability upto 4-tonne class of satellites into Geosynchronous Transfer Orbit (GTO). PSLV-C37 that successfully launching 104 satellites on February 15, 2017 was recorded as the maximum number of satellites launched in a single flight.

Major Events

1.1 Polar Satellite Launch Vehicle (PSLV)

PSLV conducted three launches during the year, namely, PSLV-C37, PSLV-C38 and PSLV-C39 launching two Cartosat-2 Series Satellites successfully and many new technologies were flight demonstrated. Launching of 104 satellites on-board PSLV-C37 and the fourth stage (PS4) restart in PSLV-C38 to lower the orbit are the two major accomplishments.

PSLV -C37 Lift-off

PSLV-C37/Cartosat-2 Series: In its 39th flight, PSLV successfully launched the 714 kg Cartosat-2 Series Satellite along with 103 co-passenger satellites on February 15, 2017 from Satish Dhawan Space Centre (SDSC) SHAR, Sriharikota. This was the 38th consecutively successful mission of PSLV. The total weight of all the 104 satellites carried on-board PSLV-C37 was 1378 kg. This is the highest number of satellites launched in a single flight so far.

PSLV-C38/Cartosat-2 Series: In its 40th flight, PSLV injected Cartosat-2 Series Satellite along with 30 satellites into an intended Sun Synchronous Polar Orbit on June 23, 2017 from SDSC, SHAR, Sriharikota. Two restarts of fourth stage (PS4) were carried out to lower the orbit. The mission also had 29 commercial satellites from 14 countries and one satellite from Noorul Isalm University, Tamil Nadu, on board. During this launch, a Video Imaging System with eight on-board cameras was used to capture the separation events. Coasting of PS4 stage was carried out for nine orbits after the main mission. The mission used aided navigation with IRNSS data as the primary source for the engine restart phases.

PSLV-C39/IRNSS-1H Mission: The 41st flight of PSLV, carrying IRNSS-1H Navigation Satellite conducted on August 31, 2017 from SDSC, SHAR, Sriharikota, was unsuccessful. The IRNSS-1H satellite was identified as the eighth satellite to join the NavIC navigation satellite constellation. PSLV lift-off at 19:00 hrs was normal and all the launch events occurred successfully except the heat shield separation, due to which the satellite could not be injected into the orbit. Detailed failure analysis was completed by the Failure Analysis Committee to identify the anomaly that led to the non-separation of the heat shield. The recommendations of the Failure Analysis Committee were implemented.

PSLV-C40/ Cartosat-2 Series Mission: In its 42nd flight, PSLV successfully launched the 710 kg Cartosat-2 Series Remote Sensing Satellite along with 30 co-passenger satellites on January 12, 2018 from Satish Dhawan Space Centre SHAR, Sriharikota. The lift-off of PSLV-C40 occurred at 9:29 hrs IST from the First Launch Pad. After a flight lasting 16 minutes 37 seconds, the satellites achieved the polar Sun Synchronous Orbit of 503 km. In the succeeding seven minutes, Cartosat-2 series satellite, INS-1C and 28 customer satellites successfully separated from the PSLV in a predetermined sequence. The fourth stage of PSLV-C40 fired twice for short durations to achieve a polar orbit of 365 km height in which India's Microsat was successfully separated.

PSLV-C40 on First Launch Pad

So far, PSLV has successfully launched 51 Indian satellites and 237 customer satellites from abroad.

1.2 Geosynchronous Satellite Launch Vehicle (GSLV)

GSLV is a three-stage vehicle with solid, liquid and cryogenic upper stage, designed to place 2000 kg class of satellites in Geosynchronous Transfer Orbit (GTO).

The fully integrated GSLV-F09 carrying GSAT-9 at the Second Launch Pad

GSLV-F09/ South Asia Satellite (GSAT-9) Mission: GSLV, in its eleventh flight successfully launched the 2230 kg South Asia Satellite from SDSC SHAR, Sriharikota, into its intended GTO on May 05,

2017. South Asia Satellite is a communication satellite built by ISRO to provide a variety of communication services over the South Asian region. This is the fourth consecutive success achieved by GSLV carrying indigenously developed Cryogenic Upper Stage.

GSLV-F10/ Chandrayaan-2 Mission: Chandrayaan-2, India's second mission to the Moon, is an indigenous mission comprising of an Orbiter, Lander and a Rover. After reaching the 100 km lunar orbit, the Lander housing the Rover will separate from the Orbiter. After a controlled descent, the Lander will soft land on the lunar surface at a specified site and deploy the Rover. Chandrayaan-2, weighing approximately 3,290 kg, would orbit around the moon and perform the objectives of remote sensing of the moon. The payloads will collect scientific information on lunar topography, mineralogy, elemental abundance, lunar exosphere and signatures of hydroxyl and water-ice.

GSLV-F10/Chandrayaan-2 Mission is planned during first half of 2018.

1.3 Geosynchronous Satellite Launch Vehicle Mark III (GSLV-MkIII)

GSLV-MkIII has been developed towards achieving indigenous capability to launch 4 tonne class satellites into Geosynchronous Transfer Orbit (GTO). GSLV-MkIII is configured as a three-stage vehicle with two solid strap-on motors (S200), one liquid core stage (L110) and a high thrust cryogenic upper stage (C25). The overall length of the vehicle is 43.5 m with a gross lift-off weight of 640 tonnes and a 5 m diameter payload fairing.

GSLV-MkIII-D1/GSAT-19 Mission: The first development flight of GSLV-MkIII (D1 mission) with first C25 Cryogenic Stage and CE20 Cryogenic Engine successfully launched GSAT-19 spacecraft on June 05, 2017 from SDSC SHAR. Weighing 3,136 kg at lift-off, GSAT-19 is the heaviest satellite launched from the Indian soil.

GSLV-MkIII D1 Lift-off from Second Launch Pad

Based on the flight data analysis of LVM3-X mission (December 18, 2014), suitable improvements were incorporated in GSLV-MkIII vehicle configuration, mainly on aerodynamic shaping, which included Ogive shaped Payload Fairing, Slanted Nose Cones for S200, etc. The upper stage of GSLV-MkIII vehicle is a new cryogenic stage (C25) indigenously configured, designed and realised by ISRO. The cryogenic stage uses liquid Hydrogen and liquid Oxygen as propellants with a total loading of 28 tons. The stage is powered by a 20 ton thrust cryogenic engine (CE20) operating on 'gas generator cycle'. The performance of the engine and stage during the mission was as predicted. About sixteen minutes after the lift-off, GSAT-19 satellite was successfully placed into GTO.

GSLV-MkIII D2/GSAT-29 Mission: GSAT-29, a communication satellite, will be the payload for second developmental flight of GSLV-Mk III. Major improvements of GSLV-MkIII include High thrust Vikas Engines and Propellant Siphoning Device for L110, Li-ion battery for Avionic systems and L110 Actuators, mass optimisation of upper stage composite structures, increased propellant loading in C25 stage etc.

GSLV-MkIII-D2/GSAT-29 Mission is scheduled to be launched during the first half of 2018.

Semi-cryogenic Project

The semi-cryogenic Project envisages the design and development of a 2000 kN semi-cryogenic engine for a future heavy-lift Launch Vehicle. The semi-cryo engine development moved from design and hardware realisation phase to testing and verification phase. Major thrust was provided towards hardware roll out from industry. Most of the hardware are in the advanced stage of completion. 12 types of Flow control valves required for power head test have been realised and testing is in progress. As part of the Turbo-pump development, Low Pressure Oxidizer Turbopump (LPOT-D2) and Main Oxidizer Pump (MOP-D1) have been realised and cold flow test conducted for nominal operating conditions. Qualification of engine turbo-pump systems such as bearing and seals are in progress. Semi-cryo engine Thrust Chamber Pre-Burner, injector head and heat exchanger were realised for mock up engine for engine integration trials. Integrated engine test facility for testing the engine is under construction.

Reusable Launch Vehicle (RLV-TD)

Activities are progressing for autonomous runway Landing Experiment of Technology Development Vehicle (TDV) by releasing it from helicopter. Wind tunnel model realised with landing gear and low subsonic tests completed at IIT, Kanpur. In the next phase, it is proposed to design and develop scaled-up version of RLV and carryout an Orbital Re-entry experiment. Landing site has been identified for configuring landing runway with land based navigational aids for an autonomous descent and land experiment. For unmanned landing, land based navigational aids and associated systems have to be established.

Critical Technologies for Human Spaceflight Project (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. Critical technologies that are needed to undertake human spaceflight are Crew Module (CM) System, Crew Escape System (CES) and Environmental Control and Life Support System (ECLSS). The crew module was successfully flight tested in the GSLV-MkIII-X / CARE mission in December 2014. Various sub-systems of ECLSS including Thermal and Humidity Control System (THCS), CO2 and Odour Removal System (CORS) and Cabin Pressure Control System (CPCS) have been integrated into Cabin Environment Simulation Chamber simulating the Crew cabin volume and integrated tests are in progress.

Air Breathing Propulsion Project (ABPP)

The first experimental mission of ISRO's Scramjet Engine towards the realisation of an Air Breathing Propulsion System was successfully conducted on August 28, 2016 from SDSC, SHAR, Sriharikota. With this flight, critical technologies such as ignition of air breathing engines at supersonic speed, holding the flame at supersonic speed, air intake mechanism and fuel injection systems have been successfully demonstrated.

The flight data of Scramjet Engine experiment [ATV-D02] have been reviewed at various levels confirming supersonic combustion. Advanced Ethanol burned high pressure and high temperature air heater (thermal power rating ~50 MW) were realised and integrated with test setup at IPRC for combustion studies. System qualification hot tests were carried out where temperature up to 2200 K and flow rate of 13 kg/s achieved.

Advanced Technology Vehicle and Sounding Rocket

ATVP of VSSC is responsible for conducting sounding rocket development and launches for the scientific exploration of middle and upper atmosphere, realisation of new vehicles to support demonstration of advanced technologies. It provides a cost effective platform for testing the airworthiness of new subsystems, new avionics packages and technologies before introducing into launch vehicles.

Sounding Rockets

Rohini Sounding Rocket RH-200 flights: RH-200 rockets are regularly launched from TERLS range. 133rd consecutively successful launch of RH-200 rocket was conducted. Indigenously developed non-aqueous Super Capacitor was successfully flight-tested. All systems were ready for seven RH-200 launches (3 from VSSC and 4 from SDSC) planned during World Space Week 2017.

Public Viewing the Sounding Rocket Launch at Thumba

2.0 Space Infrastructure

2.1 Communication and Navigation Satellite System

2.1.1 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: INSAT-3C, INSAT-4A, INSAT-4B, INSAT-4CR, GSAT-6, GSAT-8, GSAT-9, GSAT-10, GSAT-12, GSAT-14, GSAT-15, GSAT-16, GSAT-17, GSAT-18 and GSAT-19.

2.1.1a Satellites in Service

INSAT-3C

Launched in January 2002, INSAT-3C payloads include Normal C-band transponders, Extended C-band transponders and S-band transponders to provide BSS and MSS services. All the transponders provide coverage over India.

INSAT-4A

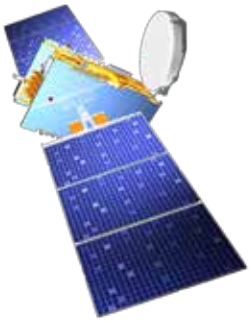
Launched in December 2005, INSAT-4A carries Ku-band transponders with footprint covering Indian mainland and C-band transponders with expanded coverage encompassing Indian geographical boundary and area beyond India.

INSAT-4B

Configured with payloads similar to that of INSAT-4A, INSAT-4B was launched in March 2007. INSAT-4B carries Ku-band and C-band transponders. Due to a power anomaly, the satellite is operating with reduced capacity.

INSAT-4CR

INSAT-4CR, launched in September 2007, carries Ku-band transponders. These transponders have capability to support Digital Satellite News Gathering (DSNG), Very Small Aperture Terminals (VSATs), Tele-education networks and other data communication services.



GSAT-8

GSAT-8 is a communication satellite configured around 3,000 Kg class (I-3K) bus with a lift-off mass of 3,093 kg 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.

GSAT-12

GSAT-12 satellite is configured around 1,000 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 1,410 kg.

GSAT-10

GSAT-10 was successfully launched by Ariane-5 from Kourou, French Guiana on September 29, 2012. Weighing 3,400 kg at lift-off, GSAT-10 commercial payload includes communication transponders in normal C-band, 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-14

GSAT–14 satellite provides Extended C-band and Ku-band communication transponder capacity. It also carries 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 2,600 W and a lift off mass of 1,982 kg. GSAT-14 was successfully launched on January 05, 2014 on-board GSLV-D5, the second developmental 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 3,150 kg with a mission life of more than 12 years. The spacecraft's payload includes transponders in Ku-band, C-band and Extended-C band. The satellite was launched by Ariane-5 from Kourou, French Guiana on December 06, 2014.

GSAT-15

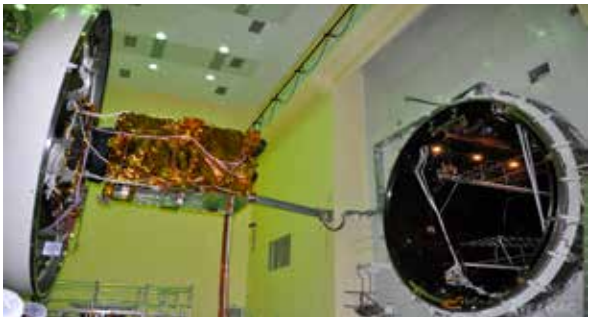
GSAT-15 is a communication satellite configured around I-3K bus with 3,164 kg lift-off mass and 6200 W power generation capacity. It is designed for a mission life of more than 12 years. The satellite's commercial payload includes Ku-Band transponders and a two-channel GAGAN payload. The satellite was launched by Ariane-5 from Kourou, French Guiana on November 11, 2015.

GSAT-18

GSAT-18 is a communication satellite configured around I-3K extended bus with a lift off mass of 3,404 Kg. The satellite carries Ku, Normal C & Extended C band transponders. It is designed for a mission life of more than 15 years. The satellite was launched by Ariane-5 on October 06, 2016 from Kourou, French Guiana.

GSAT-9 (South Asia Satellite)

GSAT-9 is a Geostationary Communication satellite realised with the objective of providing various communication services in Ku-band with coverage over South Asian countries. It was launched onboard GSLV-F09 on May 05, 2017 from Sriharikota with a lift-off mass of 2,230 kg. It is configured around the ISRO's standard I-2K bus. The satellite is designed for a mission life of 12 years.



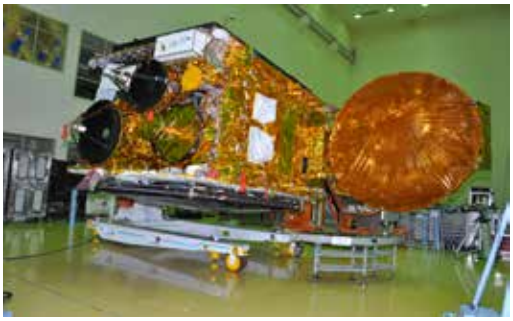
GSAT-9 being Prepared for Thermovac Test

GSAT-19

GSAT-19 satellite with a lift-off mass of 3,136 kg is a communication satellite configured around ISRO's I-3K bus. It carries Ka / Ku-band high throughput communication transponders. The satellite provides 8 user beams in Ku-band and 2 gateway beams in Ka-band. It was launched onboard first developmental flight GSLV-MkIII-D1 on June 05, 2017 from Sriharikota.

GSAT-17

GSAT-17 is a communication satellite launched on June 29, 2017 from Kourou, French Guiana onboard Ariane-5 VA-238 with a lift-off mass of 3,477 kg. It carries payloads in Normal C-band, Extended C-band and S-band to provide various communication services. It also carries payload for data relay and satellite based search and rescue services. The satellite also has transponders in Extended C-band that provide connectivity to Antarctica. The designed in-orbit operational life of GSAT-17 is about 15 years.



GSAT-17 at Clean Room with one of its Antennas Deployed

2.1.1b Satellites Under Development

GSAT-11

GSAT-11 is a multi beam high throughput communication satellite operating in Ka and Ku-bands employing a new bus. It provides 32 user beams in Ku-band and 8 gateway beams in Ka-band. The payload includes Ka x Ku-band forward link transponders and Ku x Ka band return link transponders. The satellite is in advance stage of realisation and is planned to be launched in 2018.

Ka-Band Antenna Reflector for GSAT-11

GSAT-29

GSAT-29 Spacecraft is a communication satellite configured with ISRO's enhanced I-3K bus. It will be

launched onboard second developmental flight of GSLV-MKIII-D2. It will have a lift-off mass of around 3,500 kg. It is configured with payloads to provide spot beams in Ku and Ka-band. The satellite will carry Q/V band payload, optical communication payload and geo high-resolution camera as technology demonstrators. The spacecraft will also carry a steerable Ka-beam over India. This spacecraft is planned to be launched in the first half of 2018.

GSAT-20

GSAT-20 Spacecraft is configured based on ISRO's standard I-3K bus. It is a communication spacecraft to be launched onboard first operational flight of GSLV-MkIII. It has Ka x Ka high throughput payload. It is estimated to have a lift-off mass of 3,650 kg. Presently, the satellite subsystems are under realisation.

GSAT-22, 23 & 24

The three communication satellites GSAT-22, 23 & 24 will be configured with ISRO's standard I-3K bus. These satellites will carry Ku-band transponders. The satellite subsystems are under various stages of realisation.

2.1.2 Satellite Navigation Programme

Satellite Navigation (SATNAV) is one of the important programmes of the department. There are two main components of this program - GAGAN and Navigation with Indian Constellation (NavIC).

2.1.2a GPS Aided Geo Augmented Navigation (GAGAN)

GAGAN is a joint project of ISRO and Airport Authority of India (AAI). The GAGAN Signal-In-Space (SIS) is available through GSAT-8, GSAT-10 and GSAT-15 satellites. GSAT 8 (PRN 127) and GSAT 10 (PRN 128) are transmitting GAGAN signals 24x7. 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 and later it was certified by DGCA for APV1.0 precision approach services over Indian Land Mass on April 21, 2015. With the certification of GAGAN for approach and landing operations, India has become the third country in the world to have such capabilities. GAGAN is the first SBAS system in the world to serve the equatorial region. The GAGAN system was dedicated to nation on July 13, 2015. The system is providing Satellite-based Navigation services with accuracy and integrity required for civil aviation applications and is also providing efficient air traffic management services over the Indian Airspace.

2.1.2b Navigation with Indian Constellation (NavIC)

NavIC is the Indian Regional Navigation Satellite System (IRNSS) developed by India. It is an independent system designed to provide accurate position information service to users in India as well as the region extending up to 1,500 km from its boundary, which is its primary service area. IRNSS is envisaged to provide two types of services, namely Standard Positioning Service (SPS) and Restricted Service (RS) and provides a position accuracy of better than 20 m in the primary service area. The IRNSS system consists of Ground Segment, Space Segment and User Segment.

2.1.2c Space Segment

The Space Segment consists of seven satellites with three in geostationary orbit and four in inclined geo-synchronous 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 Bus with a lift-off mass of around 1,425 kg. All the seven satellites in the constellation have identical configuration and are operational after successful launches.

IRNSS-1A is presently being used exclusively for messaging services. Of the two ground spare satellites, IRNSS-1H was realised and launched onboard PSLV-C39. However, the mission was unsuccessful, as the satellite could not be placed in proper orbit. IRNSS-1I satellite is presently under realisation and is planned to be launched onboard PSLV in the first half of 2018.

2.1.2d Ground Segment

Ground Segment caters to the maintenance and operation of the IRNSS constellation. This segment comprises of IRNSS Range and Integrity Monitoring Stations (IRIMS), IRNSS CDMA Ranging Stations (IRCDR), IRNSS Spacecraft Control Facility (IRSCF), IRNSS Network Timing Facility (IRNWT) and IRNSS Navigation Centre (INC). The entire ground segment and its components have been established and the segment is operational.

2.1.2e User Segment

Interface Control Document (ICD) with relevant information and details has been placed in public domain to enable the production of the user receivers. Different types of user receivers have been developed by ISRO and Industry. It is expected that more number of Indian vendors will participate in production of the user receivers in the years to come as the adoption of NavIC among the users grows.

With the in-house capabilities of ISRO, NavIC base band processor chip for Standard Positioning Service (SPS) has been realised with 180 nm Technology. Through a developmental project, five industries have been registered to develop the receivers. Liaison with various ministries and user agencies is in progress to ensure wider adoption of NavIC.

Using the first generation receivers, the capabilities of the system have been successfully tested and demonstrated to various users in road, rail, marine, fisheries and aviations sectors.

2.2 Earth Observation and Meteorological Satellite 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, Resourcesat-2A, Cartosat-1, Cartosat-2/2A/2B, RISAT-1, RISAT-2, Oceansat-2, Megha-Tropiques, SARAL, Cartosat-2 Series Satellite, and SCATSAT-1. Though Resourcesat-1, Cartosat-1, Cartosat-2, RISAT-2, 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, KALPANA-1, INSAT-3D and INSAT-3DR are providing meteorological data to the user community. INSAT-3A was decommissioned recently.

2.2.1 Earth Observation Satellites in Service

Cartosat-1 was launched into a 617 km polar Sun synchronous orbit on May 5, 2005 onboard PSLV-C6. Two panchromatic cameras, PAN (Fore) and PAN (Aft) are providing high quality images with 2.5 m spatial resolution and a swath of 30 km. The cameras are mounted with a tilt of +26 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.

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 10 years in orbit.

Cartosat-2A, launched on April 28, 2008 onboard PSLV-C9, 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 635 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. Imageries from this satellite are used for cartographic applications like mapping, urban and rural infrastructure development and management, as well as application in Land Information (LIS) and Geographical Information System (GIS). The satellite has completed 9 years in orbit.

Radar Imaging Satellite-2 (RISAT-2), the X-band Synthetic Aperture Radar (SAR) satellite, was 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 8 years in orbit and 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 eight bands Ocean Colour Monitor provides data at 360 m spatial resolution of 1420 km swath with two-day repetivity. The data is used to generate Local Area Coverage (LAC) product of 360 m resolution (2-day

coverage cycle) and Global Area Coverage (GAC) product of 1 km resolution (8-day coverage cycle). The pencil beam Scatterometer operates in Ku-band with a ground resolution cell of 50 x 50 km and scans the Earth surface conically with a swath of 1400 km. It provides the wind vector data over ocean surface in the range of 4 to 24 m/sec with better than 10% accuracy for speed and 20 degrees for wind direction. The payload served the user community for initial 4 years and stopped functioning since March 2014. The Scatterometer data is being used for deriving the global wind velocity (magnitude and direction) over ocean surface, which is used as an input for weather forecasting, monitoring of cyclones and their trajectory and ocean state forecasting. 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.

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. It also carries an additional announcement of opportunities payload, known as AIS (Automatic Identification System) from COMDEV, Canada as an experimental payload for ship surveillance in Very High Frequency (VHF) band to derive position, speed and other information of ships. The satellite has completed nearly 6 years in orbit.

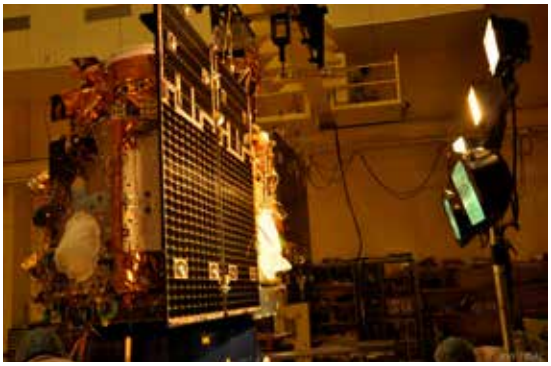
Megha-Tropiques (Megha - cloud in Sanskrit and Tropiques - tropics in French) is a ISRO-CNES joint mission for the better understanding of the life cycle of convective systems and their role in the associated energy moisture budget in the tropical regions. The satellite was launched by PSLV-C18 on October 12, 2011 into an 867 km orbit with 20o inclination. 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. MADRAS sensor is not functioning now. However, the data provided by MADRAS for the first 16 months 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. The satellite has accomplished the mission objectives. Anomalies have been observed towards the end of 5 years mission life and satellite is no more operational.

Cartosat-2B, launched on July 12, 2012 onboard PSLV-15, 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 highly agile CARTOSAT-2B is steerable up to ± 26° along as well as across track to obtain stereoscopic imagery and achieve a four to five-day revisit capability. The satellite has completed 5 years in orbit and is still providing imaging services.

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.

Cartosat-2 Series Satellite: Three Cartosat-2 series satellites were launched on June 22, 2016, February 15, 2017 & June 23, 2017 aboard PSLV-C34, PSLV-C37 & PSLV-C38 respectively. These satellites are similar to the earlier Cartosat-2, 2A and 2B. After their injection into a 500 km polar Sun Synchronous Orbit, the satellites were brought to operational configuration following which these satellites began providing regular remote sensing services using Panchromatic and Multi-spectral cameras. The Cartosat-2 series satellites are placed in orbit in phased manner. The imageries from Cartosat-2 series satellites are useful for cartographic applications, urban and rural applications, infrastructure planning, coastal land use and regulation, utility management like road network monitoring, water grids or distribution, creation of land use maps, precision study, change detection to bring out geographical and manmade features and various other Land Information System (LIS) and Geographical Information System (GIS) applications. The mission life of these satellites are 5 years each. These spacecraft are capable of along track and across track steering, nominally up to ± 45° providing spot images in continuous imaging mode.



Cartosat-2 Series Spacecraft undergoing Solar Panel Illumination Test

SCATSAT-1: The satellite was launched on September 26, 2016 onboard PSLV C-35. It is a continuity mission of 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 has been placed in Sun Synchronous Orbit of 720 km altitude with an inclination of 98.27 deg by PSLV. The mission life of the satellite is 5 years.

Resourcesat-2A: Resourcesat-2A was launched on December 07, 2016 onboard PSLV-C36. It is a

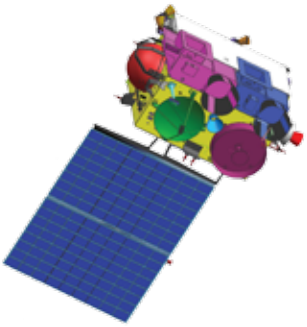
follow on mission to Resourcesat-2 and intended to provide data continuity to the users. The configuration is similar to Resourcesat-2 having three-tier imaging capability, with a unique combination of payloads consisting of three solid-state cameras, namely, a high resolution Linear Imaging Self Scanning 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 1235 kg with a power generation capacity of 1250 W and a mission life of 5 years. The satellite was placed in Sun Synchronous Orbit of 817 km altitude with an inclination of 98.69 deg.

2.2.2 Meteorological Satellites in Service

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 15 years of life in orbit.

INSAT-3D, an advanced weather satellite, was launched on July 26, 2013 and positioned at the orbital slot of 82° 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.

INSAT-3DR was launched on September 08, 2016 aboard GSLV F-05 launch vehicle and positioned at the orbital slot of 74° East longitude in the geostationary orbit. It is repeat mission of INSAT-3D satellite with improved geolocation accuracy and enhanced band to band registration. The radiometric measurements have been also improved using Black Body calibration. It is also having payloads Data Relay Transponder (DRT) and Satellite Aided Search and Rescue (SAS & R) Transponder.



2.2.3 Future Earth Observation Missions

India's future Earth Observation (EO) programme will ensure the continuity of the application thematic series of satellites, namely, Resourcesat & RISAT (Land & Water), Cartosat (Cartography), Oceansat (Ocean & Atmosphere) and INSAT (Meteorology). It is also envisaged to realise Geo Imaging Satellites (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, several satellites have been planned to be launched in conversant with ISRO's vision document. Brief description of these future missions is given hereunder:

Cartosat-3: It is an advanced agile satellite to obtain panchromatic and multispectral imagery with an operational life of 5 years. The payload has the capability of imaging with 0.25m GSD in Panchromatic

and 1m GSD in 4 Band Multispectral modes with a swath of 16km. Many new technologies/elements are being developed like highly agile structural platform, payload platform, higher rate data handling and transmission systems, advanced onboard computer and new power electronics, dual gimbal antenna, etc. The spacecraft readiness is expected by third quarter of 2018.

GISAT-1: It is a geo imaging satellite operating from geostationary orbit to provide high temporal resolution. The GISAT-1 payload 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° 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. It is expected to provide 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. GISAT-1 will be realised for launch by June 2019.

RISAT-1A & 1B is a repeat mission of RISAT-1 with C-Band Synthetic Aperture Radar (SAR) payload to facilitate cloud penetration and to carry out the other earth observation applications. The satellite is planned to be launched onboard PSLV into a Sun synchronous orbit at an altitude of 536 km. The satellite will carry a Synthetic Aperture Radar (SAR) Payload operating in C-band (5.35 GHz), which has the capability to penetrate clouds and take images during day/night. The data from RISAT-1A will be used for applications in the areas of agriculture, forestry, soil moisture & hydrology, oceanography and disaster management. RISAT-1A & 1B are planned to be launched in the year December 2018 and March 2021 respectively.

Oceansat-3 & 3A is a continuity mission of Oceansat-2 with enhanced imaging capability. It has three payloads onboard a 13-Band Ocean Color Monitor (OCM), a 2-Band Long Wave (thermal) Infrared Sea Surface Temperature Monitor (SSTM) and Ku-Band Pencil Beam Scatterometer. Improvements planned in the Oceansat-3 are simultaneous measurement of Ocean Color and SST, newer applications with increased number of bands and reduced bandwidth, wind vectors at 25km spatial resolution, improvements in signal to noise ratio, coverage from near pole to pole, etc. Oceansat 3 & 3A are planned to be launched in November 2018 and July 2019 respectively.

