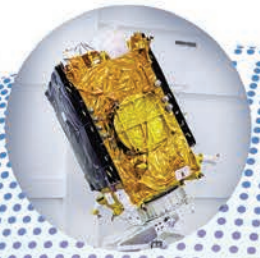
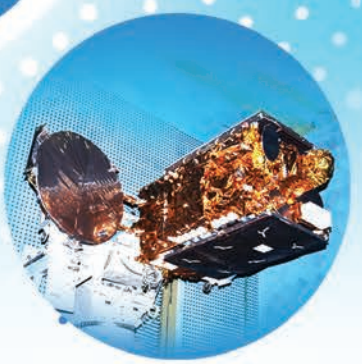
भारत सरकार
अंतरिक्ष विभाग

सत्यमेव जयते

GOVERNMENT OF INDIA
DEPARTMENT OF SPACE



वार्षिक रिपोर्ट
Annual Report
2018-2019



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Citizens' Charter of Department of Space

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

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

Mission	2017-2018	2018-2019	2019-2020	2020-2021
EARTH OBSERVATION SATELLITES	3	3	9	10
COMMUNICATION SATELLITES	4	4	3	4
NAVIGATION SATELLITES	2	1	0	2
SPACE SCIENCE SATELLITES	0	0	2	1
TECHNOLOGY DEMONSTRATOR	0	1	1	1
PSLV	4	6	9	10
GSLV Mk II	2	1	2	3
GSLV Mk III	1	1	3	4
SMALL SATELLITE LAUNCH VEHICLE	0	0	3	2
GAGANYAAN	0	0	0	1 (Unmanned)
TOTAL	**16**	**17***	**32**	**38**

* 12 missions accomplished by Jan 2019. Five missions targeted by Mar 2019

Highlights

As per the mandate of the Department of Space, Satellite based services are provided to different users in the country through the development and implementation of launch vehicles, satellites and satellite based applications. The year 2018 proved to be a very 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 of ISRO. During the period of reporting, country witnessed many significant achievements of the Indian Space Programme.

Honorable Prime Minister of India announced India's first Human Space flight, ''Gaganyaan'' in his Independence Day speech on 15th August 2018. He declared that India's first Gaganyaan Mission with Indian Men or Women astronaut will be demonstrated by 2022 and mentioned that this will be an significant milestone in Indian Space Program.

Apart from this, Six launch vehicle missions were successfully accomplished during the reporting period (Apr '18-Jan '19). The successful launch of GSLV-MkIII D2, the second developmental flight of India's most powerful launch vehicle was the highlight of 2018. Successful launch of GSLV-F11 and four PSLV launches from Satish Dhawan Space Centre SHAR, Sriharikota were also accomplished during the year. ISRO could place five Indian satellites into the orbits. The five Indian satellites included one earth observation satellite, three communication satellites and one Navigation satellite. Pad Abort Test, which was conducted in July 2018 was one the major milestones in proving critical technologies for Gaganyaan.

In all ISRO accomplished 13 missions in all which includes six launch vehicle missions, six satellite missions and one technology demonstrator, Pad Abort test. During the period Feb '19 till Mar '19, five more missions (three satellites and two launch vehicle) are targeted.

In 2018, India's Mars Orbiter Mission (MOM) spacecraft completed four years in its orbit around Mars, while AstroSat, India's multi-wavelength observatory, successfully completed three years of service.

- On April 12, 2018 PSLV-C41 successfully launched the eighth navigation satellite IRNSS-1I (Indian Regional Navigaton Satellite System) satellite into the orbit weighing about 1425 kg.
- On July 05, 2018 the first test (Pad Abort Test) was demonstrated successfully for the safe recovery of the crew module in case of any exigency at the launch pad. This is a critical technology relevant for human spaceflight. The Crew Escape System is an emergency escape measure designed to quickly pull the crew module along with the astronauts to a safe distance from the launch vehicle in the event of a launch abort.
- On September 16, 2018 PSLV-C42 successfully launched two Foreign Satellites NovaSAR and S1-4 into the orbit (together weighing nearly 889 kg) from SDSC SHAR, Sriharikota.