INSAT-3DS is a stand-by mission planned to replace either of INSAT-3D in the orbital slot of 82 deg East longitude in the geostationary orbit or INSAT-3DR in the orbital slot of 74° East longitude in the geostationary orbit based on the need and is planned to be kept ready in stand-by mode by 2018. It is a stand-by mission with improved geolocation accuracy and enhanced band to band registration. It has an Atmospheric Sounding System of 19 channels (Visible -1, SWIR-6, MWIR-5, LWIR-7) capable of providing 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. INSAT-3DS is also having an Imager capable of imaging earth and its environment in six spectral channels (Visible-1, SWIR-1, MIR-1, Water Vapour IR-1, Thermal IR 1-1, Thermal IR 2-1). It will also have Data Relay Transponder (DRT) and Satellite Aided Search and Rescue (SAS & R) Transponder similar to INSAT-3D/3DR.

Resourcesat-3 & 3A is a medium resolution, wide swath satellites for advanced land and water resource management applications. Resourcesat- 3 & 3A would ensure continuity of data services required for the operational programmes in the areas of land and water resources management. It will carry Advanced Linear Imaging Scanning Sensor-3 (ALISS-3) payload consisting of VNIR and SWIR bands. Besides providing medium resolution wide-swath imagery, it is equipped with on-board atmospheric correction band to improve the data products. The ground sampling distances will be 20m for VNIR and SWIR bands with the central EOM providing 10m GSD. Hyperspectral atmospheric correction bands will operate in VNIR bands and have ground sampling distances of 240m. Total field of view of the payload system is around 925 km at 795 km altitude orbit. Resourcesat – 3 & 3A are planned to be launched in the year September 2019 and August 2020 respectively

Resourcesat-3S & 3SA is a mission for stereographic mapping with improved resolution in Panchromatic and Multispectral bands and along track stereo images for generating improved Digital Elevation Models (DEM) target of 5m for the Area of Interest (AOI). Resourcesat-3S & 3SA satellites are with capabilities to provide along track high resolution panchromatic stereo and multi-spectral imagery. It carries two panchromatic camera – PAN (fore) and PAN (aft) with 1.25m resolution providing a swath of 60km in PAN Band, and a Multispectral camera having bands in VNIR region with 2.5m resolution providing a swath of 60km. Resourcesat-3S & 3SA are planned to be launched in the year May 2019 and January 2020 respectively.

NISAR (NASA-ISRO Synthetic Aperture Radar) is built jointly with NASA, a Dual frequency (L & S Band) Radar Imaging Satellite, to provide data services for natural resources mapping and monitoring as well as studies related to deformation, ecosystem, dynamics of ice sheets, mountain glaciers, forest fires and oil slick. It carries an L Band in 1260 MHz and S Band in 3200 MHz SAR payloads, both operating in Interferometric SAR (InsAR) with multiple polarisation. The L Band SAR would be augmented with S Band component and both these SAR systems would make use of 12m diameter large size common unfurlable reflector antenna. The payload uses innovative Sweep SAR technique for both L- and S-band in full polarimetric configuration to enable very wide swath measurements (>200 km) and very high resolution (5-10m) with repeat pass interferometric capability. The launch vehicle identified for NISAR is GSLV-MkII and is planned to be launched in the year 2021.

HRSAT (High Resolution Satellite constellation) is a satellite constellation (three satellites in a single orbital plane) to be launched by a single Polar Satellite Launch Vehicle into a 660 km Polar Sun Synchronous orbit. The constellation will have daily revisit capability with ± 45° tilts. The payloads will have imaging capability of ~1 m Ground Sampling Distance (GSD) with 15 km swath in Panchromatic mode, 2m / 4m GSD in three band multi-spectral (Mx) mode with 15 km swath, and 20 m GSD in IR band with a swath of 6 km. A constellation of small satellites with sub meter resolution in PAN and a daily revisit capability has a great potential for commercial applications in large scale mapping, agriculture, urban planning, rural development, infrastructure development, Disaster management, etc. HRSAT is planned to be launched in the year February 2019.

3.0 Space Applications

3.1 Satellite Communication Applications

A fleet of Indian communication satellites are operating over India with communication transponders in C-band, Extended C-band, Ku-band, Ka/Ku-band and S-band. These satellites together support the services like television, telecommunication, radio networking, communication and societal applications. The prominent users of the transponders are BSNL, Doordarshan, DTH and TV operators, All India Radio, Government users, Public Sector Units, Private VSAT operators, banking and financial institutions, etc.

DOS/ISRO has continued the support for societal programmes like Telemedicine, Tele-education and Disaster Management Support (DMS) Programmes, which are 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, transponders are also leased from international satellite operators. Thus, satellite communication is playing a major role in the socio-economic development of the country.

3.1a Television

The communication satellites have 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 in the country.

Doordarshan is presently operating 34 satellite channels and has a vast network of 67 Studios and 1409 Transmitters of varying power installed throughout length and breadth of the country. The satellite channels of Doordarshan include 6 all-India-channels 16 regional channels, 11 state channels and one international channel. 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 antenna all over India. The free-to-air DTH service “DD Free Dish (Earlier DD Direct+)” of Doordarshan offers 59 TV channels. For Andaman and Nicobar Islands, DTH service is in C-band with a bouquet of 10 channels. DD has plans to augment the capacity to carry 250 channels. Apart from Doordarshan, the public broadcaster, 6 private DTH operators provide service in India. It is estimated that (TRAI Report - April 2017) there are about 97.05 Million DTH pay subscribers registered with Private DTH operators and with 62.65 Million subscribers are active. About 899 TV channels are registered with Ministry of Information and Broadcasting as on Dec 2016.

About 107 Ku-band transponders from both Indian and Leased satellites are catering to DTH television services. Apart from DTH, about 25 C band transponders are used for supporting Television uplink. Doordarshan alone is using a total of 19.25 Transponders (12.25 in C Band and 7 in Ku Band) of 36 MHz each on Indian Satellite System.

3.1b 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. About 7 transponders are used for DSNG services of various operators.

Majority of the news channels use their own DSNG terminals. Doordarshan alone has 16 C-band and 18 Ku-band Digital Outdoor-Broadcast Digital Satellite News Gathering terminals operating through INSAT satellites.

3.1c Radio Networking

Radio Networking (RN) through satellites provides a reliable high-fidelity programme channels for National as well as Regional Networking. Around 419 All India Radio (AIR) stations and about 607 radio transmitters have been equipped with receive terminals. AIR is utilising one C-band transponder for uplinking RN carriers across the country. 21 radio channels of AIR are broadcast through DTH platform of Doordarshan.

3.1d Telecommunications

INSAT satellites have been supporting telecommunication applications for providing voice, data and interactive communications. Satellite links are the primary means of connectivity to remote and far flung regions of the country and play the role of backup links for large number of services on terrestrial connectivity. SATCOM links have a major role in banking sectors linking the ATMs with banks.

1404 Satellite Earth Stations of different sizes are operating in the 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 2,74,000 VSATs 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 about 19,000 IPSTAR VSATs as well as one by two voice channel connectivity to remote areas through about 5000 DSPTs (Digital Satellite Phone Terminal).

Satellite based captive networks are operational using VSAT systems for establishments like NTPC, ONGC, IOCL, ICAR, ERNET, Indian Railway Karnataka Power Transmission Corporation Ltd., etc. apart from private enterprises. In addition, INSAT/GSAT satellites cater to captive government networks of various ministries and strategic agencies.

3.1e Telemedicine

The Telemedicine programme connects remote/rural/medical college hospitals and Mobile Units through the Indian satellites to super specialty hospitals in cities and towns. The telemedicine technology utilises Information and Communication Technology (ICT) based system consisting of customised medical software integrated with computer hardware along with medical diagnostic instruments connected to VSATs. Presently, around 130 Telemedicine nodes are operational across the country.

This year a telemedicine node was installed and commissioned beyond Leh through Integrated Defence Staff (IDS-Medical) to be utilised by Army from extremely remote regions at high altitudes. The operational training is provided to concerned field officers to make use of the system. Efforts are on to enhance the telemedicine connectivity to Armed Forces. The telemedicine node at Sheshnag was reinstalled and operationalised to provide telemedicine access to the pilgrims travelling to Amarnath. A new telemedicine link was provided to mobile van of Shri Shankara Cancer Hospital, Bengaluru for helping the cancer patients in parts of Southern Karnataka.

Continuing Medical Education (CME) programmes are conducted on monthly basis from DECU studio. Medical experts/doctors share their knowledge and experiences and interact with the connected remote hospitals. By October 2017, 7 CMEs were conducted benefiting more than 700 users and two more planned by December 2017. Feedback from all the participating nodes is taken and a report is prepared.

3.1f Tele-education

Under Tele-education programme, the teaching sessions conducted from customised studio are telecast through satellite(s) for connect to schools and colleges spread across. It has manifold objectives to supplement the curriculum-based teaching, imparting effective teacher training, providing access to experienced resource persons, and thus resulting in effective delivery of quality education to the nook and corners.

Tele-education Programme started in 2004 was implemented in three phases: pilot, semi-operational and operational phases. In association with State/Central user agencies 83 networks were implemented connecting around 5000 Interactive (SITs) and 55,000 Receive Only Terminals (ROTs), covering 26 States and 03 Union Territories. At present, around 44 networks are operational in various states.

During the year, Tele-education networks of North-East states were revived connecting about 230 Satellite Interactive Terminals (SITs) and work is in progress to operationalise another 120 SITs.

An MoU was signed between Government of Jammu & Kashmir (J&K) for reactivation of Tele-education network in the state. Around 36 SITs have been reactivated and efforts are on to reactivate all 103 SITs by this year-end.

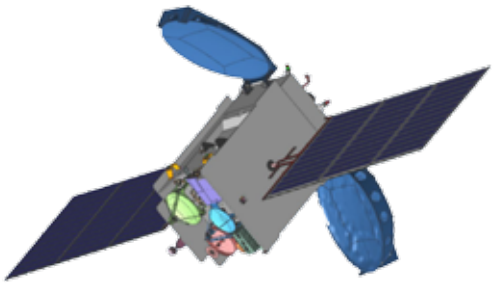
3.1g Mobile Satellite Services (MSS)

The MSS Service provides the communication to the portable and hand-held devices. Largely, two types of services, namely voice and messaging are provided using MSS. Voice communication is a two-way service supported at 2.7 Kbps and 5.4 Kbps using compact terminals. Voice call could be established from satellite terminal to any land/mobile phones apart from terminal to terminal calls. Messaging service is a low bit rate one-way reporting service using shared channels with portable and hand-held terminals. The messaging service is used from data collections, tracking and reporting applications.

3.1h 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 Low Earth Orbit (LEO) & Geostationary Earth Orbit (GEO) Search And Rescue (SAR) satellite system. Under this programme, India has established two Local User Terminals (LUTs), at Lucknow and Bengaluru. The Indian Mission Control Centre (INMCC) is located at ISTRAC, Bengaluru. The system is operational from the past 27 years.

Satellite aided Search And Rescue (SAR) payload is carried on INSAT-3D (82°E), INSAT-3DR (74°E) and GSAT-17 (93.5°E) operating in 406 MHz band. These payloads pick up and relay alert signals originating from the distress beacons of maritime, aviation and land users. Indian receiving terminals namely Local User Terminals (LUTs – both LEOLUT and GEOLUT) receive the distress messages picked up by these satellites and these messages are processed at Indian National Mission Control Centre (INMCC) located at ISTRAC, Bengaluru. INMCC service area is extended to cover Bangladesh, Bhutan, Maldives, Nepal, Seychelles, Sri Lanka and Tanzania. User agencies like Indian Coast Guard, Airports Authority of India (AAI), Directorate General of Shipping and Services, Shipping and companies, etc benefit from the SAR service.



GSAT-17

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.

During the year 2016, INMCC provided search and rescue support to four distress incidents in Indian service area through Indian system and contributed to saving 8 human lives. About 524 new radio beacons were added in Indian database (most of them for Aviation applications). The IMNCC has the facility to register and maintain the user & beacon details. There are about 873 registered user agencies

(Maritime & Aviation) in India with an Indian beacon population of more than 15,419 in the database. The next generation system MEOSAR is under implementation phase and is expected to operate under early operations capability (EOC) by mid- 2018.

3.1i 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.

3.2 Navigation – NavIC and GAGAN- Applications

Extensive Field Trials were conducted, using 36-Channel NavIC User Receivers, for NavIC Constellation's Performance Evaluation, all across India in association with Academic and Research Institutes, other ISRO Centres and Government Departments.

NavIC base band processor chip for Standard Positioning Service (SPS) is realised with 180 nm Technology leveraging the internal capabilities of ISRO. The development and validation of corresponding RF chip is in progress. Using the first generation receivers, tracking applications were demonstrated in the areas of road transport, railways, shipping, etc. NavIC capabilities are also demonstrated for time-synchronisation applications in power system operations.

A fishermen App has been developed using the messaging capability of NavIC and demonstrated. A compact NavIC device communicates to fisherman's smart phone via Bluetooth the message information to the App. This App provides position information for navigating to potential fishing zone, alert messages on rough sea and weather status and warning messages on approaching international water boundaries.

Towards utilising NavIC for the maritime services, a proposal was submitted to International Maritime Organisation (IMO) for recognising NavIC as part of World Wide Radio Navigation System. The Maritime Safety Committee (MSC) of IMO has considered the proposal to be deliberated in its technical body Navigation, Communication and Search and Rescue (NCSR) sub-committee. An input paper is submitted to NCSR for further considerations.

Ruggedised hybrid (NavIC & GPS/GAGAN) receivers have been designed, developed and tested on PSLV and GSLV launch vehicles for determining trajectories. The performance of these receivers is found satisfactory. More such receivers are realised for future launch vehicle missions.

3.3 Remote Sensing Applications

The Earth Observation satellites provide large amount of image data, which need to be processed to make it easily understandable and usable in form of maps, products user-friendly and services

3.3a Monitoring and Prediction of Extreme Weather

Now-casting & Short-range predictions were done with regard to heavy rainfall in around Mumbai. Clear-Sky radiances for assimilation in global weather prediction model using INSAT-3D/3DR was developed and implemented at NCMRWF for improved weather predictions. About 32 geophysical parameters were operationally generated from INSAT-3DR. High resolution urban surface temperature monitoring and prediction was estimated using INSAT-3D/3DR.

3.3b Crop Inventory

National-scale Inventory of pulse crops was carried out for Rabi season 2016-17 using time series AWiFS data and the methodology has been transferred to Mahalanobis National Crop Forecasting Centres (MNCFC), Ministry of Agriculture & Farmers' Welfare for operationalisation. Geo-spatial horticulture inventory for citrus, banana and mango have been completed and these have been transferred to MNCFC under CHAMAN (Coordinated programme on Horticultural Assessment and Management using geo-informatics) Project. Operational methodology of inventorying for three major fruit crops - mango, banana and citrus has been developed using high-resolution satellite data

3.3c Crop Intensification

The 'Bringing Green Revolution in Eastern India (BGREI)' under Food Security Mission aims at mapping and inventorying of kharif rice area, rabi crop area and kharif rice-rabi fallows. It covers the states of Odisha, Chhattisgarh, Bihar, Jharkhand, Bengal and Assam. The information on suitable area for cultivation of Rabi pulses in the rice fallows was generated by adopting an integrated approach in GIS with various climatic and edaphic factors. Geo-spatial layers such as Land Surface Wetness Index (LSWI), surface water bodies' map, slope (%), temperature, NBSSLUP soil map and drainage network were used to assess suitability of these rice fallows for pulses on the basis of multi-criteria decision rule approach. Analysis is completed for Chhattisgarh state and the results indicated that approximately 74% (26.35 lakh ha) of kharif rice areas are left as rabi fallows, and it is these areas that require immediate attention to bring them under double crop

Satellite Image depicting Wheat and Fallow Land

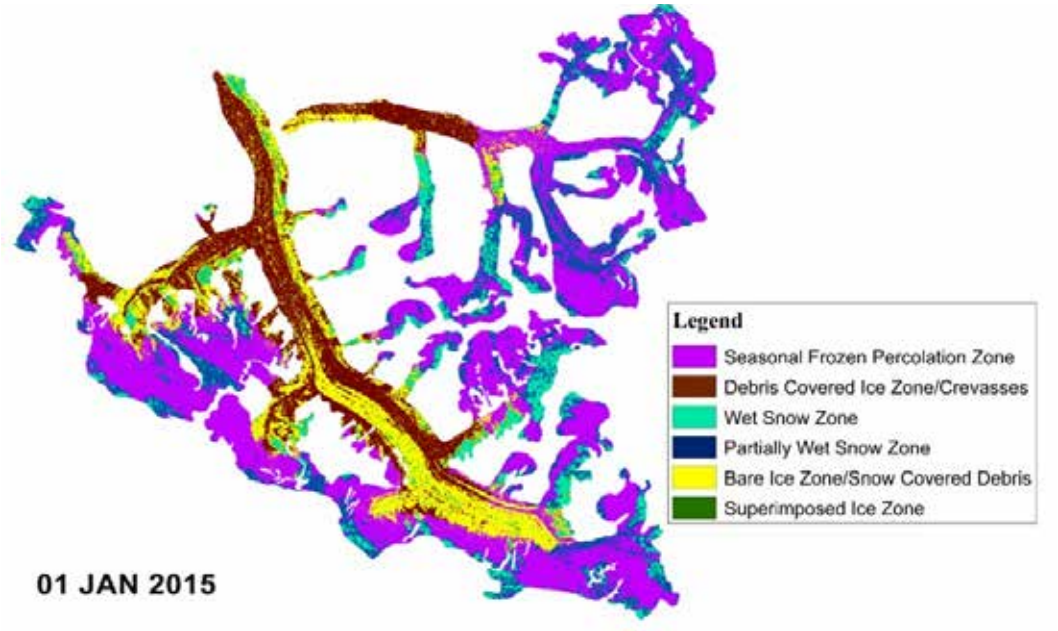
areas. Suitability analysis indicated that 29% of kharif rice-rabi fallow lands have potential to grow rabi pulses. The results are hosted on Bhuvan geo portal to increase the outreach for enhanced end use.

3.3d Fiber Crop Information System

A Fiber Crop Information System is being developed using geo-spatial technologies. This will aid in collection of field level observations and centralised monitoring and assessment of cotton and jute crop condition towards informed decision making, assistance in crop acreage and pre-harvest production estimates includimg validation of satellite-derived crop maps which is also hosted on Bhuvan. Geo-tagging of field centres related to these crops is also being carried out. Collection of significant amount of field based observations (over 12,000 covering cotton crop across nine states and over 2000 covering jute crop across four states) was carried out during 2016-17 by the user departments.

3.3e Snow and Glacier studies

Snow and ice zones of the glaciers of Himalayan-Karakoram region were extracted from about 300 RISAT-1 SAR MRS scenes of the period from October 2015 to September 2016 using an in-house developed algorithm. Pilot studies of retrieving ice velocity of glaciers of Himalayan region were carried out using LISS III and SAR MRS data. About 250 Himalayan glaciers were monitored based on changes in the area using LISS III data of ablation season of the year 2001 and 2016. Snow products were produced for 33 sub-basins of Himalayan region at 5 days interval using AWiFS data. An advanced automatic weather stationwas installed on a glacier near Batal village in Lahaul and Spiti district (Himachal Pradesh) to record the atmospheric data to be used for Energy balance studies of the nearby glaciers. The products are made available to users through VEDAS web portal.

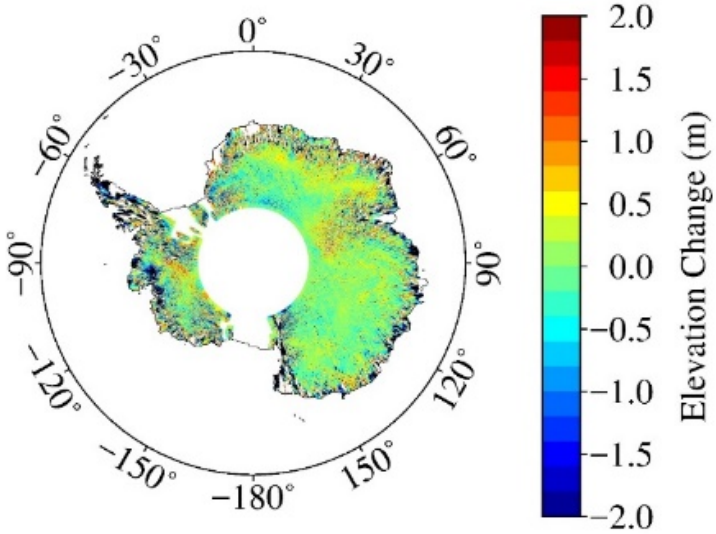


Features extracted from RISAT-1 SAR MRS data over Gangotri glacier

An AWS near Batal glacier in Lahaul & Spiti district (Himachal Pradesh)

3.3f Antarctic Ice Studies

Products of global sea ice extents of polar regions were generated from Scatsat-1 data. It provides the spatio-temporal variation of sea ice in the polar regions. Elevation changes of ice over Antarctic continent have been estimated utilizing SARAl AltiKa data. During 2013 to 2016, a decrease of 3m elevation has been observed in parts of west Antarctica and an increase of about 1m has been recorded in parts of east Antarctica. Stakes (markers) were installed on the ice of Polar record glacier of Antarctica to validate the ice velocity products. DGPS data was collected on these markers. Ground Penetrating Radars (GPR) of 400 MHz, 500 MHz and 1 GHz were used to collect the data of snow cover and ice stratification over sea ice and land ice in Antarctic region. The snow depth over sea ice estimated using multi-frequency GPR varies between of 30 to 40 cm. Over land ice snow depth up to 1m has been observed near Bharati research station.



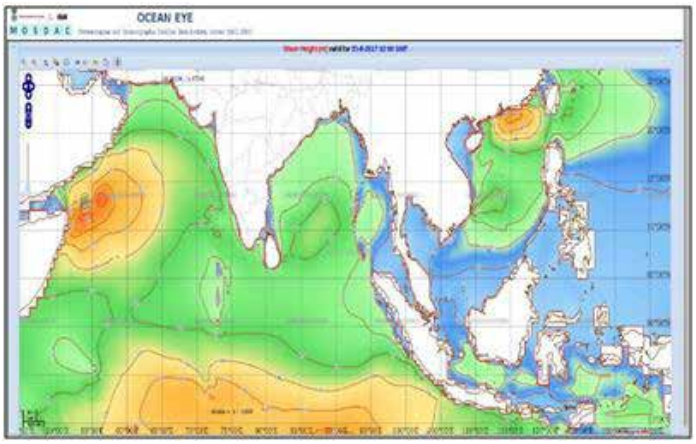
Antarctic ice sheet surface elevation changes derived from AltiKa ERM and Geodatic phase data (2013-2016).

3.3g Hydrological Studies

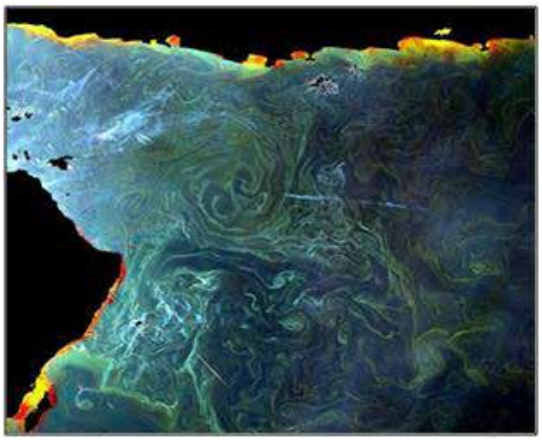
Flood affected regionsin India was detected using SCATSAT-1 & SARAL/Altika on near real time basis. Satellite based Hydrological Model was developed which simulate surface water balance (Runoff, Infiltration ET, Soil Moisture, Snow melt,etc.) using satellite inputs over India at 5x5 km Grid.

3.3h Satellite Oceanography Program

Integrated oceanography of satellite derived information and numerical ocean models were developed to simulate and predict the 3-D ocean state. These ocean states are extremely useful for navigation, communication and naval operations. “Ocean Eye” for Shipping Corporation of India is a web portal providing the ocean state forecast (currents, wave height, sea surface winds and pressure) for smart navigation.



Significant wave height (m) DA-wave model used for ocean state forecast.



Noctiluca algal bloom in the Arabian Sea OS-2 OCM , Feb 11, 2017

3.3i Air Quality Monitoring from Space

Aerosol optical depth (AOD) retrieval technique has been developed using INSAT-3D data. Temporal behavior of AOD profile is available at VEDAS web portal (vedas.sac.gov.in) at pixel level. It contains information on INSAT-3D based Aerosol Optical depth, wind forecast, MODIS AOD and other ancillary data for CPCB, New Delhi.

3.3j Master Plan Formulation for Cities

Ministry of Housing and Urban Affairs, GOI awarded the first lot of 56 AMRUT (Atal Mission for Rejuvenation and Urban Transformation) cities from 9 states for geo-spatial database creation for the formulation of Master Plan during July 2017. Large scale Urban geo-spatial database from Very High Resolution Satellite data is being created on 1:4000 scale for three Cities from Kerala, namely, Alappuzha, Kochi and Thrissur. The third AMRUT National meet was held at NRSC, Hyderabad on September 22, 2017 to work out the modalities for geo-spatial database creation and appraise the Urban Local Bodies of different states / Union Territories about the preparedness for undertaking this

task. About 103 Officers from 32 States and Union Territories from Urban Local Bodies (ULBs), State Remote Sensing Centres (SRSAC), Academia and Town and Country Planning Organisation (TCPO) attended the meet.

3.3k Monitoring of Integrated Watershed Management Programme (IWMP)

Monitoring of IWMP watersheds is being carried out using Bhuvan - Srishti, a Web based GIS application and Drishti, an android based tool developed for the Department of Land Resources, Ministry of Rural Development. Accordingly, information about 6700 IWMP projects along with their satellite data for four time periods is hosted on Bhuvan. A mobile app Drishti has been developed and released for use by the ground staff for geotagging and capturing information about assets created at the field level. The new features of the App include dynamically showing the current location on a map interface. Also the field enumerator can visualise the assets already captured in a particular project and this facilitates revisit to these locations for periodic monitoring. The existing activity is displayed with a work code while the new activity can also be captured afresh. As on date, around 7.11 lakh assets are uploaded on to Bhuvan.

3.3l GIS Implementation of MGNREGA (GeoMGNREGA)

GIS implementation of MGNREGA is carried out by NRSC for the Department of Rural Development, Ministry of Rural Development. The project aims at geotagging of all the assets created under the scheme since its inception during 2006 and also facilitates their visualisation on the Bhuvan Portal under the Geo-MGNREGA tool. Till September 2017, a total of 2.38 crore geotags of the state wise assets have been collected, of which 2.08 crore are accepted by the respective states. MoRD further intends to enhance the scope of the project into second phase by a) incorporating analytics tools for the geo-tagged asset database and b) using satellite data along with thematic database in planning the MGNREGA activities. These activities are envisaged under Natural Resources Management (NRM) through implementation of earthworks, plantations, conservation structures etc., towards assured irrigation under PMKSY (Pradhan Mantri Krishi Sinchayee Yojana) guidelines.

3.3m Automated Detection of Annual Forest Loss Locations using Satellite data

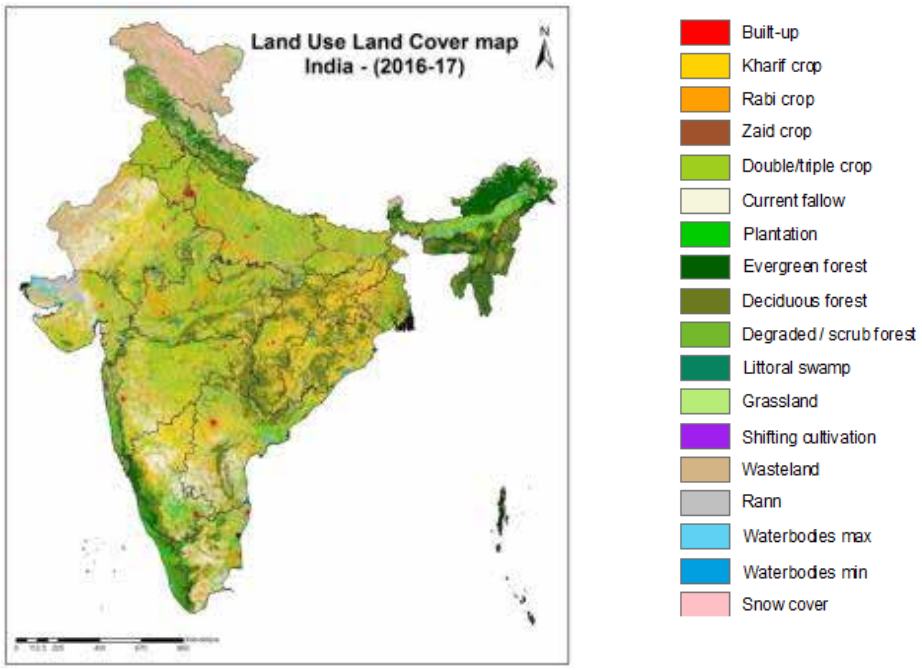
Identification of forest disturbances is a crucial step in effective forest management. Forests need to be monitored at annual to sub-annual scale for the detection of forest cover change. Time series satellite data is analysed for accurate identification of forest loss locations. An automated algorithm has been developed and used for identification of forest loss areas using satellite images from 2011 to 2016. The algorithm is based on spectral characteristics of the forests in different spectral bands. The algorithm was tested in different forest types and was found to be efficiently delineating forest loss locations. Operational results at National levels have been generated for three cycles. Forest loss locations are published on Bhuvan. An Android mobile application has been developed by NRSC for collection of field attributes for field verification and feedback mechanism for the improvement of the algorithm. Change locations have been subject to visual quality check to ensure no errors of commission. Field verification and corroboration with high resolution satellite data has also been carried out to ensure accuracy.

3.3n Reassessment of Water Availability in India

A pilot study in Godavari and Brahmani-Baitarani river basins was carried out to estimate basin-level mean annual water resources using hydrological model and space based geo-spatial data. The study was up scaled to all river basins of the country through Regional Offices of Central Water Commission and technical support provided for carrying out the study. Estimated average water resources availability, including water resources availability in maximum and minimum rainfall conditions have been completedfor a period of 1985 to 2015 (i.e., 30 years) for all river basins.

3.3o National Land Use / Land Cover Mapping on 1:250,000 Scale

Mapping of Land Use / Land Cover (LULC) using multi-temporal satellite data was initiated in the year 2004-05 and 13 annual cycles of assessments have been completed till 2016-17 (Figure). The LULC classification was done using rule based approach on multi-temporal AWiFS satellite data. At the end of year, the forest cover, built-up and shifting cultivation changes are assessed separately. Water spread as well as snow cover information has been generated though rule-based process The entire 13 cycles database are hosted on Bhuvan geo-portal for public use.



National Land Use / Land Cover mapping on 1:250,000 scale

3.3p Empowering Panchayati Raj Institutions Spatially (EPRIS)

It is a comprehensive outreach programme initiated by ISRO to build the capacity for grass root-level planners towards spatial resource-based integrated developmental planning in rural areas. The goal is to empower Panchayati Raj Institutions for resource-based and integrated spatial developmental planning in a user-friendly enabling environment towards e-governance. Activities carried out under this project

include (a) Organisation of several capacity building programmes at state level for entire country and district and block level for 10 % of the country for PRIs, line departments, academia and NGOs (b) Asset mapping using Bhuvan Panchayat mobile application for 10% of Panchayats of the country and (c) Activity planning at three tiers of Panchayati Raj along with its implementation and monitoring.

MoUs were signed with 35 partner institutions for covering 23,729 Gram Panchayats. Additionally, 28 academic institutions have come forward to cover 9,827 Gram Panchayats. Under EPRIS, more than 12,400 Panchayats are already covered for asset mapping and 9.2 lakh assets have been mapped so far.

3.3q Promoting Space Technology based Tools: Applications in Governance and Development

Specific initiative taken, in the form of national meet on application, during Sept 2015 has resulted in 156 projects with various ministries/ departments of which 125 of them have progressed as scheduled, in terms of development of methodology, web & mobile applications, online and offline geo-spatial database creation, training and execution of work. Some of the significant outcome are the inventory of orchards in more than 160 districts under the Horticulture Development and Management project (CHAMAN), geotagging of more than 2.38 crore assets under GeoMGNREGA, assessment of renewable energy potential of solar, wind and wave energy towards its enhanced utilisation, Geospatially enabled monitoring of IWMP watersheds (more than 10 lakh field photographs depicting watershed development interventions on Bhuvan portal) and monitoring the stage of construction of beneficiary houses under PMAY (Urban) (about 5.6 lakh houses have been monitored so far).

120 MoUs have been signed in relation to the execution of Space Application projects, out of which, 72 MoUs are with Central Agencies and 48 MoUs are with the State Governments/Departments. This includes about 50 MoUs signed in the current year. More than 10,000 officials from various Ministries have so far been trained in Geo-spatial technology utilisation. Space Technology Cell or mechanism for the utilisation of Space technology have been established in 21 Ministries/Departments

3.3r State Level Meets for Promotion of Space Technology based Applications

For strengthening the involvement of States in utilising space technology for Governance and Development, ISRO has proactively interacted with State Governments for organising State level meetings similar to the National Meet. These interactions have so far resulted in 15 State level meets, in Haryana, Bihar, Uttarakhand, Mizoram, Nagaland, Rajasthan, Punjab, Jharkhand, Meghalaya, Himachal Pradesh, Kerala, Chhattisgarh, Assam, Madhya Pradesh and Tamil Nadu.

In many of these meets, the State Chief Ministers or Ministers actively participated and addressed during the Special Sessions. For other States, discussions are ongoing for finalising the modalities of organising the State meets.

3.3s Mobile Applications

More than 30 mobile applications have been developed for variuos users in Ministries and Departments of State and Central Government. The mobile apps for Android platform, are mainly used for geotagging of assets, monitoring of infarstructure creation and development programmes, ground truth and field data collection and other geo-governance applications.

3.4 Satellite Meteorology

Satellite technology is of great use in meteorology and plays a very significant role in the improvement of weather forecasting and dissemination. INSAT-3D and INSAT-3DR satellites are carrying meteorological payloads. The meteorological data of these satellites is processed and disseminated by INSAT Meteorological Data Processing System (IMDPS) of India Meteorological Department (IMD). The performance of the system during the current year has been maintained to the level of 98% operation efficiency (24x365 basis). Satellite images are used in monitoring Cyclones. Intensity and position of cyclones is given to forecasters in real time using Dvorak technique. Satellite data and images are also used in monitoring various other significant weather phenomena such as Fog and thunderstorms.

The output generated by the processing systems is used for efficient and successful forecasting of major cyclones like Maruthain April 2017 and Mora in May 2017.

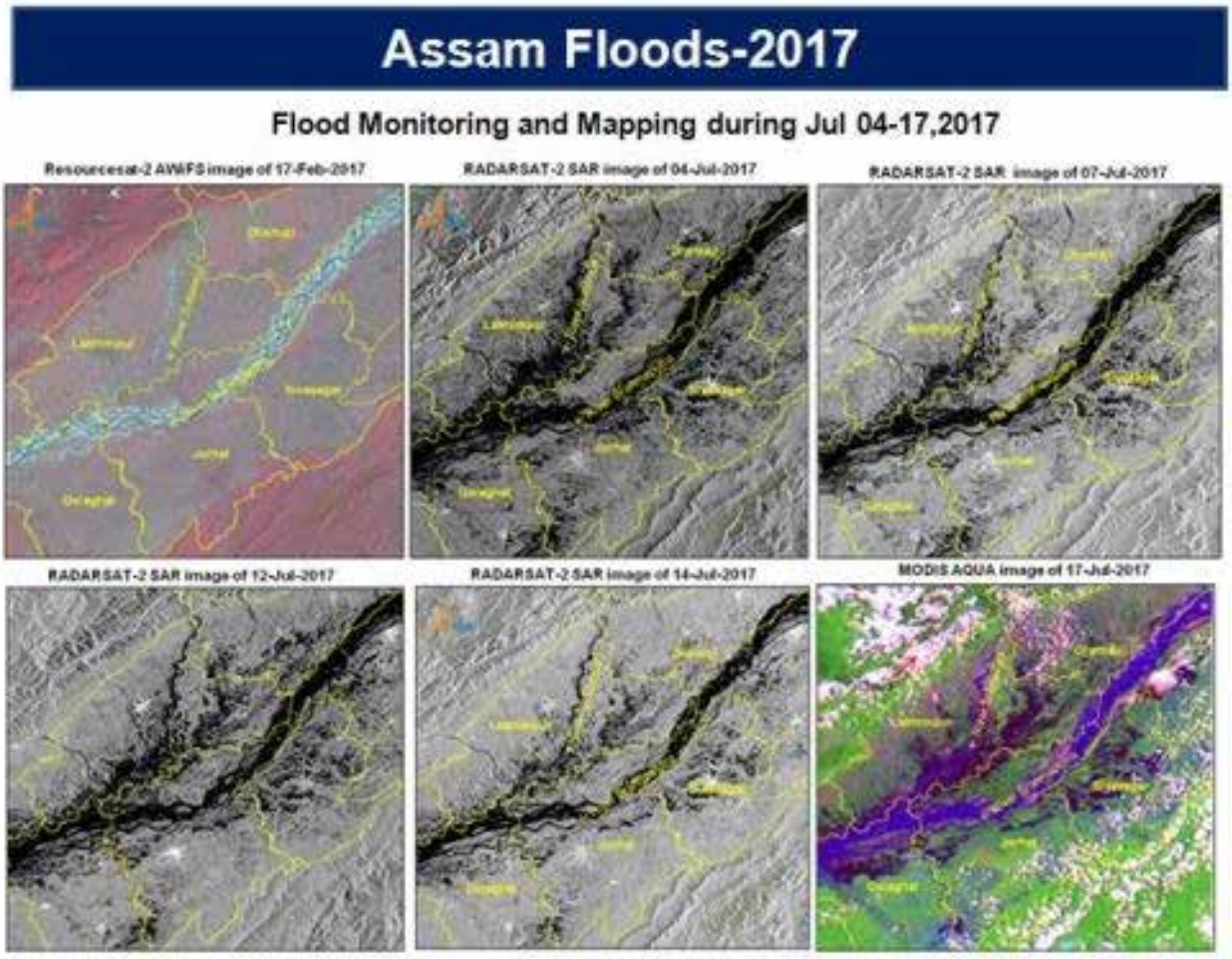
IMD has installed 682 Automatic Weather Stations (AWS) and other agencies have installed about 1200 AWS all over the country. IMD has also installed 1350 Automatic Rain Gauge (ARG) Stations. AWS and ARG services are operational by using the Data Relay Transponders (DRT) of INSAT-3D and INSAT-3DR for relay of Meteorological, Hydrological, Agro-Meteorological and Oceanographic data from unattended stations.

Space Application Centre, Ahmedabad has developed the Real Time Analysis, Product and Information Dissemination (RAPID) which is a web based quick visualisation and analysis tool for satellite data on a real-time basis and IMD has hosted it operationally, since January 2015. This introduces Next Generation Weather Data Access and Advanced Visualisation Application that touch the life of common man in one or other way ranging from weather events to atmospheric phenomenona. This has capability to visualise the fog presence over railway track and highways & a pilot can see the position of clouds and fog of the entire route on real time basis interactively.

3.5 Disaster Management Support (DMS) Programme

Under Disaster Management Support (DMS) Programme, ISRO is supporting the management of major disasters by providing space based data and information as well as communication services. The major disasters covered in this programme includes flood, earth quake, forest fire, land slide and cyclone.

Floods: During 2017, India witnessed major floods during June to September in eight states affecting more than 104 districts spread across the states namely Assam, Gujarat, Manipur, Bihar, Uttar Pradesh, Arunachal Pradesh, Odisha and West Bengal. All the major flood affected states were monitored using satellite data and about 100 maps were disseminated to the concerned departments. Assam state was worst affected by the four waves of floods during June to September. Bihar state witnessed severe floods during August and September months and during second week of August a section of railway tracks in East Champaran district was affected. High resolution data from RESOURCESAT-2 LISS IV FMx & LISS III were used for identifying the length of railway line affected and value-added maps of submerged railway tracks were generated. The inundation maps generated for all the flood affected states were disseminated to MHA, NDMA, IMD, CWC, State/Central Nodal departments and State Disaster Management Centres.



Forest Fires: During the fire season (February to June) every year, daily near real time fire alerts are generated in automated manner using satellite data. The turn-around time for production and dissemination is less than 30 minutes from completion of satellite overpass. The activity is carried out in collaboration with the Forest Survey of India. In 2017 fire season 32,546 active fire locations were generated.

Landslides: A massive landslide occurred on National Highway 154 (the road between Mandi and Pathankot) near the village of Kotropi, Mandi District, Himachal Pradesh on 13th of August, 2017. Analysis of Resourcesat-2 LISS-IV FMx (5.8 m) shows the occurrence of a large landslide in the area where an old landslide was observed in the pre-event satellite data. The landslide is a 'debris flow' type. It has a long runout which clearly suggests that the heavy rainfall is the main cause of its occurrence. The width of the landslide is 190 m and the run out length is 1155 m. Zones of accumulation and depletion and new drainage were mapped from Cartosat-2 Series Satellite data.

Landslide morphology of Katropi Landslide from Cartosat-2 Series Satellite data

National Database for Emergency Management (NDEM): NDEM has been implemented for all 36 States/UTs with multi-scale geo-spatial database covering base, thematic, infrastructure, and satellite imagery along with a set of customised decision support tools. In addition to these daily data, alerts/warnings from forecasting agencies were also integrated in the form of NDEM dashboard. The portal is equipped with near/real time disaster specific products along with satellite imageries. In order to enhance NDEM features and services, NDEM portal has been upgraded with advanced technology. The portal was officially launched by Honourable Home Minister, Shri Rajnath Singh on May 05. 2017 in the presence of Chairman, ISRO on National Platform for Disaster Risk Reduction (NPDRR) 2017 at Vigyan Bhavan, New Delhi. The portal is browser independent and compatible to all computer

devices and Mobile phones with high quality of vector rendering services. Further, NDEM services are customised to suit the requirements of National Disaster Response Force (NDRF) to provide technical support for disaster response, rescue and relief operations. The portal for NDRF was released by the Honourable Minister of State for Home, Shri Kiren Rijiju on January 31, 2017.

Release of NDRF Portal

International Support for Disaster Management: ISRO is a signatory of the International Charter 'Space and Major Disasters', which aims at providing a unified system of space data acquisition and delivery to users affected by disasters. Towards this, ISRO supports the provisions of charter as well as Sentinel Asia by planning acquisition of data from various Indian Remote Sensing Satellites and supplying the data at fastest possible time. In 2017, ISRO has supported 29 disasters across 22 countries by providing around 140 sets of IRS data. Through Sentinel Asia Programme, ISRO supported 16 disaster activations across nine Asia Pacific countries. In addition, NRSC has also analysed the worst floods of Sri Lanka during May 2017 using Resourcesat-2 AWiFS and LISS IV FMX data and assessed the approximate flood inundated area. The information generated was sent to the concerned for aiding relief and rescue measures.

3.6 Aerial Services & Digital Mapping

The Aerial Services and Digital Mapping (AS&DM) of National Remote Sensing Centre, Hyderabad is a unique facility that has end-to-end capability and state-of-the-art infrastructure for Aerial Remote Sensing that comprises of data acquisition of high resolution data (upto 5 cm GSD), ground survey, photogrammetric processing, generation of high resolution digital elevation model with vertical accuracy of 20 cm, fine contours of 0.4m and large Scale Mapping up to 1:500 scale. Major applications are sensor validation, urban planning and data for disaster events like floods, landslides etc.

NRSC owns and operates two Beech craft super King Air B200 aircraft, VT-EQK and VT-EBB which are being operated within the guidelines of DGCA and AAI to meet the regulatory requirements.

Projects

Testing and validation of Airborne X band mini SAR and L&S band SAR: The SAR sensors (X-Band Mini SAR and L&S band SAR) developed by SAC were installed in VT-EBB aircraft and test flights have been carried out from April 2017 onwards from Hyderabad and Ahmedabad airports. Data was acquired over 9 sites from Ahmedabad base.

ISRO-DMSP project: Geodatabase generation has been completed for 6300 sq.km suitable to generate large scale digital maps in 1:5000 scale with 50 cm contour interval required for Disaster Management Support Programme (DMSP). With the current batch of data, AS&DM completed generation of geodatabase targeted under phase-I of the project (66,239 sq.km).

INCOIS Phase II Mapping project - West coast of India: The study area is along west coast covering about 10000 sq. km extending from Cochin to Gujarat. Geodatabase is being generated for the data already acquired for 3412 sq. km using airborne laser scanner Digital camera (LSDC) system. The requirement of the project is to generate high resolution Digital Terrain Models (DTMs), Digital Ortho-images (50 cm ground sampling distance) and 2D large scale digital maps in 1: 5000 scale and height information with 1.0 m contour interval. Acquisition for the remaining area is planned in October-November 2017.

National Carbon Project (NCP): The project was intended for estimating above ground biomass of a tropical forest in India using LiDAR canopy volume profiles. LiDAR data acquisition was carried out over Yellapur forest area covering 387 sq. km, with 12-15 points per square meter as per the requirement of the biomass application. DSM/DTM is generated in tiff format with 1m point resolution after dividing the area into smaller sub blocks and subsequently tree statistical parameters have been derived.

2D Mapping for AMRUT project: Towards preparation of large scale geospatial maps at 1:4000 scale using high resolution satellite ortho images (50 cm GSD), three towns namely, Kochi, Alappuzha and Thrissur covering 400 sq. km have been mapped.

Large Scale Topographic Mapping from Cartosat-2 Series Satellite: Towards this a study on ortho rectification of Cartosat-2 Series data covering part of Bikaner, Rajasthan is carried out to evaluate the large scale mapping potential of Cartosat-2 Series satellite in terms of both accuracy and information content. Validation of mapping is carried out by two methods, namely, i) with a reference map of 1:2500 scale generated from aerial data. ii) through field measurements.

Accuracy analysis of Cartosat-2 Series merged data with field measurement shows that the error is less than 10%. 80% of features extracted from Cartosat-2 Seriesmerged data could match with aerial map scale 1:2500. Therefore, it can be concluded that using Cartosat-2 Series, a large scale topographic map of 1:4000 scale can be prepared.

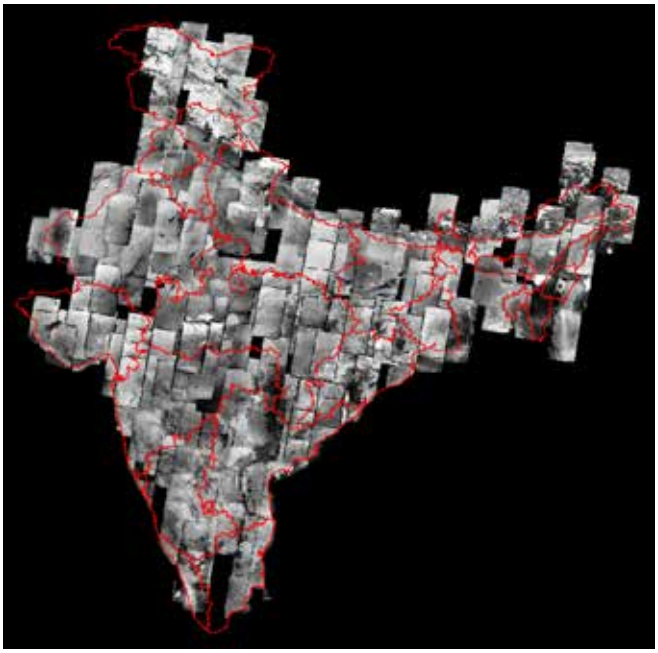
Cartosat-2 Series Event Video Monitoring (EVM-1) data / Multiview analysis

Digital Surface Model (DSM) is generated after extracting one frame for every 2 seconds and triangulating the same using GCPs (Geo Control Points). Automatic Digital Terrain Model (DTM) was generated from DSM and edited further to generate contours at 2m interval and orthoimage. Various features like buildings, roads, streams, etc. are captured in stereo mode. After validation with respect to aerial reference data of 20 cm GSD, the RMSE of building heights extracted from EVM-1 data has been estimated to be 1.8 m.

First Day Image of Cartosat-2 Series Satellite - Part of Indore

Generation of Historical Ortho Images from Corona dataset for India

Corona is a photo reconnaissance satellite program launched and operated by USA during 1960-1980 which acquired image data in high resolution over several parts of the world. This data was declassified in the years 1995 and 2002 for civilian use. Application of historical data has been presented for few areas with respect to mining, water bodies growth, and urban sprawl etc. Since the data is quite old, it is subjected to many distortions.



Ortho-rectified Corona data covering Indian Region

The images were corrected using the standard procedures. A total of 320 ortho images were generated covering entire India.

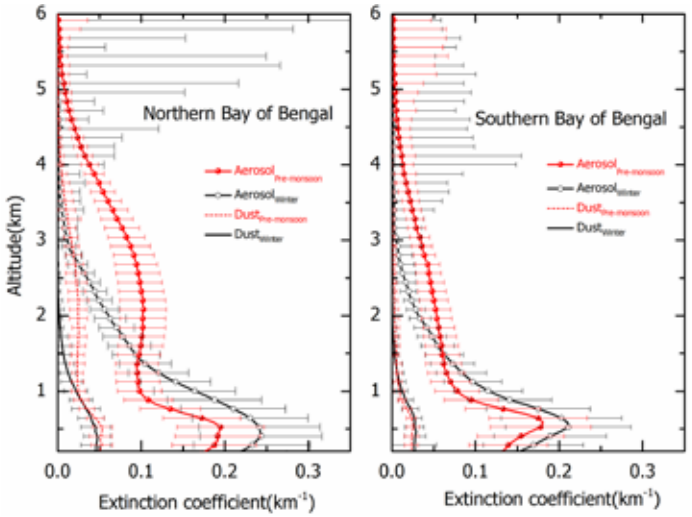
3.7 ISRO Geo-sphere Biosphere Programme (IGBP)

The major goal of IGBP is to study and understand the interactive physical, chemical and biological processes between Biosphere and Geo-sphere with particular reference to the potential impact of regional factors on climate system. It is important to understand the global interactions by studying the local and regional aspects such as impact of deforestations, aerosol loading in atmosphere and its radiative forcing and carbon sequestration in vegetation and soils.

The ongoing programmes include Climate Impact Assessment of Aerosols over India, 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) and Energy and Mass Exchange in Vegetative Systems. The participating ISRO/ DOS Centres are SPL, NRSC, IIRS and PRL. Around 70 partner institutions representing research centres and Universities across the country are also involved in these projects and contributing significantly towards ground based observations and data analysis.

The National Carbon Project (NCP) is implemented under seven inter-related sub-projects namely, (i) Spatial Assessment of Soil Carbon Dynamics (ii) Soil-Vegetation Atmosphere Fluxes Studies in Forest Ecosystem (iii) Vegetation Carbon Pools and Dynamics (iv) Assessment of Carbon and Moisture Fluxes over Agro-ecosystem (v) Coastal Carbon and Hydro / Geo Chemical Fluxes (vi) Regional Carbon Cycle Modeling and Simulation, and (vii) Atmospheric CO_2 Retrieval and Monitoring.

Under the project on 'Climate Impact assessment of aerosols over India', the vertical structure of aerosols and mineral dust over the Bay of Bengal from multi-satellite observations has been estimated. Bay of Bengal played an important role in the onset and progress of Indian monsoon through ocean – atmosphere coupling. The atmosphere over Bay of Bengal is more turbid compared to Arabian Sea and Indian Ocean. In this context, the vertical distribution of aerosol and dust extinction coefficient over the Bay of Bengal is examined using multi-satellite observations (Cloud Aerosol Lidar with Orthogonal Polarization (CALIOP) and Moderate Resolution Imaging Spectroradiometer (MODIS)) for the period from 2006 to 2017. Distinct seasonal pattern is observed in the vertical structure of both aerosol and dust over the Bay of Bengal with an enhancement of 24% in the aerosol extinction above 1 km from winter (December, January and February) to pre-monsoon (March, April, and May). Significant contribution of mineral dust is observed over the northern Bay of Bengal during pre-monsoon season where 22% of the total aerosol extinction is contributed by dust aerosols transported from the nearby continental regions. During winter, dust transport is found to be less significant with fractional contribution of ~10% to 13%to the total aerosol optical depth over the Bay of Bengal. MODIS derived dust fraction (fine-mode based) shows an overestimation up to 2 fold compared to CALIOP dust fraction (depolarization based) whereas the GOCART (chemical transport model) simulated dust fraction underestimates the satellite derived dust fractions over the Bay of Bengal. The long term variation in dust aerosol showed a decreasing trend over the Bay of Bengal. However, significant dust induced heating is observed above the atmospheric boundary layer during pre-monsoon season. This dust induced elevated heating during the pre-monsoon can affect the convection over the Bay of Bengal which will have implication on the monsoon dynamics over the Indian region.



Vertical profiles of total aerosol extinction coefficient and dust aerosol extinction coefficient over Bay of Bengal derived from the combination of data from space-borne LIDAR (CALIPSO) and MODIS.

3.8 Space Sciences and Planetary Research

The landmark Mars Orbiter Mission (MOM) has completed 3 years in Mars Orbit and is still providing appreciable data. AstroSat the first Indian multi-wavelength astronomy mission, has completed two years in orbit. It is operating as a space observatory and providing researchers both in India and abroad with excellent data. The Indian space programme is now gearing up for the next Lunar Mission Chandrayaan-2 and preliminary design review has been completed for the solar mission Aditya-L1.

Space science research activities at par with international scenario are continuously being pursued at premier research laboratories of ISRO/DOS, namely, Physical Research Laboratory (PRL), National Atmospheric Research Laboratory (NARL), and Space Physics Laboratory (SPL) at VSSC, Space Astronomy Group at ISAC. Feasibility studies are undertaken in several ISRO centres.

In order to expand the planetary science community, projects using MOM data and Chandrayaan-1 data have been funded. In addition, novel research projects in the field of atmospheric science, astronomy and planetary exploration are supported at various Universities and Research Institutes. Interested scientists from various Research Institutes are encouraged to undertake space instrument/payload development with ISRO funding support, based on the recommendations of Advisory Committee for Space Science (ADCOS).

The major activities carried out under space science and planetary research during the period of reporting is summarised in the following paragraphs:

3.8.1 Mars Orbiter Mission

MOM, the first interplanetary mission of ISRO, completed three years in its orbit on September 24, 2017 well beyond its designed mission life of six months. The Spacecraft is in good health and continues to work as expected.

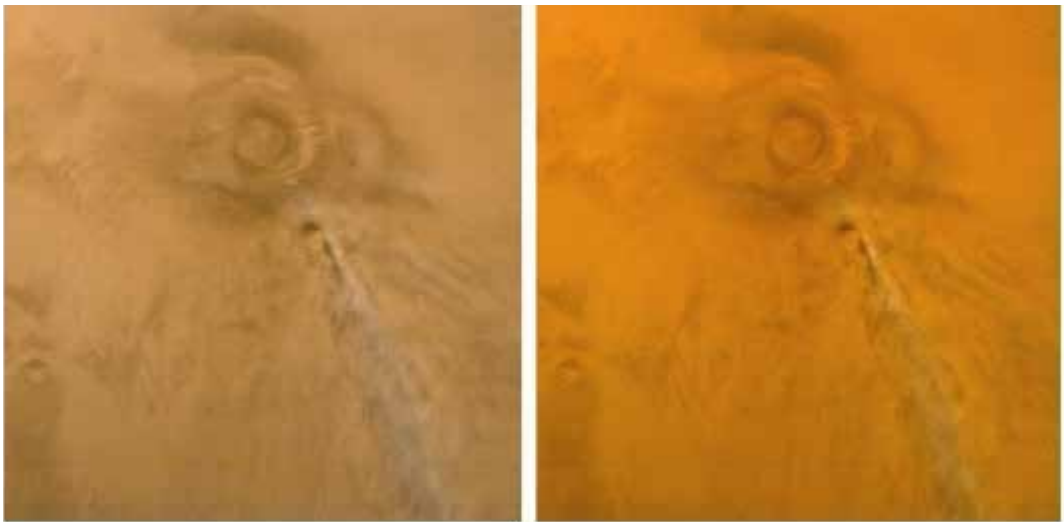
MOM would have encountered a long eclipse duration of 480 minutes from January 21, 2017 to February 06, 2017 and to avoid this, an Orbit Manoeuvre (OM) was carried out successfully on January 17, 2017. OM was necessitated due to the fact that MOM battery could not have supported eclipse duration of more than ~100 minutes. The MOM orbit was changed from 522 km x 70,992 km (before OM as per epoch on Jan 17, 2017) to 465 km x 70866 km (after OM epoch on Jan 30, 2017). Due to this OM, the total eclipse duration will not cross 90 minutes till 2021. MOM also successfully crossed second blackout (superior solar conjunction) in July 2017.

Scientific analysis of the data being received from the Mars Orbiter spacecraft is in progress. Twenty scientific papers have been published so far in peer reviewed journals. The Mars Colour Camera, one of the scientific payloads onboard MOM, has produced more than 900 images so far.

Global image of Mars taken on Oct 8, 2017 at an altitude of 70,157 km

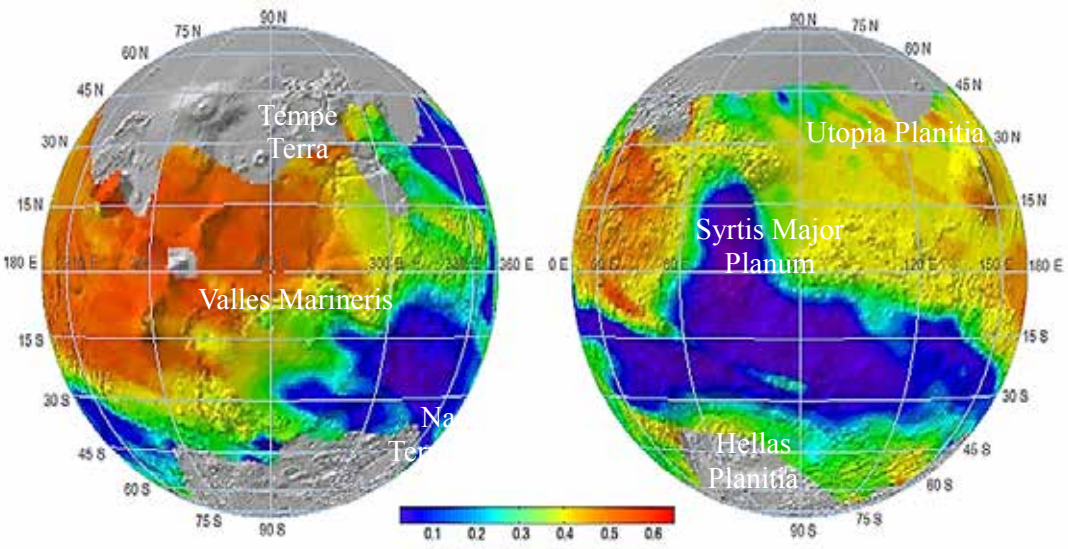
Sabaeus quadrangle of Mars imaged on May 27, 2017 at an altitude of 4,406 km.