- On November 14, 2018 GSLV MK III-D2 successfully launched communication satellite, GSAT-29 into the orbit weighing about 3423 kg launches from SDSC SHAR, Sriharikota.
- On November 29, 2018 PSLV-C43 successfully launched India's Hyper spectral Imaging Satellite (HysIS) and 30 international co-passenger satellites. HysIS, the primary satellite of PSLV-C43 mission, weighing about 380 kg, is an earth observation satellite configured around ISRO's Mini Satellite-2 (IMS-2) bus. The co-passengers of HysIS include 1 Micro and 29 Nano satellites from 8 different countries. These satellites have been commercially contracted for launch through Antrix Corporation Limited, the commercial arm of ISRO.
- On December 05, 2018 GSAT-11 the communication satellite was successfully launched from Kourou launch base, French Guiana by Ariane-5 VA-246. Weighing about 5854 kg, GSAT-11 is the heaviest satellite built by ISRO.
- On December 19, 2018 GSLV-F11 successfully launched GSAT-7A communication satellite into the orbit weighing about 2250 kg from SDSC SHAR, Sriharikota.
- On January 24, 2019, PSLV-C44 successfully launched Microsat-R and Kalamsat-V2 (Student satellite) from SDSC SHAR, Sriharikota.

Space Transportation System

There were four PSLV launches during the reporting period of the year 2018-19. PSLV-C41 launched IRNSS-1I, PSLV-C42 launched two foreign satellites NovaSAR and S1-4 of UK, PSLV-C43 launched HysIS along with 30 co-passenger satellites and PSLV-C44 launched Microsat-R & Kalamsat-V2. GSLV-F11 equipped with the indigenous Cryogenic Upper Stage (CUS) successfully launched GSAT-7A weighing 2250 kg. GSLV-MkIII mission with its C25 cryogenic proved to be successful in demonstrating the capability of putting 4 ton class of satellite into GTO. GSLV-Mk III-D2 successfully launched the communication satellite GSAT-29.

Apart from these achievements, The first test (Pad Abort Test) was successfully demonstrated on July 05, 2018 to safely recovery of the crew module in case of any exigency at the launch pad. This technology demonstration was to qualify a Crew Escape System, which is a critical technology relevant for human spaceflight.

Space Infrastructure

During the year 2018-19, ISRO could place five Indian satellites into the orbits which are providing services. The five Indian satellites includes one earth observation satellite, three communication satellites and one Navigation satellite.

Hyper Spectral Imaging Satellite, HysIS weighing 380 kgs was successfully on PSLV-C43 on November 29, 2018. This satellite employs Hyper Spectral Imager to take images in Visible and Near Infra Red and Short wave Infra red bands.

PSLV-C41 successfully launched the eighth navigation satellite IRNSS-1I (Indian Regional Navigaton Satellite System) satellite weighing about 1425 kg on April 12, 2018 into GTO.

In the communication satellite domain, three communication satellites, viz., GSAT-11, GSAT-7A and GSAT-29 were launched. These three communication satellites successfully reached their respective geostationary orbital slots and are operational.

Space Applications

15 communication satellites are operating over India with communication transponders in C-band, Extended C-band, Ku-band, Ka/Ku band and S-band. All together, these satellites provide, 276.5 operational bent-pipe transponders and 3.5Gbps high throughput satellite (HTS) capacity to support the services like television, telecommunication, radio networking and other societal applications.

Satellite News Gathering using INSAT system enables coverage of on-the-spot real-time news and important events at different locations. About 6 transponders are used for DSNG services of various operators. Radio Networking (RN) through satellite provides a reliable high-fidelity programme channels for National as well as Regional Networking. Around 472 All India Radio (AIR) stations and about 671 radio transmitters have been equipped with receive terminals. INSAT satellites have been supporting telecommunication applications for providing voice, data and interactive communications. The Telemedicine programme connects remote/rural/medical college hospitals and Mobile Units through the Indian satellites to major specialty hospitals in cities and towns. Presently, around 165 Telemedicine nodes are operational across the country. Under Tele-education programme, the teaching sessions conducted from customised studio are telecast through satellite(s) for connecting schools and colleges spread across the country. 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. The messaging services are used for data collection, tracking and reporting applications.

INSAT-3D and INSAT-3DR satellites are carrying meteorological payloads. Satellite images are used in monitoring Cyclones, and other significant weather phenomena such as Fog and thunderstorms.

High-throughput satellites like GSAT-19 and GSAT-29 provide HTS services to the country. The capacity on these satellites will be used for catering to BharatNet and other VSAT based applications. These satellites are expected to pave way for greater capabilities in terms of capacity and capability to reach out to people of our country. Recently launched GSAT-11 will further enhance the HTS capacity.

With the satellite constellation established, NavIC system is now fully available for position, navigation and timing solution and for derived location based services. NavIC can be extensively used for positioning, navigation and timing applications in a variety of civil and commercial activities related to land transportation, aviation, maritime; mapping, surveying and geodesy; scientific research; timing and telecommunications.

During 2018, India witnessed major floods during June to September in 120 districts spread across Assam, Bihar, Manipur, Odisha, Uttar Pradesh, Kerala, Tripura and Delhi. Very devastating floods occurred in Kerala State during second week of August, and 10 out of 14 districts were affected very severely. The floods were monitored and inundations mapped using Indian and foreign satellite datasets on a regular basis. Flood inundation maps at State and District level were generated and disseminated to Kerala State Disaster Management Authority (KSDMA), KSREC and Central departments. Products were also disseminated through Bhuvan and NDEM web-portals in near real-time. During 2018, Active forest fire monitoring was carried out using satellite data during Feb-Jun period. About 38,900 active fire locations were identified and the information was shared with Forest Survey of India (FSI), Dehra Dun in near real time mode. Fire alerts are published on Bhuvan and sent as SMS to selected State Forest Departments. Kerala and Karnataka witnessed widespread occurrence of landslides due to heavy rainfall in August, 2018. Satellite data were analysed to identify landslides in Kerala. A total of 120 landslides were mapped using high resolution satellite data. Value added products such as flood inundation maps, forest fire hotspots, damage assessment maps, drought indices maps, earthquake locations etc., were hosted on NDEM portal for all major disaster events during 2018.

Space Science and Planetary Research

India's first inter-planetary mission "Mars Orbiter Mission (MOM)" completed four years in Martian Orbit in September 2018. Scientific analysis of data received from the MOM is in progress and twenty four scientific papers have been published so far in peer-reviewed journals. The Mars Colour Camera (MCC), one of the payloads onboard MOM, has produced 1000+ images so far.

AstroSat, the first Indian multi-wavelength space observatory, completed three years in orbit in Sept 2018. It is providing researchers both in India and abroad with excellent data on a variety of astrophysical objects in our Milky Way galaxy to those far away sources external to our galaxy. On 26th of September, 2018, AstroSat data was made open to public. As of October 2018, AstroSat has a total of 917 registered users from 24 countries.

India's second mission to the Moon, Chandrayaan-2, with an indigenous Orbiter, Lander (VIKRAM) and Rover (PRAGYAAN), is being prepared for 2019 launch. Aditya-L1, India's first dedicated solar exploration mission, and X-ray Polarimeter Satellite (XPoSat) mission, a dedicated mission for polarization studies, are upcoming space science missions.

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 01.03.2018 is 18,074, out of which 12,999 are in Scientific and Technical (S&T) category and 5,075 is 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.

As per the future plan, ISRO is gearing up for enhanced Launch frequency in coming years. In order to meet the increased launch demand, it is planned to increase the participation of Indian industries in the realization of PSLV systems through a suitable mechanism. Based on this, ISRO plans to produce and launch a significant number of PSLVs / year with industry participation. In order to strengthen the industry participation in spacecraft AIT, URSC-ISRO has entered into contract with three qualified industries in private & public sector. This is expected to accelerate the pace of satellite building activities, so as to meet the increased demands.