MCC makes use of a Bayer pattern detector. Spectral response of RGB (Red, Green and Blue) pixels of Bayer detector showed large overlap which reduced the spectral information content of the image. Scientists at ISRO developed a method to correct the MCC data for spectral overlap. It was shown that correction process significantly increased the spectral information content of the image and enhanced the ability of the sensor to identify different target types like dust clouds and water ice clouds. The following figure shows the image before and after overlap correction.



Composite Image of Arsia Mons before and after overlap correction

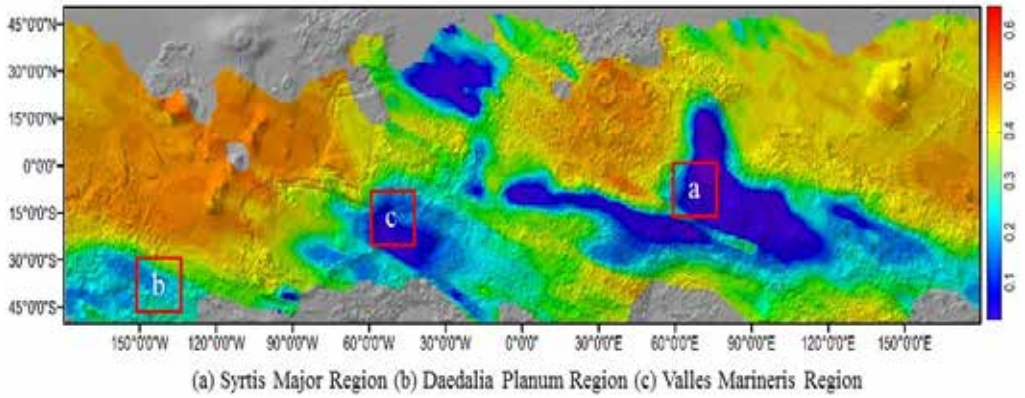
Global apparent Short Wave Infrared (SWIR) (1.64 – 1.66μm) albedo mapping results from data acquired by Methane Sensor for Mars (MSM) on-board MOM were prepared.



The one pixel per degree binned global MSM SWIR (1.65 m) albedo map over MOLA map.

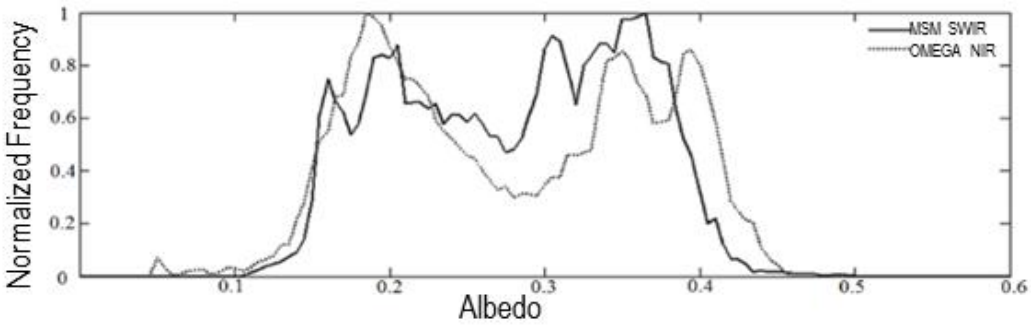
The occurrence frequency of MSM apparent SWIR albedo showed a clear bimodal behaviour and is in good agreement with OMEGA NIR albedo distribution. Based on MSM apparent SWIR albedo values,

three classes (high, intermediate and low albedo values) are defined, which show a clear elevation dependency. Variation of weekly average apparent albedo during the study period (October 2014 to February 2015) over Syrtis Major, Daedalia Planum and Valles Marineris region respectively were studied.

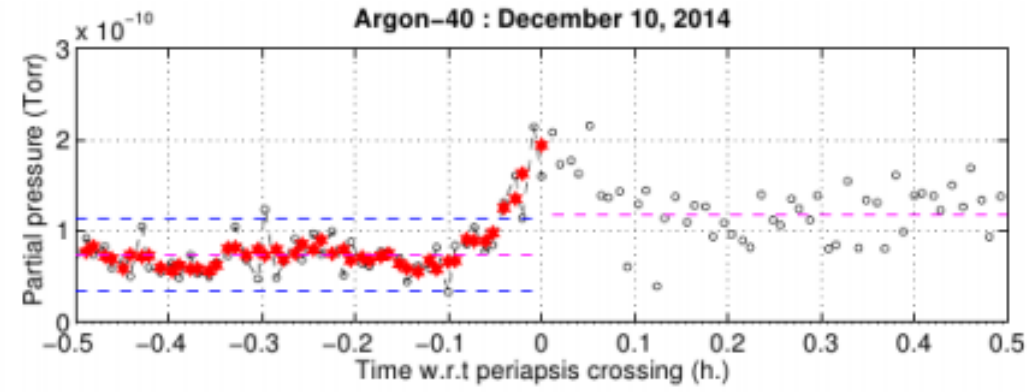


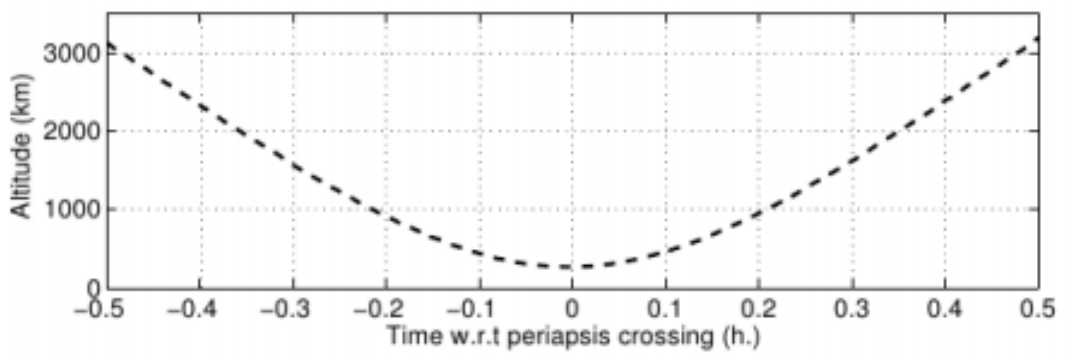
(a) Syrtis Major Region (b) Daedalia Planum Region (c) Valles Marineris Region

The MSM SWIR albedo map over MOLA background used for histogram analysis (as in the figure shown below) and for comparison with OMEGA NIR albedo map.



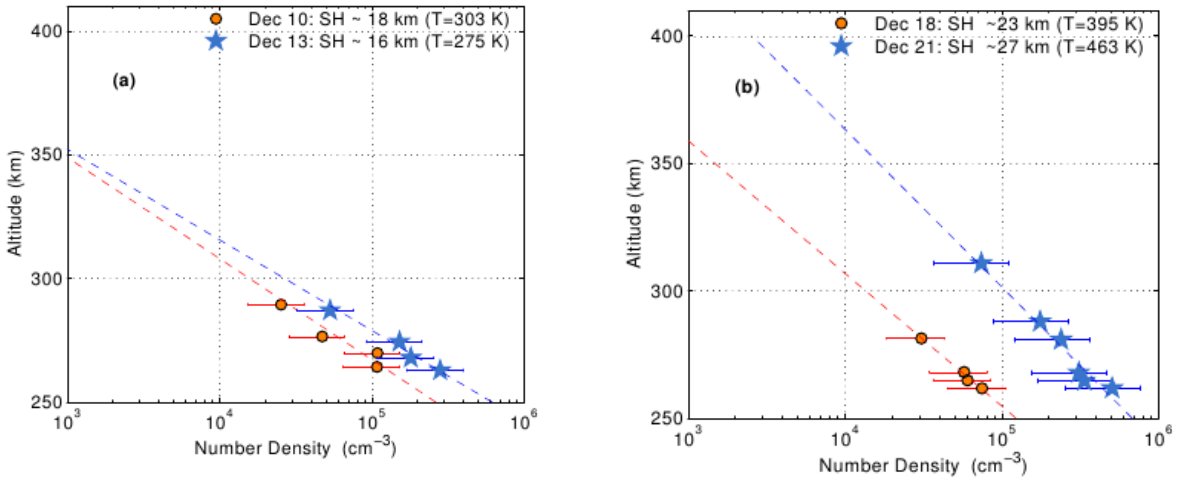
The outermost region of a planetary atmosphere, called the exosphere, is the region being explored in-situ by MENCA (Mars Exospheric Neutral Composition Analyser) experiment aboard the Mars Orbiter Mission (MOM). MENCA has discovered the presence of suprathermal Argon atoms. The altitude variation of argon-40 (Ar) in the Martian exosphere were obtained using MENCA during December 2014 when MOM's periapsis altitude was the lowest. An example of such an observation is shown in the following figure.





Temporal variation of the partial pressure of Ar observed by MENCA. This corresponds to the observation on December 10, 2014 (Ls= 250^0). The time in the x-axis is given in hours with respect to the time of the periapsis crossing. The black circles represent the observed amu 40 spectral data points. The red stars represent the data points after a smoothing using 3-. The mean background levels of the inbound and outbound legs are shown with pink dashed lines. The corresponding altitude variation is shown in the bottom panel.

The upper limit of Ar number density corresponding to this period is ~5 x 10^5 cm^{-3} (250 km), and the typical scale height is ~16 km, corresponding to an exospheric temperature of ~275 K. However, on two orbits, the scale height over this altitude region is found to increase significantly making the effective temperature >400 K (see the following figure).



Altitude variation of the number density of Ar corresponding to four different orbits. (a) 2014 December 10 and 13, (b) 2014 December 18 and 21. The error-bars represent 40% uncertainty level. SH is the scale height and T is the exospheric temperature derived from scale height.

These observations indicate significant suprathermal CO_2 and Ar populations in the Martian exosphere. Neutral Gas and Ion Mass Spectrometer observations on the Mars Atmosphere and Volatile Evolution (MAVEN) mission also indicate that such suprathermal atoms are present on certain days and significant wave-like perturbations are observed only on certain days when suprathermal population is seen. Pickup ion-induced heating is discussed as the other viable source.

The discovery has important implications in the context of understanding the energy deposition in the Martian upper atmosphere, and will help understand why the Martian atmospheric escape rates are higher than what was believed previously.

3.8.1a Science Meet of MOM

A 'MOM Science Meet' was conducted at ISRO HQ on September 25, 2017 on the occasion of three years completion of MOM in Martian orbit on September 24, 2017. The second year data of MOM (Sept 24, 2015 to Sept 23, 2016) was released to public through ISSDC website.

The inaugural session was followed by presentations by payload teams and by project leads/members of the funded projects, which were reviewed by the review committees.

3.8.2 AstroSat Mission

AstroSat, the first Indian Multi-wavelength space astronomy mission, completed two years in orbit on September 28, 2017.

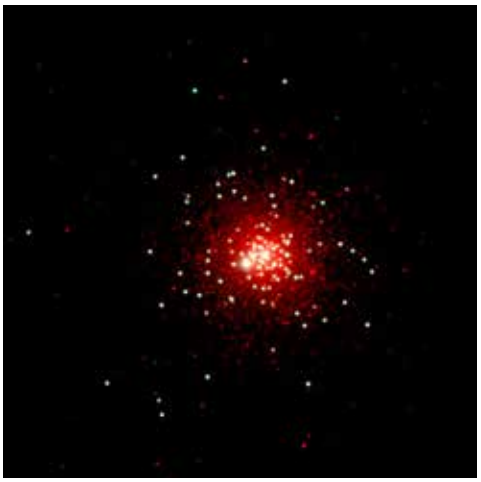
A unique feature of AstroSat mission is that it enables simultaneous multi-wavelength observations (optical, UV and X-rays) of various astronomical objects with a single satellite.

The satellite is being operated as an "Observatory", in which observing time is allotted based on the proposals received from interested researchers and scientists in the country through ISRO's Announcements of Opportunity (AO). From October 2017, the observatory is open to Indian and International Astronomy Community.

Some salient science highlights from AstroSat payloads are provided below:

Ultraviolet Imaging Telescope (UVIT) imaged hot stars, evolved stars, planetary nebulae, star clusters, star-forming galaxies, active galactic nuclei, cluster of galaxies and star formation history in the distant universe.

False colour composite image of WLM galaxy where FUV and NUV are displayed in blue and yellow colours respectively

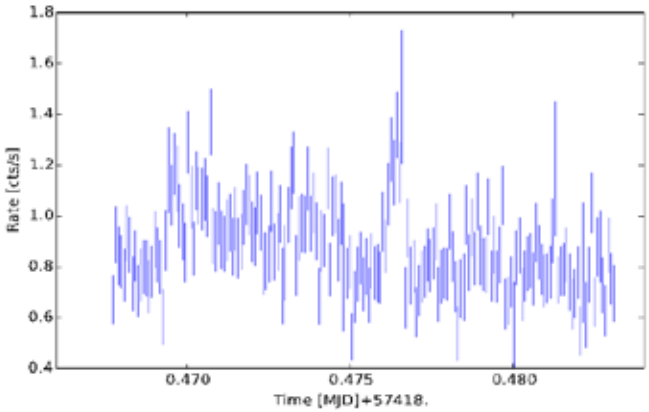


Colour composite image of NGC 1851 in which Blue and Red colors are UVIT images in FUV and NUV filters.

Wolf-Lundmark-Melotte, or WLM is a faint dwarf galaxy, located in the constellation Cetus which is three million light years away. Though it has low mass and less metallicity, WLM forms stars at a rate that is 12 times higher than our own Milky Way. The blue dots are the star clusters imaged in Far Ultra-Violet (130-180 nm) and the yellow dots are those imaged in Near UltraViolet (180-300 nm).

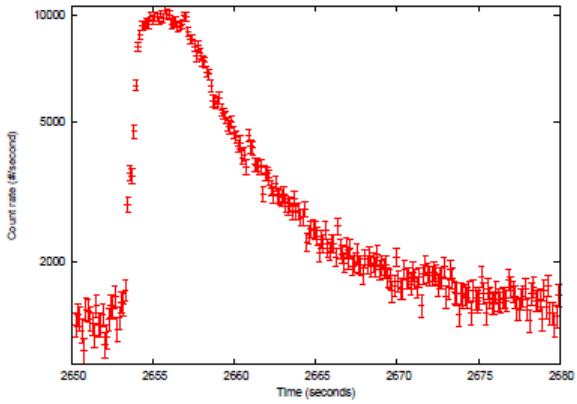
NGC 1851 is a globular cluster located in the southern constellation of Columba. It appears to be surrounded by a diffuse stellar halo extending to radii of ~250 pc. 300 stars were detected in FUV and 2300 stars in NUV.

Soft X-ray Telescope (SXT) has observed a variety of objects ranging from nearby active stars, X-ray binaries, supernova remnants to many types of distant active galaxies and clusters of galaxies. The X-ray light curve of a very rapidly rotating nearby active star known as AB Dor in the energy band 0.3 – 7.0 keV is shown below. A lot of flaring activity is observed which corresponds to the rapid rotation of the star.



X-ray Flaring Activity of AB DOR

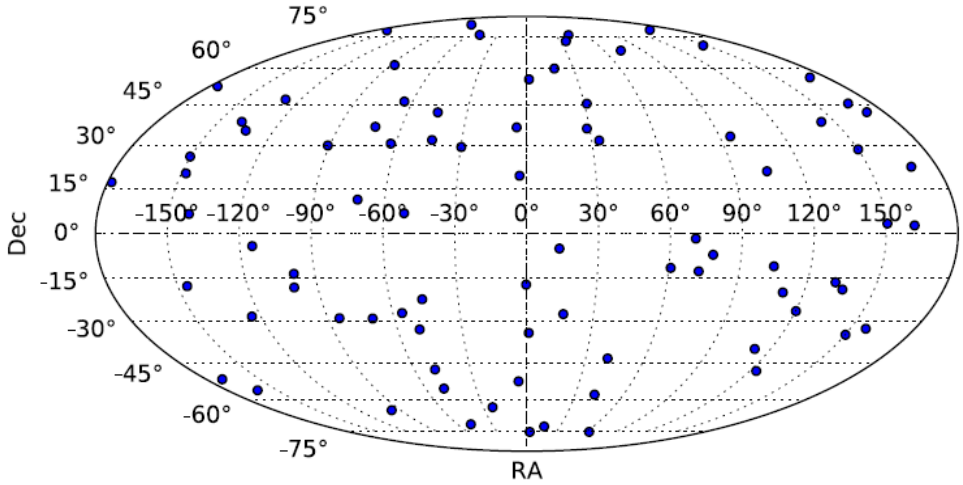
Large Area X-ray Proportional Counter (LAXPC) detected both kinds of milli-second variability-kHz Quasi-Periodic Oscillation (QPO) and Burst Oscillation (BO) in the low mass X-ray binary (LMXB) 4U 1728-34, from a single ~ 3 ksec observation, for the first time.



Light curve of the Type I X-ray burst observed in 4U 1728-34 in the energy range 3-20 keV. The time bin is 0.128 second.

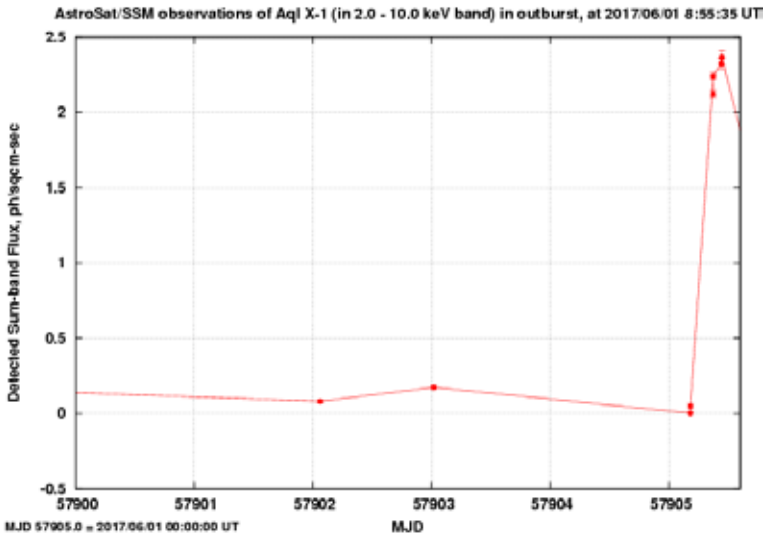
Burst Oscillations are periodic fluctuations observed during the X-ray burst, which infer the spin period of the Neutron Star. The type-1 burst profile is typical with a fast rise and slower decay lasting for ~20 seconds. The frequencies range from ~361.5 to ~363.5 Hz.

Cadmium Zinc Telluride Imager (CZTI) has detected over 100 Gamma Ray Bursts (GRBs). It has demonstrated capability to detect polarisation in GRBs and Crab Nebula. CZTI team searched for X-ray counterparts to the third gravitational wave source GW170104. The speculated optical transient of this gravitational wave event was indeed identified to be corresponding to a GRB event GRB 170105A and not the gravitational wave event.



GRBs detected by CZTI from Oct 10, 2015 to Jan 27, 2017

Scanning Sky Monitor (SSM) has detected Aql X-1, a neutron star Low mass X-ray binary in its outburst on June 01, 2017 at 08:55 UT. It has been reported as Atel # 10452.



Source was in softer state while rising phase of the outburst. Observations are consistent with Optical/ IR and enhanced hard X-ray activities.

3.8.3 Chandrayaan-2 Mission

Chandrayaan-2, India's second mission to the Moon is a totally indigenous mission comprising an Orbiter, Lander and Rover. After reaching the 100 km lunar orbit, the Lander housing the Rover will separate from the Orbiter. After a controlled descent, the Lander will soft land on the lunar surface at a specified site and deploy a Rover.

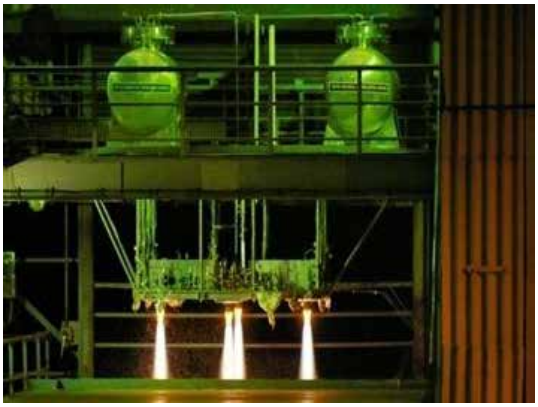
The mission will carry a six-wheeled Rover which will move around the landing site in semi-autonomous mode as decided by the ground commands. The instruments on the rover will observe the lunar surface and send back data, which will be useful for analysis of the lunar soil.

The payloads will collect scientific information on lunar topography. mineralogy, elemental abundance, lunar exosphere and signatures of hydroxyl and water-ice.

Orbiter: Majority of bus elements have been integrated and tested in the orbiter. Dis-Assembled mode testing in integration is in progress. Integration of propulsion elements is completed. Payloads from various centres are in advanced stages of realisation.

Orbiter during Integration

Lander: Realisation of flight model of Lander Structure is in progress. Engineering models of sensors have been realised and tested during the Lander Sensor Performance Test (LSPT) phase-1 and 2. System Demonstration Module (SDM) was realised and performance of Lander propulsion system with throttlable engines was successfully demonstrated. Preparations for Lander Actuator Performance Test (LAPT) are in the final stages.



SDM Tests Lander Leg Drop Test

Rover: All the flight systems are in advanced stage of realisation. Mobility tests to evaluate the Rover's wheel – soil interaction have been completed. All the mobility related constraints with respect to slope, boulder size etc have been verified. Rover Qualification Model (QM) integration is in progress and majority of the subsystems are delivered.

Rover Mobility tests

3.8.4 Aditya-L1 Mission

Aditya-L1 can provide observations on the solar corona and in addition can provide observations on the solar chromosphere using an UV payload and on the photosphere and flares using X-ray payload. These payloads taken together are expected to provide a comprehensive understanding of how solar flares originate and propagate. In addition, the charged particle detectors and the magnetometer payloads can provide information on in-situ charged particles and the magnetic field which emanate from the eruptive events. To enable this, the Aditya-L1 spacecraft is to be placed in a halo orbit around the Sun-Earth Lagrangian point 1 (L1) which is about 1.5 million km from the Earth.

Preliminary Design Review including payloads has been completed. Spacecraft configuration, thermal analysis, payload interfaces and mounting locations have been finalised.

3.8.5 X-ray Polarimeter Satellite (XPoSat) Mission

The X-ray Polarimeter Satellite (XPoSat) mission is the dedicated mission for polarisation studies. Polarimeter Instrument in X-rays (POLIX) payload will study the degree and angle of polarisation of bright X-ray sources in the energy range 5-30 keV. Payload development is in progress at Raman Research Institute (RRI), Bengaluru.

Preliminary Design Review document, Ground and in-flight calibration plan have been prepared. Payload accommodation studies and interfaces with the satellite have been studied. Mechanical analysis of the

four detector system, including the collimator, has been carried out and the installation of X-ray beam line for collimator calibration is under progress. Mechanical vibration test has been carried out for one detector and a thermovac test has been carried out for one High Voltage unit.

3.8.6 Payload selection for future Mars Orbiter Mission (MOM-2)

Expert committees constituted by ISRO reviewed the proposals received against the announcement of opportunity for developing scientific payloads for the future Mars orbiter mission. The committee selected a dozen scientific payloads for development and the mission will be focusing more on science in order to study in depth on the Martian surface, atmospheric / exospheric and ionospheric features. Configuration study of the satellite to accommodate the selected payloads is under progress.

3.8.7 Short listing of payloads for future Venus Mission

The selection process for finalising the scientific payloads for the future Venus Mission is underway. The expert committee has reviewed the proposals received against the announcement of opportunity for developing scientific payloads and short-listed few proposals for the final selection.

3.8.8 Expanding Planetary Scientific community

ISRO has been supporting twenty-eight MOM Announcement of Opportunity (AO) projects and nineteen Chandrayaan-1 AO projects centered at various academic institutes (IIT/NIT/Universities/other Institutes) since 2016. The main objective of supporting these projects is to expand and strengthen national scientific community, which can have access to and analyse the planetary/lunar data.

3.8.9 Research Activities in Space Sciences

Some of the important studies during this year are as follows:

1. The Aditya-L1 Solar wind Particle Experiment (ASPEX) payload developed by PRL consists of two independent packages, namely, Solar wind Ion Spectrometer (SWIS) and Supra thermal and Energetic Particle Spectrometer (STEPS). While SWIS will have the capability to measure solar wind particles in the energy range of 100 eV to 20 keV in the plane of the ecliptic and normal to the plane of the ecliptic, the STEPS package will measure the particle flux in the 20 keV - 5 MeV energy range in the sunward, anti sunward, Parker and ecliptic north and south directions.

2. The equatorial upper atmospheric dynamic processes show both latitudinal and longitudinal variabilities. While the variability in latitudes can exist over small distances (~100s of km), the longitudinal behaviour has been shown to be present mainly over large spatial separations (~1000s of km). From the observed variations in thermospheric optical day-glow emissions at OI 557.7, 630.0, and 777.4 nm from Hyderabad, a low-latitude location, we have shown for the first time that longitudinal differences in upper atmospheric processes do exist in as small as 3° longitude separations. These are attributed to the zonal variation in the drivers of daytime equatorial electrodynamics.

3. Response to the variations of solar flux in the thermosphere is expected; however, based on over three years of mesospheric OH and O_2 optical nightglow emission data from Gurushikhar, Mt Abu, it is shown that mesosphere too is affected by the variation in solar flux. This solar influence on OH and O_2 emissions emanates from the requirement of O and O_3 concentrations as reactants for their production, which are known to be solar activity dependent.

4. Black Carbon (BC) aerosol loading produces a large radiative impact on climate. For the first time, using simultaneous measurements over a 2-year period, the spatial and temporal variability in BC mass concentration are investigated over two distinct locations in western India, namely, Ahmedabad (urban industrialised location, 55 m above mean sea level) and Gurushikhar (high altitude remote site, 1680 m above mean sea level). The observed BC mass concentrations at Ahmedabad are about a factor of 4-higher than Gurushikhar values. The BC maximum at Gurushikhar corresponds to the BC minimum observed at Ahmedabad, due to the significant effect of the diurnal evolution of atmospheric boundary layer. During the sunlit time, the Earth's surface gets heated which increases the surface temperature resulting in the transport of pollutants from the foothills to the observational location which is in the free troposphere. Gurushikhar BC values can be considered as the representative of the regional background values for the western Indian region. The study highlights the significant role the atmospheric dynamics plays in modulating the BC levels in different locations.

5. Analysis of vertical profile of O_3 and carbon monoxide (CO) over the southern region of India reveal a significant impact of ENSO conditions such as El Nino and La Nina. This analysis shows that the events of a tropical cyclone and deep convection over the Bay of Bengal had a significant impact on the vertical distribution of tropospheric O_3 and CO.

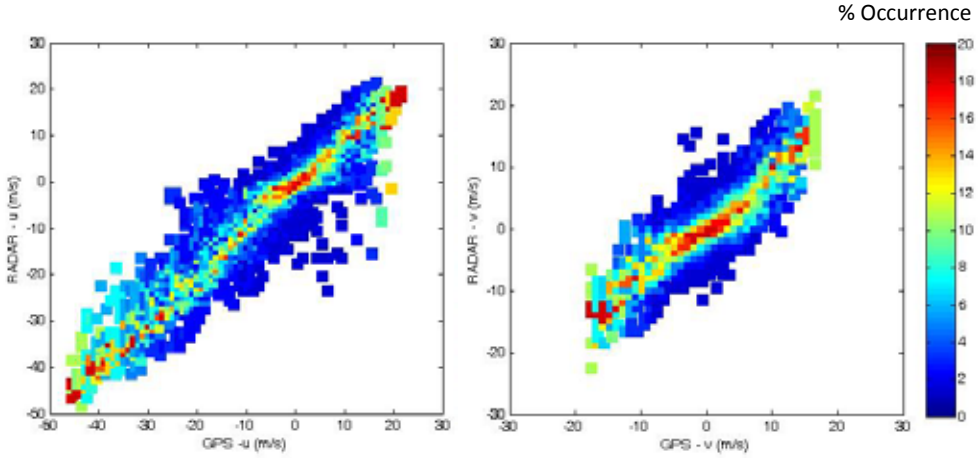
6. The CZT-Imager of AstroSat is the first satellite borne instrument in last four decades which is capable of measuring hard X-ray polarisation and was calibrated on the ground with both polarised and more importantly unpolarised X-rays. During first 18 months, AstroSat observed the Crab nebula and pulsar for 21 times resulting in the net effective exposure of 800 ks. This yielded the most sensitive hard X-ray polarisation measurement of the Crab in 100 to 380 keV energy range, with measured polarisation fraction of 32.7 ± 5.8% and polarisation angle of 143.5 ± 2.8° NE. While this is a tremendous improvement over the previous measurement by INTEGRAL, a major break-through coming from the AstroSat-CZTI observations is the measurement of polarisation as a function of pulse phase. Such phase resolved polarisation measurement is very important to understand the magnetosphere geometry close to the pulsar as well as the mechanism and site of the acceleration of high energy particles leading to the high energy emission from the pulsar. This is the first observation of such variation and no present pulsar emission models can explain this variation.

7. It is known that the solar corona - the outermost layer of the sun's atmosphere - is roughly 100 times hotter than its photosphere - the sun's visible layer. Considering that chaotically tangled magnetic field lines exist throughout astrophysical plasmas, based on high-performance computer simulation an attempt has been made to understand the role of chaotic field lines in

coronal heating. Specifically, the conditions that create ribbons of intense electric current, known as current sheets have been examined, which are known to be potential sites for magnetic reconnections, and therefore responsible for the extreme heating of the corona.

8. Gravitational waves propagate through ideal fluids without experiencing any dispersion or dissipation. However, if the medium has a nonzero shear viscosity, gravitational waves will be dissipated. The dark matter and dark energy models are with nonzero shear viscosity are constrained by calculating the dissipation of gravitational waves from GW150914 which propagate over a distance of 410 Mpc through the dissipative fluid and comparing the data with the theoretical prediction. This provides a proof-of-principle demonstration of the fact that future observations of gravitational waves at LIGO have the potential of better constraining the viscosity of dark matter and dark energy.

9. The MST radar has been upgraded into a full-fledged active phased array system having 1024 independent Transmit/Receive modules. Capability of the new system to probe different regions of the atmosphere - troposphere, stratosphere, mesosphere and ionosphere has been successfully demonstrated. Comparison of wind speeds using Doppler Beam Swinging technique with that of GPS balloon (as shown in the figure below) has been found to be good.



Comparison of MST radar and GPS balloon winds a) Zonal wind and b) Meridional wind

10. The development of payloads for Chandrayaan-2 Mission (Chandrayaan Atmospheric Composition Explorer (CHACE-2), Chandrayaan Surface Thermophysical Experiment (ChaSTE) and Radio Anatomy of Moon Bound Hyper-Sensitive Atmosphere and Ionosphere (RAMBHA) is progressing and characterisations of these payloads are being carried out. The Engineering models of these payloads have been developed and the Qualification and Flight models are nearing completion. Similarly, the development of the payload for Aditya-L1 mission and Plasma Analyser Package for Aditya (PAPA), has been progressing as per schedule and the engineering model is nearing completion.

11. Long-term trend in atmospheric methane content over the Indian region is estimated from SCIAMACHY observations. These are validated against the observation at global hotspots besides validating the model simulations of spatio-temporal variability of different trace gases (O_3, CO and CH_4) over the Bay of Bengal using WRF Chem model and observations.

Experimental setup for thermo-physical characterisation of ChaSTE and CHACE-2 probes

12. The newly commissioned C-band polarimetric radar at TERLS Thumba, is being evaluated against disdrometer observations. The radar reflectivity and radial velocity from the radar are being assimilated into mesoscale weather models for thunderstorm prediction and capture of deep convective events.

13. The versatility as an in-situ probe, and potential as a satellite payload, of the indigenously developed 'Ionization Density and Electric Field (IDEA)' probe - a suite of three probes namely a Langmuir Probe, Magnetic field probe, and Drift probe flown onboard PSLV-C38 on a short mission was amply demonstrated, as it successfully measured the ionospheric parameters.

Sensors used in the IDEA payload flown on PSLV-C38

3.8.10 ISRO's Space Science Promotion Scheme: ISRO-SSPS

The basic aim of this scheme is to strengthen the research activities in Space Science in Universities. ISRO-SSPS aims to meet the demand/requirement of high quality human resources for the growth of space science activities and to address the issue of attracting more faculty and students' participation in space science research at national level. Seven Universities are being supported under the phase-II activities of this scheme.

Funding support consists of the recurring grant for a period of five years which includes the M.Sc/M.Tech fellowship to meritorious students and honorarium and travel support to guest faculty.

3.8.11 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. In 2017, the International Olympiad in Astronomy and Astrophysics was held at Thailand during November 12-21.

As a part of the Astronomy Olympiad programme, yearly winter camps have been introduced for the past Olympiad students. The camp is organized at different astronomical research institutes where the students work on projects to gain some insight into Astronomy research. IIST, Thiruvananthapuram hosted the 12th Astronomy Nurture Camp during Dec 10-20, 2017.

4.0 Capacity Building

4.1 Introduction

Capacity building is an intense activity closely linked to development of human capabilities to perform functions and processes for realisation of goals, establishment of infrastructure for ensured throughput, strategies for achieving targets and mobilisation of resources. The capacity building activity is an essential requirement for managing transformations in all fields.

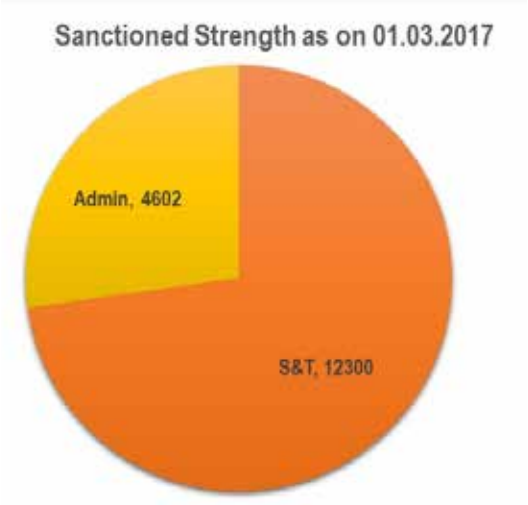
To cater to the increased demand in the current areas of space-based applications, including supporting a few national flagship programmes of Government of India, it is required to increase the number of satellites and launch vehicles.

Towards meeting the set goals, the organisational capabilities will have to be enhanced in tune with the increased level of operation. A host of new developments in fields of space transportation, space infrastructure, space applications and scientific exploration are contemplated. ISRO is developing systematic capacity enhancement plans at individual, organisational, institutional, industrial and user / community levels.

4.2 Human Resources Capacity Enhancement

4.2.1 Internal Resources

The total approved sanctioned strength of the department as on 01.03.2017 was 16,902, out of which 12,300 are in Scientific and Technical (S&T) category and 4602 is under administrative category.



Proposals for phased augmentation of human resources for DOS/ISRO Centres/Units, in tune with the programmatic targets laid down, is under process.

The existing welfare measures such are housing, medical, canteen, schooling for children, etc., are extended to the employees of ISRO under various approved institutional schemes. Life insurance coverage from accidents in the work place is provided to the employees by schemes such as VISWAS and SAFE, a special scheme for assistance to families in exigency, at a relatively low premium through internal trusts.

Key importance is laid to the competency requirements of the individuals, required for contributing effectively and efficiently towards the realisation of the organisational goals and resulting achievements. Hence, stringent recruitment process is adopted to ensure that quality personnel are inducted into the system and greater importance is attached towards continuous development of the human resources periodically in tune with the programmatic requirements.

Centralised recruitment of Scientist/Engineers with degree in engineering is continued during the year. Online applications are invited through ISRO website and selections/inductions are completed through the process of written test and interview on an all India basis. Also, Centralised recruitment process is continued for the recruitment of Officers in Administrative area, Office Assistants and Junior Personal Assistants during the year. Further, specialised recruitments, based on the requirements of the Centres, are made by respective Centres/Units.

In order to induct quality manpower into the system, the campus recruitments at IITs has been revived and selections are under process.

ISRO/DOS has been absorbing graduates from the Indian Institute of Space Science and Technology (IIST) on successful completion of the B.Tech programme, meeting the benchmark set. The sixth batch of students, who were admitted to B. Tech during September 2013 at IIST have graduated during June 2017. A total of 101 eligible students were inducted in all ISRO/DOS Centres/Units.

ISRO has established a scheme of 'Live Register', wherein a PG degree holder from foreign academic institution with minimum of two years of research experience in scientific and technical areas relevant to space and a PhD holder in specialised areas of studies in engineering/technology/science relevant to the Indian Space programme can submit their dossiers to ISRO. The candidature is reviewed depending on the suitability and recommendations of Centres. Till date, opportunity has been extended to more than 200 candidates.

4.2.1.1 Internal Training

Training and Development activities are envisaged through both Centralised and Decentralised systems. The scheme of Centralised Induction Training Programme for newly joined scientists/engineers, introduced during 2002, is being continued. The training programme is aimed at introducing the newly recruited engineers to the ISRO systems by providing necessary exposure to the ISRO programmes, achievements, rules, regulations, systems, processes, etc. Similar Centralised Induction Training programmes are being Provided to Office Assistants and Junior Personal Assistants in Administrative areas, conducted by different Centres/Units on a rotational basis.

All the officers in Purchase and Stores area have been sponsored for a specialised training programmes at National Institute of Financial Management, Faridabad on Public Procurement Policies.

Customised, exclusive management development training programmes for middle level S&T personnel were organised at Administrative Staff College of India (ASCI), in three batches of 25 each.

Annual calendar is drawn for organising Centralised Structured Training Programmes (STPs) to deal with the training on core technical subjects. Middle level engineers from various Centres engaged in relevant activities are training through these STPs organised by the different Centres, as per the annual STP calendar.

Space Studies Programme (SSP) 2017 for young Scientists/Engineers organised by International Space University (ISU) at Cork Institute of Technology, Ireland during June-August, 2017 was continued during the year and six Scientists/Engineers from different Centres/Units attended the programme. Additionally, ISRO participated in the Southern Hemisphere Space Studies Programme, an abridge version of SSP of ISU during 2017 and three Scientists/Engineers from different Centres/Units attended the programme during January-February 2017.

As a part of executive training, senior executives were trained at Indian Institute of Management, Ahmedabad (IIM-A). As the need of the hour, in order to strength in the cyber and network security, training programmes and workshops on Cyber Security and ethical hacking were organised for officials from across the Centres involved in ensuring IT security.

Based on the functional and specialised requirements, decentralised training programmes are administered at respective Centres/Units of ISRO/DOS at various intervals.

4.2.1.2 Apprentice Training

Under the Apprentices Act, 1961, training has been imparted to 3,226 apprentices in Centres/Units of the Department in the Technical and Commercial Trades.

4.2.1.3 Reservation in Services

a) 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.

b) Differently Abled Persons

Position regarding appointed Differently Abled Persons is given in Table - II

c) Ex-Servicemen

The status of representation of Ex-servicemen is given in Table – III

d) Other Backward Classes (OBCs)

3,922 persons belonging to Other Backward Classes are employed at present. Out of this, 152 persons have been appointed during the year.

4.2.1.4 Women Employees

There are 1,978 Women Employees in the Scientific and Technical categories and 1,210 Women Employees in Administrative categories in the Department as per the details given in Table - IV. They represent nearly 20% of personnel in the Department.

4.2.1.5 Joint Consultative Machinery (JCM)

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

4.2.1.6 Conferences and Workshops

a) National Conference for ISRO Women Employees

National Conference for ISRO Women Employees was organised at ISRO Satellite Centre (ISAC) at Bengaluru during March 2017. Women employees from various ISRO/DOS 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 Harmony and Peace'. As part of the celebrations, a mass yoga practice/ demonstration was organised in ISRO/DOS establishments.

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

The 126th Birth Anniversary of Bharat Ratna Dr. Bhimrao Ramji Ambedkar was celebrated in DOS/ISRO establishments in 2017.

Table - I: Status Of Scheduled Caste / Scheduled Tribe Personnel

Sl.No	Centre / Unit	Total Strength of Employees 2017-18	Strength of SC Employees 2017-2018	Strength of ST Employees 2017 -2018
1	DOS / ISRO HQ	393	54	21
2	VSSC	4467	344	66
3	ISAC	2538	287	94
4	SDSC-SHAR	1971	308	122
5	SAC & DECU	1977	182	125
6	LPSC	1211	135	25
7	NRSC	834	102	35
8	ISTRAC	434	67	14
9	MCF	318	40	16
10	ADRIN	162	19	5
11	IIRS	113	13	5
12	PRL	233	9	1
13	SCL	585	108	6
14	NARL	63	9	1
15	NESAC	40	2	4
16	IIST	97	3	0
17	IPRC	636	132	10
TOTAL		**16072**	**1814**	**550**

Table - II: Status of Differently Abled Persons

Sl. No	Centre / Unit	Total Strength of Employees 2017-2018	Strength of Differently Abled Persons	Classification of Employees with Disabilities			
				Deaf & Dumb	Blind	Partially Blind	Orthopedically Handicapped
1	DOS / ISRO HQ	393	8	0	0	1	7
2	VSSC	4467	100	20	0	12	68
3	ISAC	2538	63	13	7	1	42
4	SDSC-SHAR	1971	48	2	2	0	44
5	SAC & DECU	1977	39	5	3	0	31
6	LPSC	1211	47	25	0	0	22
7	NRSC	834	20	2	0	0	18
8	ISTRAC	434	10	1	0	0	9
9	MCF	318	4	1	0	0	3
10	ADRIN	162	3	0	0	0	3
11	IIRS	113	6	0	1	0	5
12	PRL	233	4	1	0	0	3
13	SCL	585	3	0	0	0	3
14	NARL	63	1	0	0	0	1
15	NESAC	40	1	0	0	0	1
16	IIST	97	1	0	0	0	1
17	IPRC	636	13	0	0	0	13
TOTAL		**16072**	**371**	**70**	**13**	**14**	**274**

Table - III: Status Of Representation Of Ex-Servicemen

Sl. No	Centre / Unit	Total Number of Employees in Group - C 2017-2018	Total Number of Ex-Servicemen in Group - C 2017-2018
1	DOS / ISRO HQ	56	5
2	VSSC	785	93
3	ISAC	327	10
4	SDSC-SHAR	588	25
5	SAC & DECU	210	3
6	LPSC	181	35
7	NRSC	82	1
8	ISTRAC	35	3
9	MCF	51	3
10	ADRIN	25	1
11	IIRS	15	1
12	PRL	22	0
13	SCL	58	0
14	NARL	5	0
15	NESAC	0	0
16	IIST	0	0
17	IPRC	108	17
TOTAL		**2548**	**197**

Table - IV: Women Employees in DOS / ISRO

Sl. No	Centre / Unit	Total Number of Employees 2017-2018	Number of Women Employees 2017-2018	
			Scientific & Technical Staff	Administrative Staff
1	DOS / ISRO HQ	393	26	109
2	VSSC	4467	520	443
3	ISAC	2538	544	129
4	SDSC-SHAR	1971	127	129
5	SAC & DECU	1977	260	82
6	LPSC	1211	80	108
7	NRSC	834	146	56
8	ISTRAC	434	70	35
9	MCF	318	32	11
10	ADRIN	162	29	10
11	IIRS	113	17	8
12	PRL	233	19	18
13	SCL	585	35	16
14	NARL	63	5	7
15	NESAC	40	8	4
16	IIST	97	18	6
17	IPRC	636	42	39
TOTAL		**16072**	**1978**	**1210**

4.3 Human Resource Development at Centres

4.3.1 Indian Institute of Remote Sensing (IIRS)

Indian Institute of Remote Sensing (IIRS), 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 has trained 10,899 professionals (till August, 2017), including 1064 professionals from abroad representing 95 countries mainly from the Asia, Africa and South America. A total of 180 students in M.Sc. and 263 Students in M.Tech. courses have graduated since 2002. Special tailor-made/on-demand courses are conducted at the request of the User Departments, both national and international. In the last few years, demand for such tailor-made courses has increased significantly.

In addition to aforesaid activities, IIRS also supports the activities of UN-CSSTEAP which has conducted 52 PG Courses. CSSTEAP has conducted 52 short courses and workshops in the past 21 years. These programmes have benefited 1919 participants from 35 countries of Asia-Pacific region and 30 participants from 18 countries outside Asia Pacific region. Till date, 143 PG students from 16 different countries have been awarded M.Tech. Degree.

Further, 684 institutions/organisations in the country are currently networked with IIRS/ISRO through outreach programme and 53,288 students and professionals have been benefited so far since 2007. Under e-learning programme of IIRS outreach activity, there are currently 2,928 learners wherein 855 have registered for certificates including 160 participants.

4.3.2 Indian Institute of Space Science and Technology (IIST)

Indian Institute of Space Science and Technology (IIST) has faculty strength of nearly 100 spread across seven Departments. 140 undergraduate students and 85 postgraduate students were enrolled in July 2017. Also, 27 scholars were admitted to PhD, which includes 4 sponsored candidates from ISRO. The total degrees awarded by the institute will be 1,259, comprising of 931 B.Tech., 290 M.Tech. / Master of Science and 38 Ph. D. Out of successful 151 B.Tech. students, 104 were offered placement in ISRO in 2017. Thus, total of 775 B.Tech graduates from the institute have been absorbed in ISRO.

4.3.3 Space Applications Centre (SAC)

During the period of reporting, four Training & Development Programmes are conducted at ISRO level. 26 In-house programmes/workshops, 26 lectures, 4 open-house seminars & 18 educational visits are conducted at SAC level. About 56 cases were processed for higher studies including IIST/IISc /IIT.

About 34 research projects in the field of Meteorology and Oceanography were completed under Satellite Meteorology Research and Training (SMART) programme and 10 training programmes were conducted under Training & Research in Earth Ecosystems (TREES).

4.3.4 North Eastern Space Applications Centre (NE-SAC)

Newer technologies like Unmanned Aerial Vehicle (UAV) based Remote Sensing have been tried apart from the Remote Sensing and GIS based projects. Ten UAV, have been procured with the financial support from NEC. One week training on UAV data processing was organised at NE-SAC during May 08-12, 2017 for the participants from all the State Remote Sensing Application Centres (SRSACs) of North Eastern Region (NER).

4.4 Technical Infrastructure Development

Over a period of more than four decades, a host of technical infrastructure are established and maintained by the organisation, which are required for end-to-end systems realisation. Augmentation and maintenance of existing facilities to cater to increased level of systems realisation, such as, launch pads, clean rooms, fabrication and test facilities, reference stations for global navigation, ground infrastructure for enhanced space based services, are planned.

4.4.1 Launch Infrastructure Development

Major facilities like New structural test facility, C-Band polarimetric Doppler Weather Radar, Electric Field Mill for thunderstorm monitoring, EMI Facility, Electronic Printed Circuit Facility. Electronic Bonded stores, Hypersonic Wind Tunnel Facility, etc., were established at VSSC during the year. Autonomous Cathode Test Facility and Class 10,000 clean room and assembly area for the production of cryogenic level systems was established at LPSC during the year. An exclusive assembly and integration facility for Semi-cryo engine has been commissioned at IPRC. For the CE20 E5 engine test, many of the HAT facility systems underwent augmentation based on CE20 E3 engine (for GSLV-MkIII D1 mission) hot test observations. A new state of the art facility is being established for testing PS4 and PS1 Reaction Control Thruster (RCT) at IPRC.

Semi-cryogenic Engine Assembly Facility

SDSC SHAR is augmenting the infrastructure to meet the requirements of increased launch frequency. Second Casting Facility, Second machining Facility, Second Curing Facility and Bulk Storage facility for UH25 and N2O4 were realised during the year. Facilities like Autoclave, 4.5t Vertical Mixer Facility, Ammonium Perchlorate (AP) Grinding, Drying and sieving facility with common control room, etc., are under realisation. In line with the requirements of advancements in Space transportation systems, to meet the launch vehicle requirements, it is proposed to have the Third launch pad.

4.4.2 Ground Segment

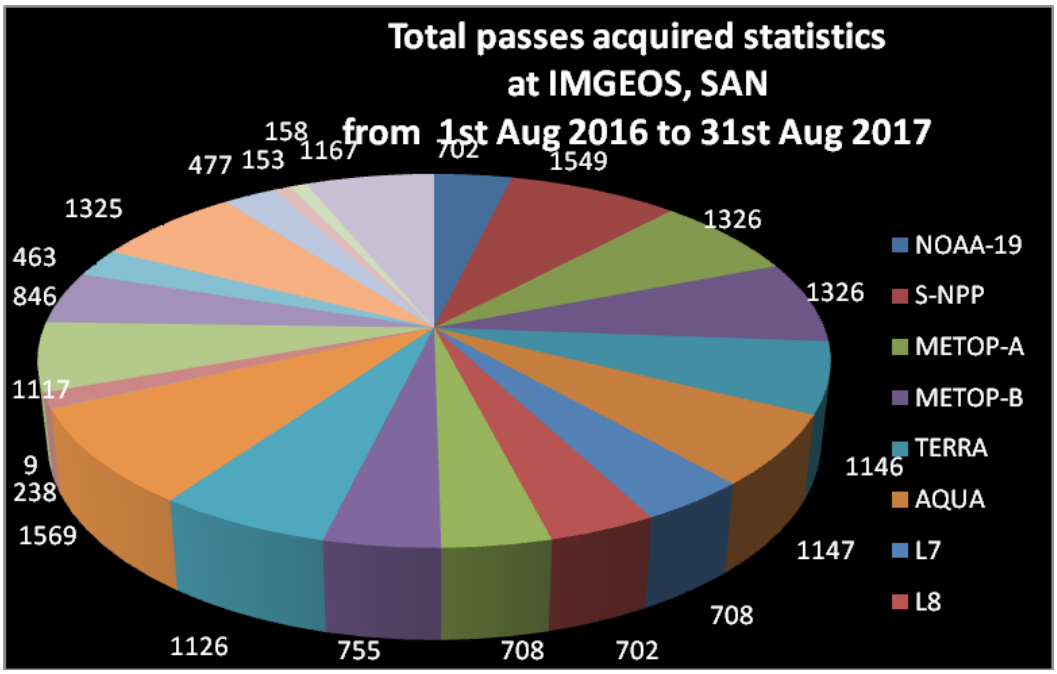
ISRO Telemetry Tracking and Command Network (ISTRAC) provides tracking support for all operational remote sensing and scientific satellites. ISTRAC also provides active support for Search & Rescue, Disaster Management Support and host space communication hub services for societal applications. ISTRAC has established a network of ground stations at Bengaluru, Lucknow, Mauritius, Sriharikota, Port Blair, Thiruvananthapuram, Brunei and Biak, Indonesia and the Deep Space Network Stations, namely, DSN-32 and DSN-18 at Byalalu near Bengaluru to provide TTC support for ISRO's space missions. The Mission Operations Complex located at Bengaluru carries out round-the-clock mission operations of all remote sensing and scientific satellites. All network stations of ISTRAC are connected to the Mission Operations Complex through dedicated high-performance satellite communication links and/or terrestrial communication links.

At present, ISTRAC provides TTC and spacecraft health monitoring and control services for 12 satellites in orbit namely, Resourcesat-2, Resourcesat-2A, Cartosat-1, Cartosat-2B, Oceansat-2, Cartosat-2A, Cartosat-2, Cartosat-2 Series Satellite, Megha-Tropiques, RISAT-2, SARAL and Scatsat-1.

4.4.2.1 National Remote Sensing Centre (NRSC) Ground Station, Shadnagar

The Integrated Multi-mission Ground Segment for Earth Observation Satellites (IMGEOS) has been operationalised to meet the objective of delivering emergency products in one hour and standard products in 24 hours.

NRSC from its ground station at namely Shadnagar campus (near Hyderabad), acquires data from various Indian Remote Sensing satellites, Cartosat-2 Series, Resourcesat-1, Resourcesat-2 & 2A, Cartosat-1, Cartosat-2, Oceansat-2, Cartosat-2B and SARAL through four 7.5 metre S/X band antenna terminals. Remote Sensing Data from different foreign satellites-AQUA, TERRA, LANDSAT-7 & 8, S-NPP, NOAA-19 & METOP-A/B satellites is also being received, processed and archived on SAN storage regularly. Data is acquired from 11 Indian missions and 8 foreign missions and about 60,000 passes resulting in ~500 TB of data archival during the last year, achieving 99.5% station efficiency.



4.4.2.2 Antarctica Ground Station - AGEOS

NRSC has established a Ground Station at Bharati (Base Station of NCAOR) in Antarctica. The Antarctica ground station (AGEOS) was successfully established in 2012-13 to receive the satellite data at Antarctica and transmit the data to IMGEOS for further processing and archival. Backward integration of AGEOS into earlier missions was also accomplished. This Ground Station is also being used to support Telemetry and Tele-command activities of ISTRAC. The satellite data received from various Remote Sensing Satellites is transferred through high speed Communication link to NRSC in near real time. C-band Communication systems at Antarctica, NRSC and NCAOR for data transfer (40 Mbps), and other services like Voice Over Internet (VOIP), Video Conference, Internet, M&C from NRSC and ISTRAC TTC were established.

4.4.2.3 International Ground Station (IGS)

Technical consultancy support for upgradation of multiple data reception systems in the country and International Ground Stations (IGS -Algeria, Tehran, Kuwait and Oman) was extended through Antrix Corporation. Front-End Hardware with PCI express card having data a rate capability of 320 Mbps, was installed at KSAT Tromso, Svalbard to acquire real time SCATSAT data.

4.4.3 Planning for Future Missions

4.4.3.1 Establishment of 2nd Data reception Antenna System (S/X/Ka-band) at AGEOS

Installation and commissioning of the 2nd data reception Antenna at Antarctica is planned during 2018. It will support X and Ka-band data reception for Cartosat-3 & NISAR satellites. The proposed 2nd Data Reception Terminal at Antarctica supports as a second / follow on station to IMGEOS at NRSC, Shadnagar.

4.4.3.2 Establishment of (S/X) Data Reception Terminal for IMGEOS at Jodhpur

For the upcoming new missions, it is planned to establish additional S/X Antenna system (5th) for IMGEOS to resolve the visibility clash scenario of multiple satellites & to ensure continuous availability of the data reception. It is planned to locate at North-Western Part of India, in the existing campus of Western Regional Remote Sensing Centre at Jodhpur.

4.4.3.3 Ka-Band Data Reception System

To meet the new Ka-band Data Reception requirements for Cartosat-3, 3A and NISAR missions, establishment of new S & Ka-band Remote Sensing Data Reception Systems have been planned at Hyderabad.

4.4.3.4 GISAT - Data Reception System

For Geosynchronous Orbit based GISAT Data Reception, first System is planned at NRSC Shadnagar and second station is planned at SAC, Ahmedabad considering the advantage of rain diversity, due to different Geographical locations. Third Station is planned at Delhi, to meet additional requirements.

The future planning also includes - Design & Development of S and Ka Band Feed & Radio Frequency Downlink; Development of Data Ingest Hardware; Design & Development of 11 metre S/X/Ka tri-axis Data Reception Antenna System; Development of Ka-band Antenna Control Servo System etc.

4.4.3.5 Establishment of a New Ground Station near North Pole

With the Advanced high-resolution satellite programs of IRS, the role of Ground Stations (GS) and their complexity has increased multi fold. These high-resolution satellites demand frequent visibilities with larger processing power, data storage capacity onboard, data downlink of stored image, to ground stations for meeting the Global and Indian user requirements. Presently, the global requirements are met through NRSC Ground Stations at Shadnagar and Antarctica and partly through SVALBARD ground station. In order to achieve 14-orbit coverage, it is planned to establish a ground station at North Pole. It provides an opportunity to download the complete data within the same orbit and enable the usage of on-board resources in every orbit and to transfer the raw data in near real-time to IMGEOS of NRSC, Shadnagar.

4.4.4 Data Processing, Products, Archival and Web Applications

During April 2017 to September 2017, 2,39,876 optical data products have been generated against various user requirements at IMGEOS Shadnagar. These include data products of Resourcesat-1/ 2/2A, Cartosat-1 and Cartosat-2 Series satellites. For SARAL satellite, Operational Geophysical Records are being generated in Near Real Time at Shadnagar.

4.4.4.1 Landsat-8 operations: For the time Acquisition and pre-processing at IMGEOS along with Dissemination is made operational. For the first time a non-ISRO Satellite is integrated into IMGEOS framework with interface adapters demonstrating the feature of a Good Architecture.

4.4.4.2 Calibration-Validation (CAL-VAL) Activities: Geometric and radiometric parameters are being monitored for all operational sensors and trending analysis is being done. In case of anomalies, the nature of anomaly and daily or periodic reports are generated for providing alerts or feed back to the respective teams for corrective action. Additionally, CAL-VAL experiments are conducted during the favorable season of October-April for the sensors namely, LISS-3, LISS-4, OLI, Cartosat-1, Cartosat-2 Series to monitor the traceability and radiometric performance using CAL-VAL targets established at IMGEOS Site.

4.4.4.3 Target deployment for Data Quality Evaluation: Mirror targets were deployed (on experimental basis) at Calibration site to compute Point Spread Function (PSF) of high resolution data from Cartosat-1 and Cartosat-2 series of satellites. Campaign mode of calibration exercises were conducted during January 26 to February 02, 2017 at Rajasthan Desert for AWiFS sensor of Resourcesat -2 & 2A and OLI of Landsat 8 satellite were conducted.

4.5 Enhanced Output Through Outsourcing

ISRO's vision for the next decade and the strategy for the next three-year progressive period has set the pace for an increased throughput of satellite and launch vehicles. In line with the laid down objectives, there has been a steady increase in the number and complexity of missions accomplished by Indian space program. ISRO Centres have adopted proactive policies for encouraging Industries to take up more of end-to-end production activities to deliver systems rather than being parts/ components manufacturers. Industries, in turn, have responded well to this initiative by upgrading their technological capabilities, adopting aerospace standard in space components realisation, developing required infrastructure, etc. The strong association and linkages forged with a large number of industrial enterprises, both in public and private sector, is set to reap rich dividends in terms of supply back to the space programme.

4.5.1 Partnering with Indian Industry

The Department has evolved a policy of realising its goals and objectives through the efforts of both organisational and external capabilities. Substantial progress is achieved in involving industries for

realisation of matured sub-assemblies for launch vehicles and satellites. To cater to increased launch manifest, a host of initiatives are being taken by ISRO, towards enhancing the productionisation at its own facilities as well as the 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.

- PSLV Integration Facilities (PIF) is being realised in coordination with industry. Additional vendors are being developed for PS0-XL motor hardware and for the supply of critical raw materials for production of solid motors. Procurement action is in progress for ensuring buffer stock of mechanical elements and materials requiring long lead-time.

- Initiative has been taken to identify additional vendors for Light Alloy Structures. VIKAS engines for L40, PS2, GS2 and L110 stages are continued to be realised through the industry consortium partners. The public sector industry based at Thiruvananthapuram has continued with the supply of L40 conical version VIKAS engine.