• International Cooperation

To pursue its bilateral and multilateral relations with International Space agencies with the aim of strengthening ties between countries and for taking up new scientific and technological challenges, international co-operation is an important programe of ISRO. Towards this, 19 Space cooperative documents with Space agencies of 15 countries and one multinational body are signed this year. ISRO has announced a programme on nano satellite development, named as UNNATI (UNispace Nanosatellite Assembly & Training by ISRO) as an initiative to commemorate the 50th Anniversary of the First United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE+50). Two senior ISRO officials have been bestowed with International Awards during this year namely Dr. B.N. Suresh, Chancellor, IIST & Honorary Distinguished Professor received '2018 INCOSE Pioneer Award' and Shri A.S. Kiran Kumar, Vikram Sarabhai Professor and former Chairman, ISRO/ Secretary, DOS was conferred with the '2018 International Von Karman Wings Award'.

• 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.

ISRO under its Outreach policy expands its horizon to provide a suitable platform to these youths by establishing Space Technology Incubation Centres (S-TIC). In line with this, the first S-TIC at National Institute of Technology–Agartala in the state of Tripura was inaugurated on 18.9.2018. Satish Dhawan Centre for Space Science was established on October 11, 2018 at Central University of Jammu to pursue atmospheric studies. During 4th India International Science Festival (IISF) in September 2018 various public outreach programmes were organized at ISRO Centres to interact with students and public. On January 17, 2019, the second S-TIC was inaugurated at NIT, Jalandhar, Punjab.

Space Commerce

On a commercial basis, Antrix is serving more than 100 Indian users, across a wide cross section of private, public, government and strategic sectors. Additionally, transponders on foreign satellites operating over India are being provisioned on a short term lease basis. Antrix is recognised as one of the prominent service provider 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 PSLV launch services to international customer satellites, a dedicated customer satellite mission for Surrey Satellite Technology Limited (SSTL), UK viz, PSLV-C42 launched NovaSAR a 450 kg S-Band Synthetic Aperture Radar satellite and S1-4, a 450 kg optical imaging satellite. The 6th edition of Bengaluru Space Expo (BSX-2018) was held during 6th-8th September 2018. The theme for BSX-2018 was “Creating Dynamism in Indian Space Ecosystem” with specific focus on “Enabling New Space in India” to enable Indian industries to get exposed to the growing business environment, various business opportunities and technologies, to spur the growth of space commerce in India.

Indian Institute of Space Science and Technology

The Indian Institute of Space Science and Technology (IIST), a deemed University, was established at Thiruvananthapuram in 2007 towards capacity building in human resources and meet the growing demands of the Indian Space Programme. During 2018, a total of 69 eligible students are inducted in all DOS/ISRO Centres/Units.

Summary

Announcement of India's first Human Space flight, Gaganyaan'' on 15th August 2018 by Honorable Prime Minister of India was an important milestone in Indian Space Program. The year 2018 was very eventful year for ISRO with a total of 12 missions accomplished in the reporting period of the year, which includes six launch vehicle missions, five satellite missions and one technology demonstrator, Pad Abort test. The Indian space programme, during the year, made significant progress in its missions by achieving most of its targets with many unique accomplishments. The first test (Pad Abort Test) demonstrated the safe recovery of the crew module in case of any exigency at the launch pad was one of the critical technologies for Gaganyaan which demonstrated ISRO's build up towards Gaganyaan.

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

With the setting up of Indian National Committee for Space Research (INCOSPAR) in 1962, Space activities in the country were initiated. Work on Thumba Equatorial Rocket Launching Station (TERLS) near Thiruvananthapuram was also started during the same year. In August 1969, Indian Space Research Organisation (ISRO) was established. In June 1972, the Space Commission and the Department of Space (DOS) were constituted by the Government of India 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, Human Spaceflight, international cooperation, system reliability and quality, safety, media & 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), GSLV Mk III, Small Satellite launch Vehicle (SSLV) and Rohini Sounding Rockets. The Centre also focuses on developing capabilities towards advanced technology vehicles, air breathing propulsion and modular heavy lift launch vehicles.

U R Rao Satellite Centre (URSC)

ISRO Satellite Centre, Bengaluru was renamed as U R Rao Satellite Centre (URSC), Bengaluru on 26th July 2018 as a tribute to late Prof. U R Rao, who was architect of Satellite Centre. URSC is the lead centre for design, development and integration of satellites for communication, remote sensing, navigation, scientific studies and small satellites. URSC is actively involved in research and development in the area of advanced state-of-the-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. URSC 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. URSC has realised the spacecraft in the area of communication, meteorology, remote sensing, 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 of telemetry, tracking and command network and mission control centre.

Satish Dhawan Space Centre (SDSC) SHAR

The Centre has two launch pads from where the rocket launching operations of PSLV, GSLV and GSLV-Mk III 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-2, Mars Orbiter Mission, etc.

Thaltej Campus, Ahmedabad

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.

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. In addition, SAC has operationalized Payload Assembly, Integration and Testing facility at its new campus at Bopal, Ahmedabad. 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 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, Lucknow, Mauritius, Sriharikota, Port Blair, Thiruvananthapuram, Brunei, Biak, Indonesia and the Deep Space Network Stations at Bylallu near Bangalore. 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 four 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)

Satellite Control Centre – MCF, Bhopal

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 all active satellites belonging to INSAT/GSAT, IRNSS series and Meteorological satellites. To carry out these operations effectively, MCF Hassan is having an integrated facility consisting of nine Satellite Control Earth Stations.

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 Main Building

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 scalable sensors and systems.

Human Space Flight Centre (HSFC)

A new center namely Human Space Flight Centre (HSFC) is created within ISRO/DOS with the responsibility to act as the lead center for Human Space Flight Program. This center will be responsible for the execution of Gaganyaan program that involves R&D in new domains of Space Science and Technology.

Besides, HSFC shall focus on the development of the engineering systems related to the orbitor module, the human centric technology domains of bio-astronautics, crew training and life support, basic and applied space sciences, human and robotical space exploration etc. In addition, HSFC shall also play the role of a technology aggregator to bring together the national expertise in diverse disciplines for multi directional growth and capacity.

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

LEOS Main Building

tracker, Vision Sensors, Detectors, MEMS devices, Segmented Mirror Telescope optics and advanced optics for future spacecraft use.

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 has three campuses at Balanagar, Shadnagar and Jeedimetla in Hyderabad. It is having five 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. Apart from satellite based remote sensing, NRSC is also engaged in executing remote sensing application projects in collaboration with the users including 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.

NRSC Ground station at Shadnagar acquires Earth Observation data from Indian remote-sensing satellites as well as from foreign satellites. Presently, data acquired at foreign ground stations is also being transferred to IMGEOS for processing, product generation, archival and dissemination.

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.