- Industry has contributed towards the realisation of PS4/RCT engines. The integration of L40 stage of GSLV is being carried out at a Bengaluru based public sector industry.

- Realisation of Cryogenic Upper Stage (CUS), Cryogenic Engine-CE20 turbo pumps, CUS Steering engines and Thrust chambers by two private sector industries. The Integrated Cryogenic Engine Manufacturing Facility (ICMF) was established in a PSU delivering two numbers each of CUS, CE20 and Semi cryogenic engines every year.

- Realisation of semi-cryo engine sub systems being pursued through major industries in the private sector.

- Assembly and testing of PS1-SITVC tankage sub-assembly, PS1 RCS actuator, PSOM SITVC Injectant System Module sub assembly and PS1-SITVC nozzle mounted sub assemblies through industries.

- The Integrated Cryo Components and Modules Assembly and Test Facility (ICMAT) was established wherein industry professionals would carry out sub assembly preparation, inspection, assembly and testing of cryogenic components and modules under the supervision of ISRO. For the production of liquid propulsion stage hardware, components and systems, dedicated facilities are being established which will be operated by external industries, under the Government Owned Contractor Operated (GOCO) model.

- Private sector industry at Coimbatore has established the infrastructure for carrying out fabrication, assembly and testing for Integrated Production of Control System (IPCS) Components and Modules for PSLV and GSLV. A contract has been entered into with a private industry for the assembly and testing of SITVC injection valves. Contracts have also been established for the assembly and testing of Latchable Series Redundant Value (LSRV) and Earth Storable Control components. Stage propellant tanks, feed lines and structure fabrication are carried out at ISRO's work centre/ public sector aerospace industry located at an Bengaluru.

- The Avionics Package fabrication and end-to-end Production is outsourced through accredited and enabled work centres. SMT line qualified for three more parties and Hi rel Fabs SMT line qualification is under process. Accredited reflow facilities and Qualification of PCB manufacturing line were completed during the year. Many composite products for spacecraft like Solar panel substrate, yokes, DHAA assemblies, FST and DST tubes for antenna reflector assemblies, etc., were delivered from different industries.

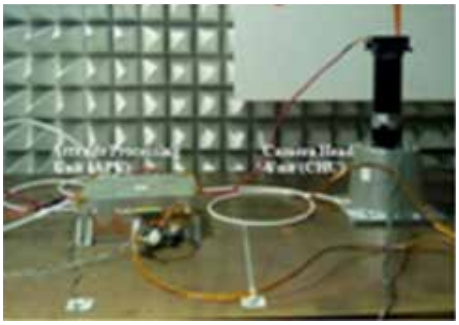
- Private industry successfully completed the Assembly, Integration and Test (AIT) activities of IRNSS-1H spacecraft and is currently progressing with the AIT of the second spacecraft, IRNSS-1I. EOI released for selection of appropriate vendors for the AIT of communication spacecraft of various classes has received a very encouraging response from the industries. Exclusive vendor labs have been established in production building at ISITE for different vendors.

- The public sector aerospace industry based at Bengaluru has supplied six spacecraft structures, apart from carrying out primary bonding of more than 103 components including heat pipe panels, sandwich panels, shells, etc. Private sector industry has supplied more than 300 heat pipes, which are used in communication satellites for the thermal equilibrium of satellite transponders. Solar array deployment mechanisms for 30 wings continue to be realised and supplied by industries in the private sector. Space qualified batteries of various capacities were supplied by industry. Fabrication and testing of S-band TT&C transponders for LEO and TTC main antenna for GEO missions have been outsourced to industry. The end to end spacecraft flight harness realisation for LEO/GEO and navigation spacecraft, along with associated spacecraft harness activities in clean room, is being realised by industries. About 80 DC-DC Converters have been realised by vendors. A total of 200 packages were realised and around 300 packages tested by vendors.

- Space grade TCXO, OCXO, HMC based low and medium power Electronic Power Conditioners, Ku-band ALC Driver amplifiers, Ku band receivers, frequency converters, C-band receivers, Ku-band LNA, driver amplifiers were realised from industry. Industry continues to deliver 15W C-band SSPAs based on the licensed technology transfer process. Joint development of 60W C band SSPA with public sector electronics industry and the development of micro power module for 140W Ku band TWTA is in progress. Activities like supply of PCBs for onboard / ground applications, Hi-Reliability fabrication and assembly etc., are continued by the industry partners. Vendor development for the surface treatment processes on various substrates is completed. The qualification process of Chromium-Copper-Chromium(Cr-Cu-Cr) metallisation on bare alumina substrates has been initiated; the requirements of bare alumina substrates for on-board applications would be met through the indigenous vendor.

- Sensor systems and optic elements for eight spacecraft were developed with cooperation from public and private sector industries. The sensors and optics for 11 spacecraft are under advance stages of fabrication and testing. Over the years, multiple vendors have been developed for supplying high performance optical elements. The technology of high absorber Optical Coatings has been transferred to a second vendor and 30 sets of space qualified black absorber coated Stainless Steel (SS) vanes are supplied by them for Star Sensor baffle. Small scale industry has been qualified for the supply of Whiffle Tree type support system for testing medium to large

size (1.2m) dia 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 development of photo masks for application in precision sun sensors for IRS and INSAT. Industry is supplying ion implanted / diffused Silicon (Si) wafers for the production of Si photo detectors and processed wafers for development of large area Si photo detector arrays required for the current IRS/INSAT projects. Mechanical components for sensors and optics, HMC design, fabrication and packaging of different categories of MEMS devices namely accelerometer, micro bolometer, RF switch and Si photodiode array is also being carried out by various industries.



MARK-III Star Sensor

- Fabrication, Assembly and Testing of Electro Optics Systems (EOS) and Sensors, Star Sensor Optics Module etc., was outsourced to private vendors. Supply of ion implanted / diffused Si wafer for the production of Si Photo Detectors for Sun Sensors was carried out by vendor. The fabrication of Seismometer HMC, such as hermetic sealing, packaging and seal leak testing was also awarded to private industry. Some specialised tasks related to Optics and thin films such as, fabrication and Supply of Corner Cube Retro-Reflector (CCRR) optical components, Refractive Optics lens elements for Star Sensor and Camera payloads, Anti-reflection coating (ARC) for silicon detector and Germanium hemispherical lens for immersed bolometer, were successfully outsourced. The other activities outsourced were PCB wiring, mechanical fabrication of parts for Sensors and Optics, etc., for which multiple vendors were identified and utilised.

4.5.2 Technology Transfer

During the year, several technologies were licensed to Indian industries for commercialisation and regular production. Notable amongst these are the technologies for SILCEM R9, Rocasin, iEPIFIL 9661, Cassegrain Feed, Coating technologies, etc. Apart from this, the technologies hitherto transferred to various industries are under production and commercialisation, pursuant to the successful absorption of the know-how.

The Solar insolation data (both historical and near real time) available from MOSDAC website has been licensed to a private industry, for developing in-house solar insolation forecasting model. ISRO's competency in electroplating technologies, particularly, in the process for gold plating on Aluminum and Kovar alloys, Pulse Hard Anodizing etc., have been successfully transferred to industries in the private sector. The technology of Fibre Optics Gyro (FOG) is progressing well pursuant to its successful absorption and productionisation. The technical know how for MEMS inclinometer and the process technology for fabrication of star sensor optics lens is in the advanced stage of discussions, for technology transfer.

MOUs were executed with various Organisations for joint collaborative activities including academic and research based interactions for the development of relevant aerospace technologies, development of

specific applications of oceanology and meteorology, establishment of a remote sensing data processing centre for fodder acreage assessment based on indigenous protocols were developed. Consultancy was provided for the indigenous development of communication systems, Synthetic Aperture Radar, Airborne Radar Simulation and Image Processing algorithms, Electro-optic payload and related technologies. In the field of navigation, specific agreements were entered into for NavIC Receiver Field trial and data collection, development of Geo-spatial Energy Portal of India, and other activities towards strengthening the technical cooperation and capacity building activities. ISRO's technical competency is being sought for the preparation of GIS based Energy map of India, expected to be useful for disaster management of possible energy disruption and safety of energy assets due to harsh climatic conditions. Development of Active and passive components related to RF and microwave systems was also taken up. The development of technology for Thermal Barrier Coating for applications up to 14000°C such as coating on their gas turbine engines was taken up. Development of a Microprocessor controlled prosthetic knee joint and True step prosthetic multi-axial foot piece for lower limb amputees was taken up under a project identified by Ministry of Social Justice and Empowerment. Under this ambit, MOUs have been entered into for design, development and standardisation of microprocessor controlled prosthetic knee joint and prosthetic multi axial foot piece for lower limb amputees.

ASIC for NavIC / IRNSS

In house efforts to build competency in the areas of computational numerical simulation for aerospace applications has led to the development of finite element based structural analysis software - Finite Element Analysis of Structures (FEAST). Consistent efforts are being devoted towards improving the capabilities and enhancing the computational abilities of the software, and more than 150 copies have been licensed to various academic institutions across the country.

To enhance the knowledge of students, researchers and industries in various domains, several training programmes were held during the year. Programmes such as – Satellite Meteorology And oceanography Research and Training (SMART), aimed at encouraging students, academicians and researchers to pursue research in the field of meteorology and oceanography using satellite data archived at MOSDAC and other datasets benefitted more than 160 students, who were trained during the year.

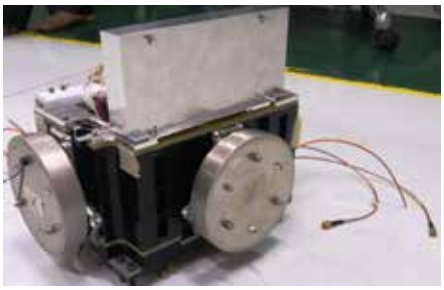
Training & Research in Earth Eco-Systems (TREES) is another programme designed in the field of earth-ecosystem process using VEDAS and related datasets for the researchers from R&D institutions, academia, students and industries. This programme has a vision to develop earth ecosystem research expertise using India satellite data and products. Other training programmes related to building competency in remote sensing and Geo Informatics, with emphasis on marine applications, satellite based hydrology and modeling, etc., were also conducted. Under an MOU with Government of Gujarat, special training is being imparted to students in the disciplines of mechanical and electronics area. This outreach activity benefitted more than 140 students spread over 138 Institutions across the country.

4.5.2.1 Intellectual Property Rights - Patents and Copyrights

Intellectual property rights are one of the most important and valuable assets for the organisation. Intellectual property protection is critical for fostering and nurturing innovation. Five new patent applications were granted during the year including circuit for compensating gain variation, fibre optic liquid level detector, process for double layer bronze seal, etc., Patents for 12 new products and processes developed by ISRO were filed during the year. Many more patent applications are in final phase of filing at Indian patent office.

4.5.3 Indigenisation – Development of Critical Space Materials/Components

ISRO, along with Indian industry, is constantly exploring avenues for the indigenisation of electronic components, materials and alloys used for space program. Efforts are on to indigenise Multi Junction Solar Cells. Pondicherry based Private sector industry has successfully supplied "Patterned mask blocks for sun sensor production" under a purchase contract with technology consultancy support from ISRO. An MoU for indigenous development of X-ray polarimeter for XPoSAT and for the development of a prototype for Satellite based secure quantum communication have been signed. Indigenous development of MEMS based solid state N_2H_4, O_2, H_2 and NO_2 Pollution Sensors have been taken up in coordination with an academic Centre of Excellence at Bengaluru. Under an MOU with a leading research Institute, the design and development of TWT in various frequency bands is being taken up. Many of the systems / elements for sensors and optics are developed/being realised on the basis of transfer of technology.



DUAL Axes FOG

4.5.4 New Technologies through Academia - Sponsored Research - RESPOND

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 with Savitribai Phule Pune University (SPPU, Pune) 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 programme. The major activity under RESPOND is to provide support to research projects in a wide range of topics in space technology, space science and space applications areas to Universities/ Institutions. In addition, conferences, workshops and publications, which are of relevance to space programme, are also being supported. Respond also participated in the National Missions like IMPRINT (IMPacting Research Innovation and Technology) programme and Uchchatar Avishkar Yojana (UAY).

Activities

During 2016-17, RESPOND supported 47 New Projects and 41 Ongoing Projects and five Space Technology Cells and Joint Research Programme with Savitribai Phule Pune University. In addition, five ISRO Chairs, 146 conferences/symposia/publication and other scientific/promotional activities have been supported. During the year, 23 sponsored projects have been successfully completed. Scientific publications have emerged out of these projects apart from fulfilling the objectives. Principal Investigators (PI), Co-PIs and research fellows involved in various projects had interacted with various ISRO focal points/experts in realising the projects.

During the year, RESPOND has supported 35 Universities/Colleges, 13 IITs / NITs and eight Research Institutes / Laboratories to take up Projects both new and ongoing (Figure-1). Further, during the year, a large number of projects have been supported in the area of Space Technology (58) followed by Space Applications (20) and Space Science (10) (Figure-2).

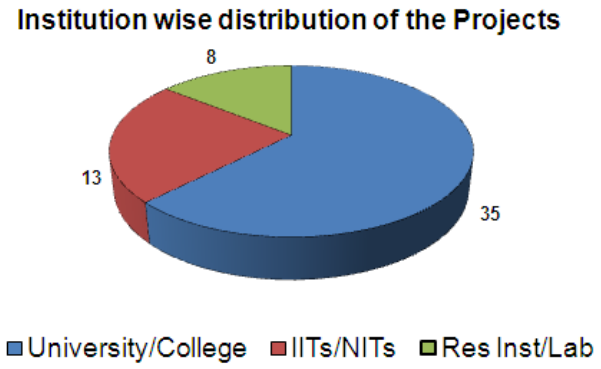


Figure-1

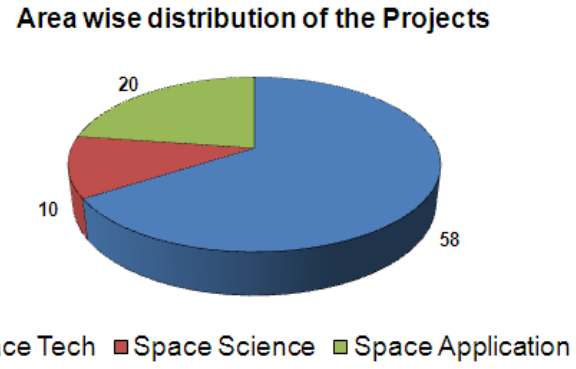


Figure-2

Projects at Space Technology Cells (STC): During the year, RESPOND has supported 70 new projects and 127 ongoing projects of five Space Technology Cells and Joint Research Programme at Savitribai Phule Pune University and further 57 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	16	33	21
2.	IIT Madras	5	21	6
3.	IIT Bombay	3	25	1
4.	IIT Kanpur	16	28	3
5.	IIT Kharagpuro	8	37	6
6	SP Pune University	8	22	1
Total		**56**	**166**	**38**

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 Bangalore University.

Highlights of Some of the RESPOND Projects

- **Development of mixed refrigerant cascade refrigerators operating with non-flammable refrigerants for cooling space simulation chambers:** The project aimed at replacing the two stage cascade vapor compression refrigerators operating with two different refrigerants for each stage with single stage vapor compression refrigerator operating with a mixture of refrigerants. A prototype refrigerator has been developed under this project.

- **Condition monitoring and health assessment for bearings of cryogenic engine turbo pump:** Under this project, unified software was developed for processing and analysis of the vibration data and for quick and easy viewing and interpretation. The software will be useful to monitor both bearing and rotor vibration signals. Through the result, it is possible to identify bearing defect and its severity level and thus achieving effective condition monitoring and health assessment of the turbo pump bearings.

- **Processing and characterisation of dispersion strengthened precipitation hardenable Aluminium alloys:** The study found that graphene is better reinforcement for aluminum matrix compared to Multi Wall Carbon Nano Tube (MWCNT) for improving matrix properties, beyond which agglomeration takes place. Further, improvement in hardness with the addition of CNT in aluminum alloy AA2219 was observed and processing parameters were optimised for obtaining high density compacts.

- **Generation of Input data / parameters through Non-Destructive Technique (NDT) / Destructive Technique (DT) for use in performance prediction model of Li ion batteries:** The project aimed at obtaining cell design parameters and materials of construction /composition by performing DPA (Destructive Physical Analysis) and DCA (Destructive Chemical Analysis) on Li on Cells from various sources of supply. Several simple techniques for extraction of cell design parameters through NDT and DT have been developed.

- **Development of Thermoplastic Elastomers for Liquid Cooling and Ventilation Garment:** Under this project, thin films have been developed by both Blow Molding and Cast Molding techniques and characterisation was done for hydrophilicity, thermal and physico-mechanical properties. The films were characterised for physico-mechanical, thermal and chemical properties by state-of-the art instrumental method.

- **Analysis of Microstrip radiator using Particle Swarm Optimisation technique:** The project aimed at designing the microstrip radiators in S-band using Particle Swarm Optimisation (PSO) technique. Under this project, PSO / Modified Real PSO/Multi Objective PSO algorithm has been developed, which can be applied for optimising the antenna performance by antenna designers. This technique is used by the design team of microstrip radiators for optimising antenna parameters. This is currently being implemented in finalising the antenna parameters, particularly in microstrip radiators.

- **Stability and Chaos in Photogravitational N-body problem with solar wind drag:** As many satellites have been placed at Lagrangian points in Sun – Earth and Earth –Moon systems by various space agencies, a study was taken up to understand the N-body problem, i.e., Sun–Earth and Earth-Moon systems using realistic potentials/values of parameters. The model of restricted three body problem, with the sun as the radiating body and the earth as the oblate spheroid was taken up to find out the Lissajous and halo orbits around the collinear langrangian points L1 and L2. The effect of the radiation pressure and oblateness on the orbits at different values was analysed and it was found that on increasing the radiation pressure and oblateness, the time period of the orbit around L1 and L2 increases and decreases respectively. Further, the linear stability of equilibrium points was examined and it was found that the Langrangian points are unstable due to the drag forces. The output of this project has relevance for the development of trajectory design, transfer and the orbit resonances of different celestial bodies.

- **Development of customised software for the data management related to integration of Cryo Upper Stage (CUS-SOFT):** The aim of this project was to develop a customised software package to carryout activities pertaining to CUS engine & stage assembly, integration and testing. Under this project, software 'CUS-SOFT' has been developed which can be used to get the data from the corresponding stakeholders and track the progress of the different levels of assembling processes. This software will help in reducing the manual document workload of the engineers and other stakeholders.

- **Development of Piezoelectric actuator for micro-positioning of space structures:** Under this project, an analytical mathematical model was developed based on variational method of energy representing electromechanical coupling and control strategy /adaptive control algorithm. Simulation results showed that tip deflection can be altered by changing voltage to the actuator. Further, a closed loop model of the system was developed to control the actuator voltage to nullify tip deflection as sensed by the sensor.

- **Intelligent Satellite Image retrieval and Analysis based on Ontology approach:** This study brought out a clear understanding of the segmentation techniques applied on the satellite images, feature extraction process and ontology model for image database system. Study on Protégé for developing the ontological model, study on Relational Database Management System (RDBMS) and study of different tools for designing software agents were also carried out.

4.6 International Cooperation

International Cooperation has been an integral component of Indian Space Programme ever since its inception. Indian Space Research Organisation (ISRO) of the Department of Space (DOS) carried out many activities in 2017-18, which were aimed at intensifying space relations with partners and establishing new relations with other nations in the peaceful uses of outer space. It included carrying out joint activities of mutual interest; sharing expertise in the applications of space technology and participation in international events.

Space cooperative documents are signed with space agencies of 42 countries and 4 multinational bodies, namely, Afghanistan, Armenia, Argentina, Australia, Bangladesh, 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, Portugal, Peru, Republic of Korea, Russia, Saudi Arabia, South Asian Association for Regional Cooperation (SAARC), Spain, Sweden, Syria, Thailand, The Netherlands, Ukraine, United Arab Emirates (UAE), United Kingdom (UK), United States of America (USA), Venezuela and Vietnam.

Exchanging India-Bangladesh Space Cooperation MoU

The cooperative agreements signed during this year are: (i) Implementing Arrangement (IA) between ISRO and Canadian Space Agency (CSA) related to cooperation in Compact Polarimetry Calibration and Validation project (ii) IA between ISRO and Japan Aerospace Exploration Agency (JAXA) concerning collaborative activities on the radio occultation experiment in JAXA's Venus orbiter mission 'Akatsuki (Planet-C)' (iii) Memorandum of Understanding (MoU) between India and Bangladesh on cooperation in the peaceful uses of outer space (iv) IA between ISRO and Geoscience Australia (GA) relating to satellite laser ranging and tracking of the Indian Regional Navigation Satellite System and (v) IA between ISRO and GA relating to using Australian corner reflector infrastructure for calibration and validation of Indian Synthetic Aperture Radar system (vi) MoU between India and Armenia on cooperation in the

peaceful uses of outer space (vii) IA between ISRO and National Aeronautics and Space Administration (NASA) for exchange of personnel under the Professional Experts and Scientist Exchange Programme (PESEP) (viii) MoU between India and the Netherlands on cooperation in exploration and uses of outer space for peaceful purposes (ix) MoU between India and Portugal on cooperation in the peaceful uses of outer space (x) MoU between ISRO and Israel Space Agency (ISA) on cooperation in GEO (Geostationary Earth Orbit) – LEO (Low Earth Orbit) optical link (xi) MoU between ISRO and ISA for cooperation in electric propulsion for small satellites (xii) Programme of Cooperation between ISRO and ISA regarding cooperation in atomic clocks (xiii) IA between ISRO and NASA for cooperation on the Balloon Measurements of the Asian Tropopause Aerosol Layer (BATAL) (xiv) Agreement between ISRO and CalTech on Prof. Satish Dhawan Endowed Fellowship at CalTech for MS programme in Avionics discipline.

The space cooperation between India and USA increased multi fold and made significant progress in the ongoing activities. ISRO and NASA made significant progress in joint realisation of microwave remote sensing satellite mission, 'NASA-ISRO Synthetic Aperture Radar (NISAR)'. Exchange of earth observation data collected by India's Resourcesat-2 data and USA's LANDSAT-8 satellite data has been operationlised under the ISRO- USGS (United States Geological Survey) cooperation. ISRO and NASA have jointly carried out Balloon borne measurement campaign in India to characterise Asian Tropospause Aerosol Layer (BATAL) in August 2017. ISRO and NASA initiated discussion for cooperation in Heliophysics through forming a Joint Working Group. The India-USA Civil Space Joint Working Group, had its Sixth meeting at Washington DC in October 2017 and reviewed the ongoing programmes and suggested future course of actions. The scope of Prof. Satish Dhawan Endowed Fellowship at Caltech has been expanded to include Avionics discipline also (in addition to Aerospace discipline). NASA has organised a special programme on Quality Assurance in satellite technology for ISRO Engineers at NASA Headquarters.

Space cooperation between India and France made significant progress in 2017 with expansion of cooperation to other domains beyond earth observation. ISRO and CNES have made significant progress in concluding a feasibility study for jointly realising an earth observation mission with Thermal Infrared imager. The technical aspects of accommodating CNES ARGOS instrument in ISRO's Oceansat-3 satellite (scheduled for launch in 2018) have been finalised and both sides are also discussing on flying the nano-ARGOS instrument in ISRO's future missions. CNES has organised a technical programme for ISRO Engineers on quality and reliability of launch vehicle systems. To expand the cooperation and to identify newer opportunities for cooperation, ISRO and CNES have established three new Joint Working Groups (JWG) - one each on 'Planetary Exploration', 'Launch Vehicle Development', and 'Communication and Navigation'. ISRO-CNES Steering Committee had a meeting in April 2017 and reviewed the on-going activities.

As a follow-up to the ISRO-JAXA MoU for enhanced space cooperation, signed in November 2016, both sides are pursuing discussions on many areas of cooperation, including earth observation, space science and planetary exploration. Both space agencies are conducting radio occultation experiment utilising ISRO's IDSN and JAXA's Venus orbiter mission Akatsuki (Planet-C). Both the space agencies are carrying out a feasibility study to jointly realise a lunar exploration mission for in-situ analysis of water ice in Moon's North Pole.

As part of India-Russia space cooperation, discussions are on to establish ground stations for satellite navigation systems (NavIC station in Russia and GLONASS station in India) and also for establishing a N_2O_4 (Nitrogen tetra-oxide) production plant in India using Russian technology.

ISRO and European Union officials are working towards concluding an agreement to enable India's access to Copernicus (Sentinel) data.

ISRO delegation participated at the 68th International Astronautical Congress (IAC-2017) held at Adelaide, Australia during September 25-29, 2017. In addition to participation in the IAC-2017 events, the delegation had meetings with those from Germany, Israel, Russia, South Korea, Sweden, USA and UAE.

ISRO officials have participated in the 'CIENCIA- 2017', the National Science Summit of Portugal in July 2017, in which India was invited as the first Guest country. ISRO made presentation on "Atmospheric and Ocean Activities using ISRO's Meteorological and Oceanographic Satellites", "Indian Planetary and Space Missions" and "ISRO's initiatives on Atmospheric and Climate Studies".

Towards establishing new relations, ISRO hosted meetings with delegations from Bolivia, Singapore and Israel.

As announced by Hon'ble Prime Minister in June 2014, ISRO has built and launched *'South Asia Satellite'* on May 5, 2017 to provide satellite communication services to individual South Asian nations and also across the region. To support in further utilisation of the services from this satellite, ground terminals for demonstration have been delivered to Bhutan, Nepal, Bangladesh, Sri Lanka, Maldives and Afghanistan.

Remote Sensing application projects were initiated for South Asian Countries as Indian Remote Sensing (IRS) satellite systems provide global coverage that enables generation of satellite data products with value addition. Exploiting the satellite data availability across the South-Asian countries (Afghanistan, Bangladesh, Bhutan, Maldives, Nepal and Sri Lanka), various Remote Sensing Applications studies have been carried out under natural resources thematic areas which include agriculture, forestry, geology, land use/cover, urban, water and disaster support.

The Indian Multi-wavelength Space Astronomy observatory, AstroSat completed two years in orbit in September 2017. The observatory was opened to national and international astronomy community for submitting proposals for observation from October 2017 onwards.

Prominent visitors to ISRO Centres in 2017 includes the Members of the Committee on Science, Space and Technology of the United States House of Representatives, Singapore Minister for Trade and Industry, JPL Director, Members of Kazakhstan's Aerospace Committee, CNES President, Ambassador of France to India, Director of The Netherlands Space Office (NSO), Israeli Minister of Science and Technology, Portugal Prime Minister, French Foreign Minister and Ambassadors of UN.

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. ISRO organised a four-week training programme for 60 Tajikistan officials (20 officials each batch) on Agricultural Resource Management under Indian Technical and Economic Cooperation (ITEC) programme.

India hosted two major international space events, namely, the 24th session of Asia Pacific Regional Space Agency Forum (APRSAF-24) at Bengaluru in November 2017, with a theme 'Space Technology for Enhanced Governance and Development' and the 38th Asian Conference of Remote Sensing with the theme "Space Applications: Touching Human Lives" at New Delhi in October 2017.

ISRO provided more than 140 satellite data sets to support more than 48 disaster events through various mechanisms. 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 the Regional Cooperative Mechanism of UNESCAP, India is offering technical support to Myanmar and Srilanka to establish agricultural drought monitoring mechanism.

ISRO continues to play an active role in the deliberation of the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS). ISRO also actively participates in the meetings of prominent 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 on Meteorological Satellites (CGMS), 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).

4.7 Outreach Activities

The significant progress achieved by India in the important areas of space science as well as technology has caught the attention of people not only within the country but outside as well. Besides, space based services are touching all facets of human life in the country. Thus, creating awareness among the general public about the benefits that have accrued from India's applications driven space programme to the society and the significant progress made by the country in space science and technology and inspiring our large student community 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 and SAKAAR - have helped in keeping the public abreast of the latest developments in our space programme apart from evoking interest in them on the nuances of space science and technology.

4.7.1 Outreach through Media

4.7.1a Print and Electronic Media

Doordarshan and many private TV channels provided prominent live coverage to the launch of PSLV-C37 / Cartosat-2 series satellite on February 15, 2017, GSLV-F09/South Asia Satellite on May 05, 2017, GSLV-MkIII-D1/GSAT-19 on June 05, 2017, PSLV-C38 / Cartosat-2 series satellite on June 23, 2017 and PSLV-C39 / IRNSS-1H Satellite on August 31, 2017 from SDSC SHAR, Sriharikota. For these launches, media from Chennai, Nellore, Tirupati and Sullurpetta were invited to Satish Dhawan Space Centre, Sriharikota to witness the launch. Additionally, Doordarshan (DD) covered the launch of India's communication satellite GSAT-17 by European Ariane 5 VA238 vehicle Live. Amongst these, the successful launch of a record 104 satellites by PSLV-C37obtained extensive coverage both in the domestic and international media. Along with this, the successful Mars Orbiter Mission (MOM) continued to get important coverage in the media. National Geographic TV channel repeatedly telecast a special one hour documentary on MOM produced earlier.

Special video capsules on the Indian space programme including those on IRNSS, GSLV-FO9 / South Asia Satellite, GSAT-17, Cartosat-2 Series Satellite, GSLV-MkIII-D1/GSAT-19 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, PSLV commercial launches, and the launch of South Asia Satellite.

'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 publicised during ISRO outreach programmes. 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, story of the week, SAKAAR, employment opportunities, RTI related information, etc.

4.7.1b Social Media

Considering the importance of social media during contemporary times, the official ISRO Facebook on Mars Orbiter Mission was launched in 2013. Based on the 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. These social media outlets are also being used to disseminate information about the various developments in the Indian space programme.