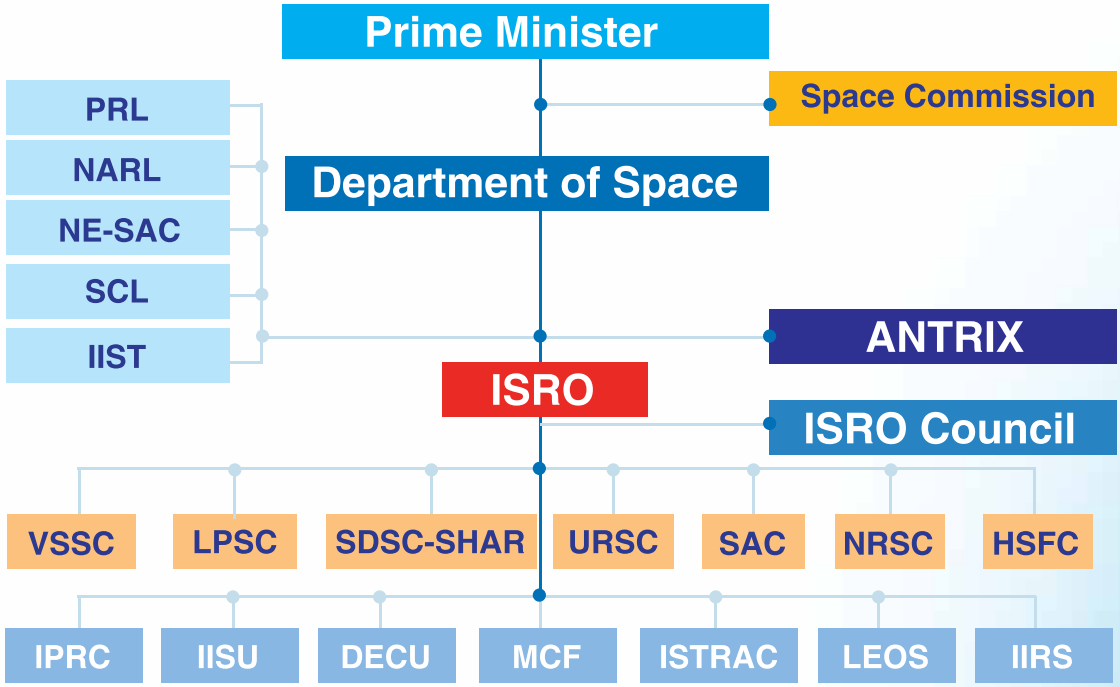
RRSCs support various remote sensing tasks specific to their regions as well as at the national level. RRSCs are carrying out application projects encompassing all the fields of natural resources like agriculture and soils, water resources, forestry, oceanography, geology, environment and urban planning. 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

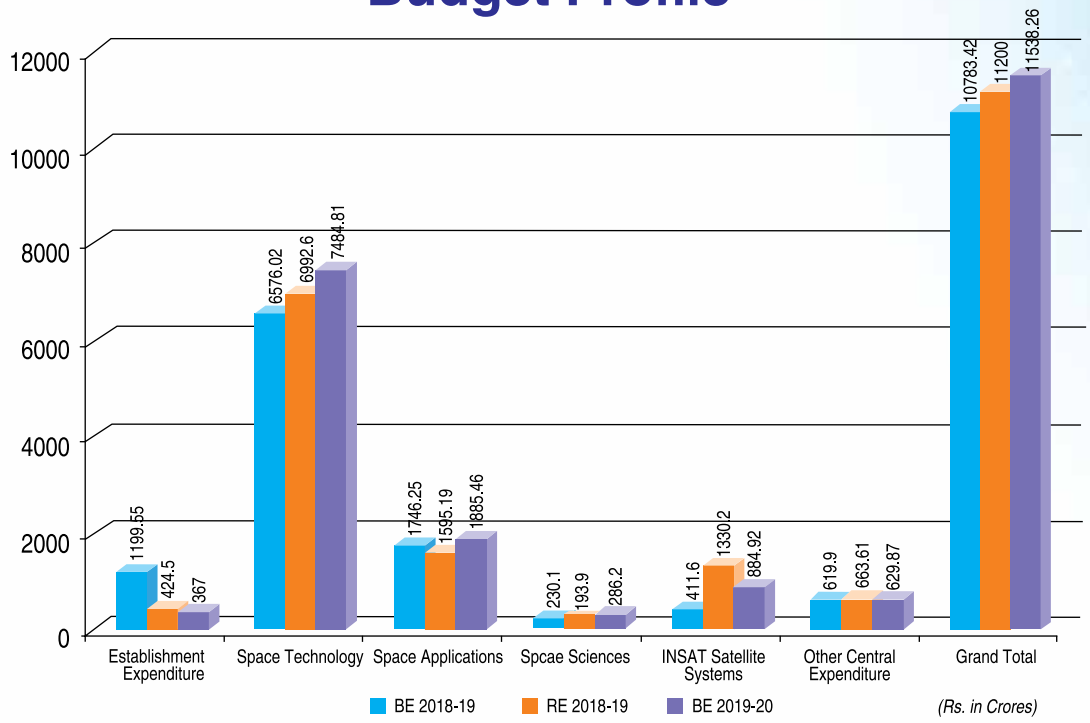
Space Centres in India

Organisation



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 **SDSC:** Satish Dhawan Space Centre **URSC:** U R Rao Satellite Centre **SAC:** Space Applications Cenrtre **NRSC:** National Remote Sensing Centre **HSFC:** Human Space Flight Centre **IPRC:** ISRO Propulsion Complex **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



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 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.

X-band radar building at NARL

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)

Aerial View of 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.

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.

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 subsystems.

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.

IIST Campus

Antrix CorporationLimited (ACL)

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 269 foreign satellites from 33 different 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. 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); 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.

1. Space Transportation System

The Indian Space Programme has made successful transition in terms of technology acquisition and launch vehicle development. Polar Satellite Launch Vehicle (PSLV) has become a favoured carrier for satellites of various countries due to its reliability and cost efficiency, promoting unprecedented international collaboration. The Geosynchronous Satellite Launch Vehicle (GSLV) with indigenous Cryogenic stage, graduated to become an operational vehicle for communication satellites. The country has achieved self-reliance in space transportation capability through the operationalisation of PSLV and GSLV for launching satellites for earth observation, communication, navigation and space exploration. R & D is the key to maintain 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 including Gaganyaan, India's Human Space Flight.

During the reporting year, all the launch complex facilities were activated and utilised to ensure timely supply of production deliverables to match with the varying needs of ISRO's Launch Vehicle and Satellite communities and also the foreign satellite customers.

Major Events

1.1 Polar Satellite Launch Vehicle (PSLV)

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

PSLV-C41 lift off

PSLV conducted four launches during the year, since January 2018. PSLV-C41 was successful in launching the Navigation Satellite, IRNSS-1I. PSLV-C42 was successful in launching two commercial Satellites and PSLV-C43 launched remote sensing satellite, HysIS along with 30 Customer satellites as co-passengers.

Many new technologies were also flight demonstrated. PSLV-C44 launched Microsat-R and Kalamsat-V2.

PSLV-C41/IRNSS-1I Mission: In its 43rd flight on 12th April 2018, IRNSS-1I the eighth navigation satellite was successfully injected by PSLV-C41 into an intended orbit, joining ISRO's indigenous "NavIC" constellation.

PSLV-C42/NovaSAR & S1-4 Mission: This was the 44th flight of PSLV. Two customer satellites from SSTL of United Kingdom were successfully launched by PSLV C-42 on 16th September 2018. The vehicle injected both the satellites viz. NovaSAR & S1-4 into their intended orbits.

PSLV-C42 lift off

PSLV-C43/HySIS Mission: This was the 45th flight of PSLV, with core alone configuration. PSLV-C43 lifted on November 29, 2018 from the First Launch Pad (FLP) of Satish Dhawan Space Centre SHAR, Sriharikota and successfully launched India's Hyperspectral Imaging Satellite (HysIS) and 30 other international co-passenger satellites. The co-passengers of HysIS include 1 Micro and 29 Nano satellites from 8 different countries. These satellites have been commercially contracted for launch through Antrix Corporation Limited, the commercial arm of ISRO.

PSLV-C44 mission with PSLV-DL configuration (two strap-ons) has successfully launched Microsat-R and Kalamsat-V2 on January 24, 2019.

So far, PSLV has successfully launched 57 Indian satellites and 269 customer satellites from abroad.