4.7.1c Exhibitions and other outreach events

During the year ISRO organised many exhibitions at national and international conferences, important

Students Participating in various competitions

Ranchi, which was inaugurated by the Honorable Chief Minister of Jharkand. A large number of scientists, academicians and students from India as well as delegates from abroad visited many of these exhibitions.

APRSAF-24 Water Rocket Workshop in Progress

APRSAF-24 Water Rocket Launch Competition

Besides exhibitions, other interesting outreach events like water rocket events, quiz programmes and interaction with students and teachers were organised during the year in educational institutions in different parts of the country. One of the most prominent outreach events of ISRO was APRSAF-24 water rocket making workshop and launch competition which was organised at Bengaluru on the occasion of the 24th session of the Asia-Pacific Regional Space Agency Forum (APRSAF). 56 students and 36 teachers and educators from 11 Asia-Pacific countries and one in South America (Colombia) as well from the host city of Bengaluru participated in the event. Additionally, a poster making competition was also organised for Asia-Pacific countries on the occasion and 12 countries including India participated in the event.

4.7.2 NRSC

ISRO has established a new facility / Incubation Centre at Jeedimetla Campus of NRSC, Hyderabad to cater to the ever growing requirements of capacity building in space based applications, support to the Startups working in Geo-spatial Technologies and associated systems in the form of mentoring and making available space for remote sensing and GIS facilities, satellite data and software access for academia and industry, outsourcing and an incubation facility. Student community and industry can fully take advantage of this facility for various developmental activities.

Students interacting with Scientists

National Remote Sensing Centre along with its five Regional Centres, conducted World Space Week celebrations themed “Exploring the New World in Outer Space" at a larger scale covering the length and breadth of the country by collaborating with the NESAC, State Remote Sensing Centres and Academia. The promotional activities focused on campaigning about ISRO’s Space Programmes, and its contributions to the nation benefiting citizens for societal good, various applications of Remote Sensing data, support in disaster management and monitoring climate change, etc. More than 4 Lakh students participated the celebration.

4.7.3 Data Dissemination from NDC

NRSC Data Centre (NDC) is responsible for Remote Sensing Satellite data acquisition, processing and dissemination to the National and International user communities. NDC supplies the data directly to the users based on the orders placed either for Indian satellites data or data from foreign satellites. Data is being downloaded free of cost through Bhuvan and web portals. Data downlinks through International Ground Stations and data supply to International Charter also being provided. During this year, total products disseminated are 4,84,356, which comprises of 68,266 products through sales and 4,16,090 free downloads through Bhuvan and Oceansat-2 portal.

ISRO also collects and archives global data as part of satellite data acquisitions plan, apart from Indian region.

Value added services products: Information products from Oceansat-2 are automated for chlorophyll from and are being made available through NICES portal.

Orthorectified Normalised Difference Vegetation Index (NDVI) is being generated for full India for six cycles in a month using Resourcesat-2 AWiFS scenes on daily basis (~70 products / cycle).

Operational active fire alerts is generated in near real time from Aqua/Terra and Suomi-NPP and used during agricultural and forest fire seasons.

NOAA Vegetation products are regularly provided to Mahalanobis National Crop Forecasting Centre for Crop acreage and production forecasts.

Geophysical products: Satellite products such as NDVI, Vegetation Fraction products, Filtered NDVI, Land surface albedo (broad band and visible), surface water body, snow albedo, temperature profiles and surface reflectance for atmospheric correction are regularly being generated.

4.7.4 Web Services

4.7.4.1 BHUVAN

BHUVAN [http:bhuvan.nrsc.gov.in] is ISRO's web geo-portal providing geo-spatial services and earth observation data to users. The portal has witnessed about 18 lakh unique visitors. Installation of 100 servers, 300 TB storage, redundant networking components and network software have been carried out as part of Bhuvan scale-up initiative. Regular updates of data are carried out for visualisation purpose as well as download by the users. There are more than 1.5 lakhs registered BHUVAN users and more than 20 million crowd source points. On an average, more than one terabyte free data is being downloaded from BHUVAN.

PRAGATI: Pro-Active Governance and Timely Implementation (PRAGATI) is a unique integrating and interactive platform in BHUVAN. The platform is aimed at simultaneously monitoring and reviewing important programmes and projects of the Government of India as well as projects flagged by State Governments. The latest acquired satellite data is processed and published onto Bhuvan-Pragati.

4.7.4.2 National Information system for Climate and Environment Studies (NICES)

Under NICES initiative, currently, a total of 64 geo-physical products are being generated, of which 13 are qualified to be Essential Climate Variables (ECVs). These include ocean, atmosphere, terrestrial and cryospheric products, which are being made accessible through NICES portal developed over Bhuvan platform. A well distributed pan India ground observation network addressing atmospheric parameters, oceanic parameters and terrestrial parameters is being established for: (a) CAL-VAL studies and (b) to transform the bio-geophysical parameters climate qualified.

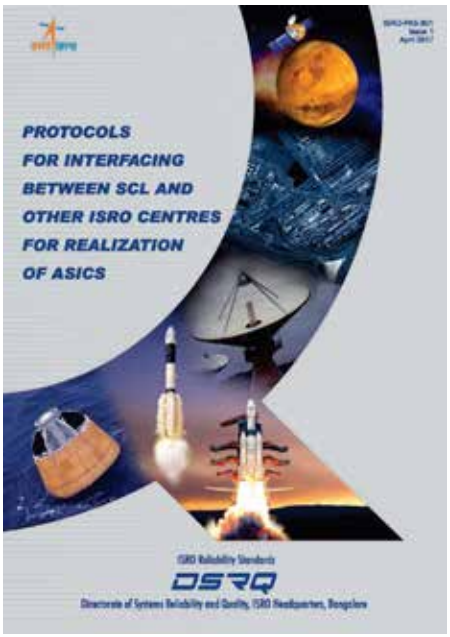
4.7.4.3 Meteorological and Oceanographic Satellite Data Archival Centre (MOSDAC)

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. New version of MOSDAC web portal released to users, contains advanced capability for visualisation, integrated decision support and location based services. Coastal geophysical products from SARAL/ AltiKa, SCATSAT-1 data product, geophysical parameters (31 products) from INSAT-3DR are hosted on MOSDAC. New Applications were released on MOSDAC for operational use, Rip current forecast, Ocean Eye and Forecasts of Discomfort Index. Operationalisation of total 31 products from INSAT-3DR

algorithms for geophysical parameters was hosted on MOSDAC. Diagnostic Rip current forecasting system was made operational for Goa coast on MOSDAC. Algorithm was developed for aerosol optical depth retrieval from INSAT-3D/3DR data and operationalisation of aerosol product has been completed on VEDAS and MOSDAC. A unique training programme "Satellite Meteorology and Oceanography Research and Training (SMART)" has been initiated. About 34 research projects in the field of Meteorology and Oceanography were completed under SMART programme and 10 training programmes were conducted under Training and Research in Earth Ecosystems (TREES).

4.7.4.4 Visualisation of Earth observation Data and Archival System (VEDAS)

VEDAS is a web based archival, dissemination and visualisation of Earth Observation derived data products for various themes with a focus on giving opportunities for academia to do research in Geo-spatial area using facilities made available at SAC, Ahmedabad premises. It will help in the use of spatial infrastructure, information dissemination system and training on R&D platform. VEDAS portal is hosting WEB GIS based applications and tools such as, Vegetation Monitoring, New and renewable energy, Himalayan Glacier Information System (HGIS), Air quality monitoring and Urban Sprawl Information System (USIS).



4.7.4.5 Indian Space Science Data Centre (ISSDC)

ISSDC is the primary data centre for the payload data archives of Indian Space Science Missions. This data centre, located at the IDSN campus in Bengaluru, is responsible for the Ingest, Archive, and Dissemination of the payload data and related ancillary data for Space Science missions like Chandrayaan, AstroSat etc.

ISSDC continued to support Megha-Tropiques, AstroSat, MOM, SARAL and AISSB / RESOURCESAT-2 for connected users, besides post mission life activities for Chandrayaan-1 and YOUTHSAT. First Year Data from Mars Orbiter Mission (MOM) was released on September 24, 2016. ISTRAC is geared up to support India's major Lunar Mission Chandrayaan-2 SPADEX, Aditya -L1 missions with upgradation to ISSDC.

4.8 Systems Reliability and Safety

Reliability and Quality are vital in the success of ISRO's space missions. Considering the importance of Quality and Reliability, Directorate of Systems Reliability and Quality (DSRQ) at ISRO Headquarters strives towards ensuring the reliability of space systems. These efforts include standardisation of procedures, sharing of best practices, continuous Quality improvement measures, Quality reviews, and Quality outreach initiatives.

4.8.1 ISRO Technical Standards (ITecS)

Taking into account the vast experience gained by ISRO over time, it was strongly felt that ISRO should bring out its own technical standards. Towards this, DSRQ has interacted with experts and came out with a list of around 30 standards to be generated in the area of Electrical & Electronics and Mechanical disciplines on priority basis. Considering the vast experience of senior retired ISRO officials, it is planned to effectively utilise their services in the realisation of ITecS. In this regard, Task teams have been constituted with these experts as Chairpersons / members.

Two new ISRO Reliability Standards have been released in critical areas, namely, "Protocols for Interfacing between SCL and Other ISRO Centres for the Realisation of ASICs" and "Rain Proofing and Thermal Protection Systems for Launch Vehicles". Efforts are also on to revise the other ISRO Reliability Standards, which are due for update.

4.8.2 Product Assurance Activities

Integrated Product Assurance Board (IPAB) is an ISRO level apex body, with the main thrust on improving the Quality and Reliability of Space systems. Efforts have been continuing through standardisation, implementation of uniform quality practices and sharing of best practices across the organisation. Identifying and addressing systemic quality issues and bringing out specific recommendations for achieving sero defects in space missions have been the key contributions of the IPAB. The board addressed systemic issues related to the missions GSAT-9, 17, 19 and Cartosat-2 Series satellite, and also the key findings of Failure Analysis Boards (FAB) across ISRO in Avionics area.

As part of Quality Improvement Programme – Launch Vehicle, (QIP-LV), a delegation of seven engineers from Quality and Reliability area was deputed to CNES, Paris during January, 2017. An exclusive IPAB meeting was convened to discuss and share the feedback from this specialist team. The suggestions include generating design rules, product defect catalogue, process FMEA and test optimisation etc.

A summary report capturing the important recommendations of IPAB over the last six years was generated and submitted to Chairman, ISRO & also disseminated to all Centre Directors. The report covers the suggestions of the board, specific to Projects, technical areas, Centres and also various other initiatives related to Quality improvement.

Towards sharing of best practices and also important lessons learnt, a one-day workshop on Aerospace mechanical hardware fabrication, is planned to be organised at LPSC, Thiruvananthapuram during early November, 2017.

4.8.3 Path-Sampada

The in-house developed software platform "Path-Sampada" for documenting and sharing the lessons learned during the life cycle of various space systems has been populated with more than 800 lessons. Taking the feedback from various users spread across the organisation, augmentation of this

platform was undertaken. Several important features including discussion forum and Quality alerts are incorporated in the upcoming version 2.0 of Path-Sampada.

4.8.4 Continual Improvement

Analysis related to in-orbit anomalies

Towards promoting continuous Quality improvement, efforts were put to analyse the in-orbit anomalies and identify the generic issues in the subsystems on-board the Spacecraft. This is a follow-up of similar activity carried out earlier during 2013. Based on this analysis, comprehensive reports were generated highlighting the problem areas and suggest corrective actions. This will be an effective feedback for designers and other related agencies, towards improving the Quality of future missions.

Comprehensive Quality Assessment and Auditing (CQAAT) for GSLV-MkIII D1

A Comprehensive Quality Audit of the entire vehicle systems for GSLV-MkIII D1 was undertaken. This exercise covered the whole gamut of activities right from verifying the compliance status of the recommendations from various review fora, adequacy of Qualification and Acceptance tests, major non-conformances and failures during the life cycle, verification of log books and performance records. Specific attention was given to the C-25 Cryo stage and vehicle operations at launch pad by organising dedicated reviews at IPRC, Mahendragiri and SDSC, SHAR. Suggestions related to timely completion of sub-system / systems qualification, and upkeep of the records well before the launch were brought out. The key findings were presented to the Mission Readiness Review (MRR).

Structured Training Programme

DSRQ as the nodal agency was instrumental in organising a five-day Structured Training Programme with a theme titled “Missions Accomplished-Lessons Learned” for the ISRO middle level (SE/SF/SG) 35 engineers during October 2017.

4.8.5 Quality Outreach

International Technical Meet on “Quality Assurance Practices”

As a way forward in the area of Quality Assurance, a unique two-day International Technical Meet on “Quality Assurance Practices” was organised during January 2018 at ISRO HQ, Bengaluru. The primary objective of organising this programme was to enable exchange of knowledge and experience between ISRO and other space faring nations, specifically on the way forward related to Quality Assurance of Space systems. Experts from various space agencies like NASA, ESA & JAXA and industries like Boeing, Arianespace, etc., were participated in this event.

4.8.6 Health QUEST

In an endeavor to improve the quality practices in Medical Profession, especially in Critical care and Emergency care departments, the Indian Medical fraternity expressed their interest in adopting some of the best quality practices followed by ISRO. In this regard, DSRQ functioned as the overall focal point. Detailed deliberations between ISRO experts and medical professionals were arranged. The efforts culminated in the generation two guideline documents titled Health-Quality Upgradation Enabled by Space Technology, "Health-QUEST" for Critical care and Emergency care. These editions were released during the National Health Conclave at New Delhi during August 2017.

4.8.7 Safety Services

The space programme continued to be free from any major incidents during this year. The scheduled launches of PSLV-C38/ CARTOSAT-2 with 30 satellites, PSLV-C39/ IRNSS-1H, GSLV-F09/GSAT-9 and first development at flight of India's GSLV-MkIII/GSAT-19 were successfully completed without any safety related non-conformance. Like previous launches, well established safety procedures, safety standards and emergency preparedness plan were implemented to prevent unforeseen incidences. Safety surveillances were available round the clock during the launch campaign activities. Activities involving production and transportation of solid propellants, earth storable propellants, cryogenic propellants, rocket motors & pyrotechnic materials etc; and assembly and integration of rocket stages, satellites and high pressure gas servicing at launch pad were carried out under the full time participation of safety team.

The most significant achievement of this year is the cold flow tests of eco-friendly Semi cryogenic Engine turbo pumps. Turbo pump systems of semi cryogenic engine namely Low Pressure Oxidiser Turbo pump, Low Pressure Fuel Turbo pump and Main Oxidiser Pump underwent cold flow tests and cavitation tests at ISRO Propulsion Complex (IPRC). The acceptance tests of Cryogenic Engines for the upcoming GSLV-F08 and GSLV-MKIII-D2 were also completed without any safety implications.

Safety surveillance was in place during fabrication, integration, thermovac test, vibration test and pressure hold test of GSAT-6A, GSAT-19, GSAT-17, GSAT-11 and IRNSS-1H satellites. Safety clearance was issued for pressure hold test and dynamic tests of IRNSS-1H and Chandrayan-2 orbiter. Safety review of radiation sources for various spacecraft was also completed without any waivers.

Safety committees at various ISRO/DOS centres reviewed and cleared locations for construction and commissioning of new facilities, imparted safety inductions to all personnel joining ISRO and specific safety awareness were given on work related hazards. Training was provided on fire fighting and general safety to all employees in ISRO. Safety promotional activities have been continued through the celebration of National safety day, Fire service day and World environment day by issuing posters and conducting safety seminars.

4.9 Space Commerce (Antrix)

Antrix Corporation Limited (ACL) is a wholly owned Government of India Company under Department of Space. Antrix is responsible for commercial exploitation of products and services emanating from Indian space program. Antrix undertakes various initiatives for global marketing of space products and services and presently includes the following:

Transponder Leasing: Through INSAT/GSAT fleet of satellites, Antrix enables Satellite Communication based services predominantly covering the Indian region. The services are provided for a multitude of applications like Television Broadcasting (TV), Direct-to-Home (DTH), Digital Satellite News Gathering (DSNG), Mobile communications (MSS) and Very Small Aperture Terminal (VSAT) in S-band, Ext. C, C and Ku-band. On a commercial basis, Antrix is serving more than 100 Indian users, across a wide cross section of Private, Public and Government sectors. Additionally, transponders on foreign satellites operating over India are being provisioned on a short term lease basis for meeting the specific requirements of DTH and VSAT customers. Various DTH and VSAT customers have been allotted capacity on recently launched INSAT/GSAT satellites to fulfill their additional bandwidth requirements, Steady plans to migrate the traffic from foreign satellites is being worked out independently with all users.

Mission Support Services: Antrix has made further strides in the provision of Telemetry and Telecommand (TTC) support to international customers. Today, Antrix is recognised as one of the most prominent service provides from this part of the world. Our capabilities in providing TTC support are well established, with prominent international customers 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 and Ku-band Transfer Orbit Support Service (TOSS) mission of international satellites from MCF, Hassan. Antrix is continuing to provide long term TTC support for two satellites through commercial agreement with prestigious international customers from Europe. There has been a growing demand from customers and new business opportunities are being constantly explored.

During the year, Antrix has also entered into Launch Service Agreements with several companies especially from USA and UK for launching their micro and nano satellites as co-passengers. Discussions are in the advanced stage for providing Dedicated PSLV launch services to one of the international customers in the coming years. Antrix is, also making its best efforts to commercially make available GSLV and GSLV-MkIII launch vehicle to cater to international customer satellite launch needs in the future.

New business opportunities: In the area of export of the satellite subsystems and systems, enquiries from prospective customers are being pursued. Sun Sensors and Silicon Photo Detectors for customer satellite requirements have been successfully delivered. Sub systems with potential for commercial demand are being identified. The customer requirements for use of specialised ISRO test facilities has been enabled.

A MoU has been entered with IMD to establish state of art Multi Mission Meteorological Data reception and Processing System.

Antrix is foraying into offering NavIC based products and services and is identifying various business opportunities and partners across India. Antrix is also taking proactive action for making NavIC receivers for various applications.

Indian Remote Sensing (IRS) and Data Services: The global marketing of IRS data is being pursued in collaboration with International partners. Currently, Antrix markets IRS data and services from Resourcesat-2, Cartosat-1 and Oceansat-2 satellites. The currently operational IRS Ground Stations (IGS) are GAF AG, Germany, for Cartosat-1 and Resourcesat-2, and University of Dundee, UK for Oceansat-2 satellites. Contract for Cartosat-1 with Algeria has been successfully concluded and being negotiated for extension of contract. Contract with KSAT for RISAT-1 data is also concluded. Antrix has signed an Umbrella agreement with GAF AG, Germany to jointly bid for International applications and training projects. Antrix is in the process of expanding the IRS ground segment and Reseller Network to promote IRS data products across the globe.

Antrix celebrated Silver Jubilee on September 15, 2017 and a souvenir on Antrix was released. Three technical sessions covering business segments of Antrix were conducted. The event was attended by over 500 delegates from ISRO/DOS, Business Partners, Industries and Customers of Antrix.

Release of Souvenir on ANTRIX during the Silver Jubilee Function

The Drafting and Evidence Sub-Committee of the Committee of Parliament on Official Language reviewed the progress of Official Language implementation in PSUs and the committee members appreciated the efforts and suggested to maximize the use of Official Language in Official Work.

As part of its Corporate Social Responsibility (CSR) efforts, Antrix has undertaken several activities in the field of rural development, drinking water supply, support to differently abled persons, Swachh Bharat Abhiyaan, health care and education.

'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 2016 as shown below:-

Questions	Budget Session		Monsoon Session		Total	
	11th session-16th Lok Sabha	242nd session of Rajya Sabha	12th Session-16th Lok Sabha	243rd Session of Rajya Sabha	L.S.	R.S.
Starred Questions	02	01	02	01	04	02
Unstarred Questions	25	17	15	07	40	24
Total	27	18	17	08	44	26

The Questions were related to ISRO Rover on Lunar Surface, Inter-Planetary Mission, Land Sensing Satellite data, Regional Positioning System, 83 Satellite in one go, Brew beer on Moon, Achievements of Mars Orbiter Mission, Private Sector participation in Space Programmes, Launch of 104 Satellites, ISRO-NASA collaboration, Global Positioning System, Plans for commercial Space Tourism and Travel, Launch of Nano Satellites, GSAT-10, NavIC, Achievements in Space Sector, Indigenous Satellites, Chandrayaan-1, Indian Satellites in Outer Surface, New Satellite Launch Pads, Updates on Mars Orbiter Spacecraft, Desi Global Positioning System, Venus Mission of ISRO etc.

During the year 2017, till September, seven (07) Parliamentary Committees have visited and held discussion with representatives of various Centres/Units of the Department of Space.

Vigilance

Vigilance Awareness Week was observed in all DOS / ISRO Centres / Units commencing with the pledge by the employees on October 30, 2017. The theme of observing the "Vigilance Awareness Week-2017" was “My Vision - Corruption Free India”.

The highlights of the activities carried out during "Vigilance Awareness Week-2017" in the Centres / Units of DOS / ISRO are:

Centre		Activity
VSSC	-	Displayed banners of Vigilance Awareness Week - 2017 at various prime locations in VSSC and IISU.
	-	Administered Pledge on 30.10.2017 at Division / Entity / Project level in VSSC and IISU.
	-	Conducted Elocution competition on Anti-Corruption topic for the students of VSSC Central School on 01.11.2017 and for employees of VSSC and IISU on 02.11.2017.
	-	A circular regarding do’s and don’ts to be followed by all Government servants has been issued.
	-	All the employees of VSSC and IISU were invited to take online integrity pledge.
	-	A Lecture was arranged by eminent personality.
SDSC-SHAR	-	Circulars were issued highlighting the importance of celebrating “Vigilance Awareness Week”.
	-	Displayed banners on Vigilance Awareness Week - 2017 at main places SDSC-SHAR.
	-	Conducted Essay writing competition.
	-	Conducted skit competitions on the vigilance related matters.
LPSC	-	Vigilance Awareness Week commenced by taking Integrity Pledge
	-	Conducted Elocution competition for college students
	-	Arranged a Lecture by eminent personality.
	-	As envisaged by Central Vigilance Commission, guidelines on personal integrity, use of public money, procurement activities, security of data / information and installation etc were circulated among the employees.

ISTRAC	-	Displayed banners on Vigilance Awareness Week - 2017 to spread awareness among the employees on the observance of Vigilance Awareness Week 2017 during the period 30.10.2017 to 04.11.2017.
	-	Pledge was administered at ISTRAC, Bengaluru and other Units / TTC Stations of ISTRAC.
	-	Integrity e-pledge took by employees of ISTRAC.
MCF	-	Displayed banners of Vigilance Awareness Week – 2017 at conspicuous places in MCF campus.
	-	All employees were informed and sensitised about the provisions of CCS (Conduct) Rules, 1964 by issuing circular.
ADRIN	-	Arranged a Lecture by eminent personality and Administered the Pledge.
ISRO HQ	-	Displayed banners with the caption "Vigilance Awareness Week" from 31.10.2017 to 04.11.2017 along with the theme at prominent places at all DOS /ISRO Centres / Units.
	-	Conducted Elocution competition for employees of DOS / ISRO and students of Kendriya Vidyalaya on the theme.
	-	Letter Writing competition was conducted for the employees of ISRO / DOS. The topic was to write a motivating letter from elder brother / sister to younger brother / sister on the theme "My Vision – "Corruption Free India".
	-	A speech by eminent personality was organised on Vigilance matters.
NARL	-	Displayed banners of Vigilance Awareness Week – at NARL Vigilance Awareness Week commenced by taking Integrity pledge
	-	Conducted an Essay writing competition, Slogan writing competition.
	-	Conducted Elocution competition.
	-	A Lecture by eminent personality was arranged on Vigilance matters.
PRL	-	Vigilance Awareness Week commenced by taking Integrity pledge
	-	Conducted an essay writing competition
	-	An awareness lecture conducted on (a) "My Vision – Corruption free India" (b) "Vigilance Machinery of the government and Vigilance Awareness in Administration"
IIST	-	Banners were displayed in the campus
	-	Vigilance Awareness Week commenced by taking Integrity pledge
	-	Arranged a Lecture by eminent personality on the theme.

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

Category of Employees	Type of cases	Cases pending as on 01.10.2016	Cases received during the Period 01.10.2016 to 30.09.2017	Total (Col. 3+4)	Disposed during 01.10.2016 to 30.09.2017	Pending (Col. 5-6)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Group - A & Group-B (Gazetted)	Disciplinary (non-vigilance)	10	07	17	02	15
	Vigilance	08	01	09	03	06
Group - B (non-Gazetted) Groups C & D	Disciplinary (non-vigilance)	02	16	18	12	06
	Vigilance	00	00	00	00	00
	Total	**20**	**24**	**44**	**17**	**27**

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 Third meeting of Sanyukt Hindi Salahkar Samiti (JHSS) for DOS and DAE under the Chairmanship of MOS, PMO was organised at New Delhi on September 26, 2017.
- The Documentation and Evidence Sub Committee of the Committee of Parliament on Official Language inspects various Centres/Units of the Department. This year the Committee visited MCF, Bhopal, Antrix and the TOLIC headed by ISAC, Bengaluru with regard to inspection of the progress made in the Implementation of Official Language.
- ISAC has been entrusted the charge of TOLIC (A), Bengaluru. Director, ISAC is the Chairman of this TOLIC.
- The Department participated in the 39th meeting of the Central Official Language Implementation Committee held at New Delhi on 28.06.2017
- All the centre/units of the Department located 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 Rs.63,643 has been spent for the purchase of Hindi books for ISRO Library, which is in accordance with the target set up by DOL.
- During the year, for the publication of advertisements in Hindi in the newspapers the expenditure by Department was according to the target prescribed by DOL.
- In order to implement Hindi in more meaningful and effective manner and to evaluate the progressive use of Hindi in DOS/ISRO Centres/Units, an Annual Inspection Programme was drawn up by Department and inspections were carried out. The Officers from Regional Implementation Offices of Department of Official Language have also inspected the various Centres/Units to review the progressive use of Hindi.
- Deputy Director, Regional Implementation Office, Bengaluru inspected DOS/ISRO HQ on 07.08.2017 with regard to the O.L. implementation. Many of the O.L. related works of the Department were appreciated by the inspecting officer. Also, many suggestions were given for the effective O.L. implementation in the Department.
- Internal inspections of various Section of DOS/ISRO and also other Centres/Units were carried out to increase use of Hindi in day to day work. Sections doing best implementation of Official Language were awarded in DOS/ISRO HQ during the Hindi Fortnight Valedictory function organised on 09.10.2017.

- Under the Hindi Training Programme under the New Hindi Training Course introduced by the Hindi Teaching Scheme of the Government of India, "Parangat", introduced by the Hindi Teaching Scheme of the Government of India, continued during the year in the Department. The second batch of 20 officers/employees from DOS/ISRO HQ had been nominated for this training for Jan-May, 2017 session.
- Other training programmes in Hindi through Hindi Teaching Scheme, under Correspondence course is on in the Department. The percentage of employees possessing working knowledge of Hindi in all DOS/ISRO Centres/Units has considerably increased to more than 80 per cent. The Centres/Units have been requested to prepare an action plan for imparting training to the remaining employees and to complete the training programme at the earliest. Out of the total strength of 16,691 in the department, 16,146 have the working knowledge of Hindi and 2,746 are proficient in Hindi and remaining 545 employees will be given training in a phased manner.
- Hindi Day, Hindi Week, Hindi Fortnight/Hindi Month and Hindi Workshops have been organised, in all DOS/ISRO Centres/Units, during which competitions in Essay Writing, Noting and Drafting, typing, quiz, poetry writing, Story Telling, What picture Speaks?, News Reading, Memory, Elocution, Conversation, etc. have been conducted. 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 propagation of Hindi door-to-door, the family members of the employees were included during Hindi Fortnight celebrations in all Centres/Units of the Department and there was an overwhelming response.
- Reward awarding the children of the employees who secure highest marks in Hindi in class X & XII continued during the year..
- With a view to refresh and update the knowledge of Official Language personnel an 'Official Language Orientation Programme' was organised by ISTRAC, Lucknow on 10.11.2017.
- world Hindi Day was celebrated on 10th January, 2018 in all Centres/Units of the Department by conducting various programmes.
- Department plays an active role in the activities of Town OLIC. It conducts various programmes under the auspices of Town OLIC. Hindi Solo singing competition was organised by the department for the Town OLIC member offices in Hindi on 06.10.2017. On the occasion of Vishwa Hindi Diwas 'Kavyagoshthi' was organized on 10 January, 2018 where in the participants presented the poems penned by them.
- During the year eight (8) Books in Hindi on Scientific subjects have been written by the Scientists of Space Applications Centre, Ahmedabad, Satish Dhawan Space Centre and ISRO Satellite Centre. All these 8 books have been published by the Department. Publication of Technical Articles by the Scientists of the Department in leading magazines continued during the year. 03 articles were sent to Department of Official Language, New Delhi to be considered for award.
- DOS/ISRO HQ in-house magazine "Disha" & compendium of technical articles "Antariksh Gyan Sarita" were published during the year.

- Several pamphlets, Panel (85) and stickers/posters on Indian Space Programme PSLV-C36, 37, 38, GSLV-MarkIII, GSAT-9, TeLEOS, RLV-TD, etc, were brought out in Hindi. "Antariksh Bharat" biannual technical magazine was also brought out by Department in Hindi. In-house Hindi magazines were brought out by various Centres/Units of the Department.

- ISRO conducts several outreach programmes also in order to reach out the space activities to the common man and student community. On the recommendation of the members of JHSS, an exhibition on space was organised during 03-04 August, 2017 in Jawahar Vidya Mandir, Ranchi by the Department. Exhibition Panels were displayed in Hindi and other publication material in Hindi was distributed to the students. This exhibition had a good media coverage and received a very good response. In this programme, apart from the exhibition, there was water rocket launch and quiz competition for the students. Around 10,000 students from over 60 schools of Ranchi participated in this programme.

- The website of the department is regularly updated in bilingual. In addition to Department's own Website, SAC, PRL, NRSC and NARL also have their own Websites. DOS/ISROHQ, SAC, VSSC, LPSC, SHAR also have internal web pages on intranet.

- 'Hindi Fortnight Incentive Scheme' continued during the year under which the Officers/Employees doing maximum work in Hindi during the Hindi month were awarded. The new incentive scheme of the Department "SOLIS" introduced two year ago, continued.

- The Incentive Scheme "Vikram Sarabhai Maulik Lekhan Yojana" introduced to encourage the Scientists of the Department to write books on Scientific subjects in Hindi continued during the year.

- During the year various centres/units of the department conducted technical seminars in Hindi on various subjects. Nine (09) technical seminars were organised. All the centres also organized a session on official language during their technical seminars. Seminar Souvenir in electronic/book form was also brought out.

- The employees of DOS/ISRO Centres/Units have also participated in the activities on progressive use of Hindi organised by various voluntary organisations and also by Town OLIC.

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

- Also, the work regarding the preparation of Basic Space Science Glossary of the Department initiated in collaboration with CSTT, New Delhi was completed during the year.

- The Space Science Glossary of the Department is available in electronic form and is uploaded on website for use by general public.

- The Department has taken up the task of inclusion of Hindi in COINS, the web version of COWAA. The translation work of the various forms have been completed and handed over to the COINS team in SDSC,SHAR who will integrate these forms into COINS.

Recognition:

National Level

- For Best implementation of Official Language policy of the GOI, Department of Space was awarded the "Rajbhasha Kirti Puraskar" (1st Prize) by His Excellency the President of India in a function organised at Rashtrapati Bhawan, New Delhi on 14.09.2017 and it was received by the Additional Secretary, DOS.

Additional Secretary, DOS receiving Rajbhasha Kirti Award (First Prize) from the His Excellency the President of India

Regional Level:

- SAC, Ahmedabad was awarded First Prize for Best Implementation at Regional Level for western region.ILC, Mumbai was awarded First prize for South Western Region – 'B' Region in the category of offices with staff strength upto 10. MCF, Bhopal was awarded First prize for Western Region – 'A' Region in the category of offices with staff strength upto 50. ARDIN, Secundrabad was awarded 3rd prize for South Region – 'B' Region.

TOWN level

- The following centre/units of DOS were awarded prizes for best implementation of Hindi for the year 2016-17 by respective Town OLICs during the year :-

1. Department of Space/ISRO HQ was awarded First Prize by Town OLIC, Bengaluru
2. DECU, Ahmedabad was awarded First Prize by the TOLIC.
3. VSSC, Thiruvananthapuram was awarded First Prize by the TOLIC. VSSC's In-house magazine received First prize by TOLIC.
4. SCL, Chandigarh was awarded Second prize by TOLIC. SCL's In-house magazine received First prize by TOLIC.
5. ISTRAC, Bengaluru was awarded Third Prize by the TOLIC.

Right to Information

Right To Information (RTI) Act 2005 is implemented in this 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) at all DOS/ISRO Centres/Units and Autonomous Bodies for receiving applications, First Appellate Authority for disposal of stage one Appeals and Transparency Officer for ensuring proper implementation of RTI Act in the Department. As per Section 4 (1) (b) of RTI Act, Department of Space has published requisite information on the web page: https://www.isro.gov.in/right-to-information

The following information is available on the website:

- Guidelines for submission of application under RTI Act, 2005.
- Milestones of the Department of Space/Indian Space Research Organisation
- Annual Report 2016 – 2017 (English / Hindi)
- Human Resources
- Citizens' Charter
- Public Grievances
- Suo-Motu disclosure of official tours of Joint Secretary level officials and above
- 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
- Particulars of arrangements for consultation with or representation by the public in relation to the formulation of policies and implementation thereof by Department of Space
- 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 its officers and employees & Monthly remuneration received by each of its officers and employees
- Budget at a glance 2017-18 & Budget Profile.
- 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

- Information available to or held by the Department of Space in an electronic form
  a. DOS Purchase Manual 2015 (English & Hindi)
  b. DOS Book of Financial Powers, 2016
- Particulars of facilities available to citizens for obtaining information on Department of Space / ISRO
- Names, designations and other particulars of the Public Information Officers, Assistant Public Information Officers.

In addition to the above, the following information also uploaded periodically in the website:

(a) Transfer Policy for the administrative cadre.
(b) Status of implementation of RTI Act, 2005
(c) Detailed Demands for Grants
(d) Output-Outcome Framework for Schemes 2017-18

For effective implementation of RTI Act in DOS/ISRO and improve the efficiency in handling the RTI applications, this Department conducted RTI workshop for its Public Information Officers & Assistant Public Information Officers on May 22, 2017.

During the period January 2017 to December 2017, 1,163 applications were received and information were disseminated under the provisions of the RTI Act. 203 Appeals were received by the First Appellate Authority and 12 appellants approached the Second Appellate Authority, i.e., Central Information Commission.

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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	One	Nil	Nil	Nil	Nil
2.	Report No. 4 of 2012-2013 Hybrid satellite digital multimedia broadcasting service agreement with Devas	One	Nil	Nil	Nil	Nil
3.	Report No. 22 of 2013 (Para No. 3.1) Edusat Utilisation Programme	One	Nil	Nil	Nil	Nil
4.	Report No. 22 of 2013 (Para No. 3.3) Loss due to unsafe transport and belated insurance of consignment	One	Nil	Nil	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
5.	Report No. 22 of 2014 (Para No. 4.1) Inordinate delay in realisation of SRE-2 mission	One	Nil	Nil	Nil	Nil
6.	Report No. 22 of 2014 (Para No.4.2) Loss in allocation of satellite Capacity	One	Nil	Nil	Nil	Nil
7.	Report No.30 of 2015 (Para No. 5.1) Implementation incentive scheme	One	Nil	Nil	Nil	Nil
8	Report No.30 of 2015 (Para No. 5.3) Avoidable payment of electricity charges	One	Nil	Nil	Nil	Nil
9	Report No.12 of 2016 (Para No.5.1) Computerisation in administration, finance and related areas	One	Nil	Nil	Nil	Nil
10	Report No.12 of 2016 (Para No.5.2) Implementation of Telemedicine Programme	One	Nil	Nil	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
11	Report No.12 of 2016 (Para No.5.3) Wasteful expenditure on material for propellant tanks	One	Nil	Nil	Nil	Nil
12	Report No.12 of 2016 (Para No.5.4) Loss due to delayed commissioning of equipment	One	Nil	Nil	Nil	Nil
13	Report No.12 of 2016 (Para No.5.5) Unfruitful expenditure on consultancy services	One	Nil	Nil	Nil	Nil
14	Report No.12 of 2016 (Para No.5.6) Non-levy of labour welfare cess on construction work payment	One	Nil	Nil	Nil	Nil
15	Report No.33 of 2016 Management of Launch Services	Nil	Nil	One	Nil	Nil
16	Report No.17 of 2017 (Para no.6.1) Management of VSAT Services	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
17	Report No.17 of 2017 (Para No.6.2) Irregular Expenditure on Pre-Project Activities"	Nil	Nil	Nil	One	Nil
18	Report No.17 of 2017 (Para No.6.3) Lack of Financial Prudence and improper contract Management in the Delivery of Commercial Spacecraft	Nil	Nil	Nil	One	Nil
19	Report No.17 of 2017 (Para No.6.4) Infructuous Expenditure in purchase of ecologically fragile land'	One	Nil	Nil	Nil	Nil

(B) Summary of important Audit Observations during 2017

1. C&AG Report Union Government, Scientific Departments Report No. 33 of 2016 Para 6.1 titled "Management of Launch Services":

The audit observations made in the said audit Report are with reference to realisation & delivery of PSLV launch services and launch of Geo-stationary satellites.

2. C&AG Report Union Government, Scientific Departments Report No. 17 of 2017 Para 6.1 titled "Management of VSAT Services":

Department of Space allocated satellite capacity for VSAT users without framing a transponder allocation policy for the allocation of transponders to various users. Consequently, there was no prescribed procedure for allocation of satellite capacity for VSAT services. There were instances of loss due to non-revision of transponder charges, under-pricing of transponder charges for VSAT services, payment of higher service charges to Antrix Corporation Limited; deficiencies in contract management leading to idling of satellite capacity, non-realisation of dues, undue benefits to VSAT users due to downward revision of prices, etc. amounting to ₹421.05 Crore in the test checked cases.

3. C&AG Report Union Government, Scientific Departments Report No. 17 of 2017 Para 6.2 titled "Irregular Expenditure on Pre-Project activities":

Expenditure of ₹136.88 Crore on pre-project activities for the Indian Manned Space Programme was incurred without obtaining approval of the competent authority.

4. C&AG Report Union Government, Scientific Departments Report No. 17 of 2017 Para 6.3 titled "Lack of Financial Prudence and improper contract Management in the Delivery of Commercial Spacecraft":

C&AG have pointed out that the Indian Space Research Organisation developed two commercial spacecraft for a foreign client at a price that was lower than its cost of production, which resulted in under recovery of ₹54.44 Crore. In addition, improper contract management resulted in further loss of ₹29.03 Crore.

5. C&AG Report Union Government, Scientific Departments Report No. 17 of 2017 Para 6.4 titled "Infructuous Expenditure in purchase of ecologically fragile land":

C&AG have pointed out that the Department of Space incurred expenditure of ₹3.70 Crore in purchase and construction work on 81.50 acres of ecologically fragile land in Thiruvananthapuram, Kerala which was rendered Infructuous as the Department was ultimately evicted from the land by the State Government.

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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 onboard (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 onboard (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 onboard (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 onboard (September 20, 1993). Satellite could not be placed in orbit

1994

- Fourth developmental launch of ASLV with SROSS-C2 onboard (May 4, 1994). Satellite placed in orbit
- PSLV-D2, the second developmental launch of PSLV with IRS-P2 onboard (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 onboard (March 21, 1996). Satellite placed in Polar Sun Synchronous Orbit

1997

- INSAT-2D, fourth satellite in INSAT-2 series, launched (June 4, 1997). Becomes in-operable 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 onboard (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 onboard
- 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 onboard 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 onboard (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 onboard 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-MkIII 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-MkIII) was successfully conducted from Satish Dhawan Space Centre SHAR, Sriharikota on December 18, 2014. CARE module carried onboard 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).

2016

- The Polar Satellite Launch Vehicle, in its 33rd flight (PSLV-C31), launches IRNSS-1E, the fifth satellite of the Indian Regional Navigation Satellite System (IRNSS) on January 20, 2016 from SDSC SHAR, Sriharikota.
- The Polar Satellite Launch Vehicle, in its 34th flight (PSLV-C32), launches IRNSS-1F, the sixth satellite of the Indian Regional Navigational Satellite System (IRNSS) on March 10, 2016 from SDSC SHAR, Sriharikota.
- The Polar Satellite Launch Vehicle, in its 35th flight (PSLV-C33), launches IRNSS-1G, the seventh satellite of the Indian Regional Navigation Satellite System (IRNSS) into a Sub-Geosynchronous Transfer Orbit (Sub-GTO) on April 28, 2016 from SDSC SHAR, Sriharikota.
- India's Reusable Launch Vehicle-Technology Demonstrator (RLV-TD), successfully flight tested on May 23, 2016 from SDSC SHAR, Sriharikota. RLV-TD is one of the most technologically challenging endeavors of ISRO towards developing essential technologies for a fully reusable launch vehicle to enable low cost access to space.
- India's Polar Satellite Launch Vehicle, in its 36th flight (PSLV-C34), launches the 727.5 kg Cartosat-2 Series Satellite for earth observation and 19 co-passenger satellites together weighing about 560 kg at lift–off into a 505 km polar Sun Synchronous Orbit (SSO) on June 22, 2016 from Sriharikota. The co-passenger satellites are from USA, Canada, Germany and Indonesia as well as two satellites (SATHYABAMASAT and SWAYAM) from Indian University / Academic Institute.
- The first experimental mission of ISRO's Scramjet Engine towards the realisation of an Air Breathing Propulsion System was successfully conducted on August 28, 2016 from Satish Dhawan Space Centre SHAR, Sriharikota.
- India's Geosynchronous Satellite Launch Vehicle (GSLV), in its tenth flight (GSLV-F05) launches INSAT-3DR, an advanced weather satellite, weighing 2,211 kg into a Geostationary Transfer Orbit (GTO) on September 08, 2016 from SDSC SHAR, Sriharikota.
- India's Polar Satellite Launch Vehicle, in its 37th flight (PSLV-C35), launches the 371 kg SCATSAT-1 for weather related studies and seven co-passenger satellites into polar Sun Synchronous Orbit (SSO) on September 26, 2016 from SDSC SHAR Sriharikota. Co-passenger satellites are ALSAT-1B, ALSAT-2B, ALSAT-1N from Algeria, NLS-19 from Canada and Pathfinder-1 from USA as well as two satellites PRATHAM from IIT Bombay and PISAT from PES University, Bengaluru.
- India's latest communication satellite, GSAT-18 was inducted into the INSAT / GSAT system on October 06, 2016 from Kourou, French Guiana by Ariane-5 VA-231. Weighing 3,404 kg at lift-off, GSAT-18 carries 48 communication transponders to provide services in Normal C-band, Upper Extended C-band and Ku-bands of the frequency spectrum along with a Ku-band beacon for accurately pointing ground antennas towards the satellite.
- In its 38th flight (PSLV-C36), ISRO's Polar Satellite Launch Vehicle successfully launches 1,235 kg Resourcesat-2A Satellite on December 07, 2016 from Satish Dhawan Space Centre SHAR, Sriharikota. This is the 37th consecutively successful mission of PSLV.

2017

- In its thirty ninth flight (PSLV-C37), ISRO's Polar Satellite Launch Vehicle successfully launched the 714 kg Cartosat-2 Series Satellite along with 103 co-passenger satellites on February 15, 2017 from Satish Dhawan Space Centre SHAR, Sriharikota. This is the thirty-eighth consecutively successful mission of PSLV. The total weight of all the 104 satellites carried on-board PSLV-C37 was 1378 kg. This is the highest number of satellites launched in a Single Flight.

- India's Geosynchronous Satellite Launch Vehicle, in its eleventh flight (GSLV-F09) successfully launched the 2230 kg South Asia Satellite (GSAT-9) from SDSC SHAR, Sriharikota, into its planned Geosynchronous Transfer Orbit (GTO) on May 05, 2017. This is the fourth consecutive success achieved by GSLV carrying indigenously developed Cryogenic Upper Stage.

- The first developmental flight (GSLV-MkIII-D1) of India's heavy lift launch vehicle GSLV-MkIII was successfully conducted on June 05, 2017 from Satish Dhawan Space Centre SHAR, Sriharikota with the launch of GSAT-19 satellite. This was the first orbital mission of GSLV-MkIII, which was mainly intended to evaluate the vehicle performance including that of its fully indigenous cryogenic upper stage during the flight. Weighing 3136 kg at lift-off, GSAT-19 is the heaviest satellite launched from the Indian soil.

- ISRO’s Polar Satellite Launch Vehicle PSLV-C38 successfully launched the 712 kg Cartosat-2 Series Satellite along with 30 co-passenger satellites on June 23, 2017 from Satish Dhawan Space Centre SHAR, Sriharikota. This is the thirty-ninth consecutively successful mission of PSLV.

- India's latest communication satellite, GSAT-17 was inducted into the INSAT/GSAT system on June 29, 2017 from Kourou, French Guiana by Ariane-5 VA-238. The 3477 kg GSAT-17 carries communication payloads in C-band, Extended C-band and S-band for providing various services to the country. The satellite also carries equipment for meteorological data relay and satellite based search and rescue services.

- The forty-first flight of India’s Polar Satellite Launch Vehicle (PSLV-C39), carrying IRNSS-1H Navigation Satellite conducted on August 31, 2017 from Satish Dhawan Space Centre SHAR, Sriharikota, was unsuccessful.

2018

- In its 42nd flight, PSLV successfully launched the 710 kg Cartosat-2 Series Remote Sensing Satellite along with 30 co-passenger satellites on January 12, 2018 from Satish Dhawan Space Centre SHAR, Sriharikota. The co-passenger satellites comprise one Microsatellite and one Nanosatellite from India as well as 3 Microsatellites and 25 Nanosatellites from six countries, namely, Canada, Finland, France, Republic of Korea, UK and USA.

Acronyms

AAI	:	Airports Authority of India
ABPP	:	Air Breathing Propulsion Project
ACL	:	Antrix Corporation Limited
ADC	:	Analog-to-Digital Converter
ADCOS	:	Advisory Committee for Space Science
AFTN	:	Aeronautical Fixed Telecommunication Network
AICIL	:	Agricultural Insurance Company of India Ltd
AIR	:	All India Radio
ALIMCO	:	Artificial Limbs Manufacturing Corporation of India
AO	:	Announcement of Opportunity
APEP	:	Ammonium Perchlorate Experimental Plant
APIOs	:	Assistant Public Information Officers
APXS	:	Alpha Particle X-ray Spectrometer
ARFI	:	Aerosol Radiative Forcing over India
ARG	:	Automatic Rain Gauge
ASC	:	AstroSat Support Cell
ASCI	:	Administrative Staff College of India
ASDM	:	Aerial Services & Digital Mapping
ASPEX	:	Aditya Solar wind Particle Experiment
ATCTM	:	Atmospheric Trace Gases Chemistry and Transport Modeling
ATV	:	Advanced Technology Vehicle
AVIRIS-NG	:	Advanced Visible and Infrared Imaging Spectrometer-Next Generation
AWiFS	:	Advanced Wide Field Sensor
AWS	:	Automatic Weather Stations
BCs	:	Boundary Conditions
BDR	:	Baseline Design Review
BIEC	:	Bengaluru International Exhibition Centre
BSX	:	Bengaluru Space Expo
CA-CFAR	:	Cell Averaging Constant False Alarm Rate

CBM-Z	:	Carbon-Bond Mechanism version Z
CCD	:	Charge Coupled Device
CEJ	:	Equatorial Counter Electrojet
CES	:	Crew Escape System
CFT	:	Cold Flow Test
CHAMAN	:	Coordinated programme on Horticulture Assessment & Management using Geoinformatics
CII	:	Confederation of Indian Industry
CM	:	Crew Module
CME	:	Continuing Medical Education
COPLOT	:	Committee on Papers Laid on the Table
COWAA	:	Computerised Working in Administrative Areas
CPCS	:	Cabin Pressure Control System
CPIOs	:	Central Public Information Officers
CRS	:	Coarse Resolution ScanSAR
CSR	:	Corporate Social Responsibility
CSSTE-AP	:	Centre for Space Science and Technology Education in Asia and the Pacific
CUS	:	Cryogenic Upper Stage
CWDS	:	Cyclone Warning Dissemination System
CZTI	:	Cadmium Zinc Telluride Imager
DC	:	Deep Convective
DECU	:	Development and Educational Communication Unit
DEM	:	Digital Elevation Models
DGCA	:	Directorate General of Civil Aviation
DLA	:	Dual Launch Adaptor
DM	:	Dark Matter
DMA	:	Delhi Management Association
DMS	:	Disaster Management Support
DOA	:	Dioctyl Adipate
DOI	:	Digital Object Identifiers
DoLR	:	Department of Land Resources

DOS	:	Department of Space
DPT	:	Differential Pressure Transducers
DRT	:	Data Relay Transponder
DSC	:	Decision Support Centre
DSI	:	Drought Severity Index
DSNG	:	Digital Satellite News Gathering
DSPTs	:	Digital Satellite Phone Terminals
DSRQ	:	Directorate of Systems Reliability and Quality
DTH	:	Direct-To-Home
DWDS	:	Disaster Warning Dissemination Systems
ECLSS	:	Environmental Control and Life Support System
ECVs	:	Essential Climate Variables
EO	:	Earth Observation
EPRIS	:	Empowering Panchayati Raj Institutions Spatially
FEAST	:	Finite Element Analysis of Structures
FOV	:	Field of View
FRS	:	Fine Resolution Stripmap
FTP	:	File Transfer Protocol
GAGAN	:	GPS Aided GEO Augmented Navigation
GALEX	:	Galaxy Evolution Explorer
GCP	:	Ground Control Points
GEO	:	Geo-stationary Earth Orbit
GEOS-Chem	:	Goddard Earth Observation System Chemical
GFS	:	Global Forecasting System
GIS	:	Geographical Information System
GISAT	:	Geo Imaging Satellite
GMRT	:	Giant Metrewave Radio Telescope
GRBs	:	Gamma Ray Bursts
GSAT	:	Geo Synchronous Satellite
GSLV	:	Geosynchronous Satellite Launch Vehicle
GTO	:	Geosynchronous Transfer Orbit

HBCSE	:	Homi Bhabha Centre for Science Education
I&CAD	:	Irrigation and CAD
IAOP	:	Indian Astronomy Olympiad Programme
ICC	:	INSAT Coordination Committee
ICD	:	Interface Control Document
ICT	:	Information & Communication Technology
IGBP	:	ISRO Geosphere Biosphere Programme
IGS	:	International Ground Stations
IIRS	:	Indian Institute of Remote Sensing
IISc	:	Indian Institute of Science
IIST	:	Indian Institute of Space Science and Technology
IISU	:	ISRO Inertial Systems Unit
IITs	:	Indian Institute of Technologies
IMD	:	India Meteorological Department
IMDPS	:	INSAT Meteorological Data Processing System
IMG	:	Inter-Ministerial Group
IMGEOS	:	Integrated Multi mission Ground segment for Earth Observation Satellites
IMO	:	International Maritime Organisation
INC	:	IRNSS Navigation Centre
INCOSPAR	:	Indian National Committee for Space Research
INLUS	:	Indian Navigation Land Uplink Stations
INMCC	:	Indian Mission Control Centre
INRES	:	Indian Reference Stations
INSAT	:	Indian National Satellite
IPAB	:	Integrated Product Assurance Board
IPR	:	Intellectual Property Rights
IPRC	:	ISRO Propulsion Complex
IRCDR	:	IRNSS CDMA Ranging Stations
IRIMS	:	IRNSS Range and Integrity Monitoring Stations
IRNSS	:	Indian Regional Navigation Satellite System
IRNWT	:	IRNSS Network Timing Facility

IRSCF	:	IRNSS Spacecraft Control Facility
ISAC	:	ISRO Satellite Centre
ISEA	:	Indian Scientific Expedition to Antarctica
ISITE	:	ISRO Satellite Integration and Test Establishment
ISRO	:	Indian Space Research Organisation
ISTRAC	:	ISRO Telemetry Tracking and Command Network
JHSS	:	Sanyukt (Joint) Hindi Salahkar Samiti
KaRA	:	Ka-Band Radio Altimeter
kbps	:	kilobits per second
LAPT	:	Lander Actuator Performance Test
LAXPC	:	Large Area X-ray Proportional Counter
LEO	:	Low Earth Orbit
LEOS	:	Laboratory for Electro-Optics Systems
LIRAP	:	Laser Inertial Reference & Accelerometer Package
LIS	:	Land Information System
LOX	:	Liquid Oxygen
LPDC	:	Lander Pattern Detection Camera
LPFT	:	Low Pressure Fuel Turbo
LPOT	:	Low Presure Oxidiser Turbo
LPSC	:	Liquid Propulsion Systems Centre
LSPT	:	Lander Sensor Performance Test
LST	:	Land Surface Temperature
LULC	:	Land Use Land Cover
LUTs	:	Local User Terminals
M & E	:	Monitoring & Evaluation
mbps	:	megabits per seconds
MCF	:	Master Control Facility
MCNC	:	Marine Carbon Nitrogen Cycles
MIP	:	Moon Impact Probe
MIS	:	Management Information System
MNREGA	:	Mahatma Gandhi National Rural Employment Guarantee Act

MOM	:	Mars Orbiter Mission
MOP	:	Main Oxidiser Pump
MoSJ&E	:	Ministry of Social Justice & Empowerment
MOTR	:	Multi-Object Tracking Radar
MOX	:	Mission Operations Complex
MPW	:	Multi-Product Wafer
MRCCs	:	Maritime Rescue Coordination Centres
MRS	:	Medium Resolution ScanSAR
MSC	:	Maritime Safety Committee
MSDE	:	Ministry of Skill Development & Entrepreneurship
NARL	:	National Atmospheric Research Laboratory
NCEP	:	National Centre for Environmental Prediction
NCP	:	National Carbon Project
NDEM	:	National Database for Emergency Management
NDRF	:	National Disaster Response Force
NDVI	:	Normalised Difference Vegetation Index
NEC	:	North Eastern Council
NER	:	North Eastern Region
NE-SAC	:	North Eastern-Space Applications Centre
NHN	:	Nickel Hydrazine Nitrate
NIAS	:	National Institute of Advanced Studies
NICES	:	National Information system for Climate and Environment Studies
NOBLE	:	Network of Observatories for Boundary Layer Experiments
NPP	:	Net Primary Productivity
NRSC	:	National Remote Sensing Centre
NSSS	:	National Space Science Symposium
OCM	:	Ocean Colour Monitor
OGDRs	:	Operational Geophysical Records
OLI	:	Operational Land Imager
OLICs	:	Official Language Implementation Committees
OPO	:	Optical Parametric Oscillator

OSCAT	:	Oceansat-2 Scatterometer
OS-CFAR	:	Ordered Statistics CFAR
PC-NNRMS	:	Planning Committee on National Natural Resources Management System
PDMS	:	Polydimethylsilane
PDR	:	Preliminary Design Review
PFA	:	Post Flight Analysis
PHMS	:	Personal Hygiene Management System
PI	:	Principal Investigators
PLANEX	:	Planetary Exploration
POLIX	:	Polarimeter Instrument in X-rays
PRL	:	Physical Research Laboratory
PSLV	:	Polar Satellite Launch Vehicle
PSP	:	Pre-Signalised Points
PSTN	:	Public Switched Telephone Network
QPOs	:	Quasi Periodic Oscillations
R&D	:	Research & Development
RAWEX	:	Regional Aerosol Warming Experiment
RCCs	:	Rescue Coordination Centres
RESPOND	:	Research Sponsored
RLV-TD	:	Reusable Launch Vehicle-Technology Demonstrator
RN	:	Radio Networking
ROTs	:	Receive Only Terminals
RoU	:	Right of Usage
RRI	:	Raman Research Institute
RRSCs	:	Regional Remote Sensing Centres
RS	:	Restricted Service
RTI	:	Right To Information
RXTE	:	Rossi X-ray Timing Explorer
SAC	:	Space Applications Centre
SAP	:	State Action Plan
SAR	:	Synthetic Aperture Radar

SAS	:	Surface Active Substances
SAS&R	:	Satellite Aided Search and Rescue
SATNAV	:	Satellite Navigation
SBAS	:	Satellite Based Augmentation System
SCAT	:	Semicryo flow control Components Assembly and Test
SCES	:	Satellite Control Earth Stations
SCFT	:	Semi-cryogenic Cold Flow Test facility
SCL	:	Semi-Conductor Laboratory
SCPD	:	Soil Carbon Pools and Dynamics
SDLP	:	Space-based Distance Learning Programme
SDM	:	System Demonstration Module
SDSC	:	Satish Dhawan Space Centre
SIS	:	Signal-In-Space
SMA	:	Shape Memory Alloy
SMART	:	Satellite Meteorology and Oceanography Research and Training
SNR	:	Signal-to-Noise Ratio
SPL	:	Space Physics Laboratory
SPPU	:	Savitribai Phule Pune University
SPS	:	Standard Positioning Service
SRSAC	:	State Remote Sensing Application Centre
SSM	:	Scanning Sky Monitor
SSP	:	Space Studies Programme
SSPA	:	Solid State Power Amplifier
SSPO	:	Sun Synchronous Polar Orbit
SSTM	:	Sea Surface Temperature Monitor
STC	:	Space Technology Cells
STFS	:	Standard Time and Frequency Signal
STPs	:	Structured Training Programmes
Sub-GTO	:	Sub-Geosynchronous Transfer Orbit
SUIT	:	Solar Ultraviolet Imaging Telescope
SVAB	:	Second Vehicle Assembly Building

SXT	:	Soft X-ray Telescope
TDP	:	Technology Development Programmes
TEC	:	Total Electron Content
TERLS	:	Thumba Equatorial Rocket Launching Station
THCS	:	Temperature and Humidity Control System
TIRS	:	Thermal Infrared Sensors
TM-CFAR	:	Trimmed Mean CFAR
TOSS	:	Transfer Orbit Support Service
TTC	:	Telemetry,Tracking and Command
TWRIS	:	Telangana Water Resources Information System
UP	:	Utilisation Program
UT	:	University of Twente
UVIT	:	Ultra Violet Imaging Telescope
VEDAS	:	Visualisation of Earth Observation Data and Archival System
VELC	:	Visible Emission Line Coronagraph
VER	:	Volume Emission Rate
VHRR	:	Very High Resolution Radiometer
VLSI	:	Very Large Scale Integrated circuit
VSAT	:	Very Small Aperture Terminal
VSSC	:	Vikram Sarabhai Space Centre
WV	:	Water Vapour
XPoSat	:	X-ray Polarimeter Satellite
XSM	:	Solar X-ray Monitor


GSAT-17
Microsat
Cartosat-2 Series Satellite
PSLV-C40
INS-1C
GSAT-19
GSLV-MkIII-D1
South Asia Satellite (GSAT-9)
GSLV-F09
PSLV-C38
Cartosat-2 Series Satellite