1.2 Geosynchronous Satellite Launch Vehicle (GSLV)

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

GSLV-F11/GSAT-7A Mission:

GSLV-F11 successfully launched GSAT-7A, ISRO's 39th communication satellite, on December 19, 2018 from SDSC, SHAR, Sriharikota. GSLV-F11 is the 13th flight of India's Geosynchronous Satellite Launch Vehicle (GSLV) and its 7th flight with indigenous Cryogenic Upper Stage (CUS). The GSLV-F11 carrying 2250 kg GSAT-7A injected the satellite into its designated Geosynchronous Transfer Orbit (GTO).

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

GSLV-Mk III is the next generation launch vehicle of ISRO capable of launching 4 ton class of satellite to Geosynchronous Transfer orbit (GTO). 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 5m diameter payload fairing.

GSLV Mk-III D2/GSAT-29 mission: GSLV MkIII-D2, the second developmental flight of GSLV MkIII successfully launched GSAT-29, a high throughput communication satelliteon November 14, 2018 from the Second Launch Pad (SLP) at Satish Dhawan Space Centre SHAR, Sriharikota. GSAT-29 satellite with a lift-off mass of 3423 kg, is a multi-beam, multiband communication satellite of India. This is the heaviest satellite launched from India till date.

GSLV Mk-III M1/Chandrayaan-2 mission: The first operational flight of GSLV-Mk-III is scheduled during 2019 with Chandrayaan-2 weighing 3850kg. Chandrayaan-2 will be carrying Moon Orbiter, Lander (VIKRAM) and Rover (PRAGYAAN) modules. The payload capability of GSLV Mk III is increased from 3500kg to 4000kg.

1.4 Small Satellite Launch Vehicle (SSLV)

Objective of SSLV project is development of a vehicle capable of launching small, micro and nano satellites. This vehicle is capable of launching upto 500 kg satellite into 500 km planar orbit at a low cost and reduced development time. Vehicle is configured with three solid propulsion stages and liquid propulsion based Velocity Trimming Module (VTM) as terminal stage. SSLV is 2m in diameter and 34m in length with lift off weight of ~120 tons. The first developmental flight of SSLV is targeted during 2019.

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

Autonomous Film Cooling (AFC) assembly for thrust chamber, brazing process technology for lift-off seal in main turbo pump, multi-layer coating of nickel, silver and copper over SS

(06X15H6M) for thrust chamber components, ultra high strength fasteners and PCTFE coating for V-type turbo pump were developed. The engine component fabrication is in progress.

1.6 Reusable Launch Vehicle (RLV-TD)

The development of Reusable Launch Vehicle (RLV) - Orbital Re-entry Experiment has been taken up by ISRO. The development envisages launch of a winged body Orbital Re-entry Vehicle (ORV) to a low earth orbit using an ascent vehicle and demonstration of re-entry of the ORV and autonomous landing on a runway.

1.7 Advanced Technology Vehicle and Sounding Rocket

RH 200 launch

ATVP is the nodal agency in VSSC for conducting sounding rocket launches for the scientific exploration of middle and upper atmosphere, realization 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.

Golden jubilee of first launch of indigenous sounding rocket and dedication of TERLS to UN has been commemorated in grandeur on 2nd February 2018.

Rohini Sounding Rocket RH 200 flights: RH 200 rockets are regularly launched from TERLS range. 7 sounding rockets were launched including the152nd consecutively successful launch, and 11 more launches are planned.

1.8 Sounding Rockets

SOUREX is one of the pioneer experiments in ISRO to carry out in-situ measurements of wind and its composition, electron/ion density and electric field at various altitudes in the atmosphere.

RH300 Mk II F21 flight launched successfully on 6th April, 2018 from TERLS, ejecting TMA payload at a height of 90 Km for a duration of 45 Sec. The TMA trail was observed from 4 different stations. Scientific payloads were the

RH 300 launch

ENWi (Electron and Neutral Wind probe) to measure the neutral wind prevailing in E region (90 - 120 km), Langmuir probe to measure electron density, and TMA chemical release technique to cross validate the ENWi data. This light marks the first successful indigenous TMA experiment with an indigenous rocket.

2. Space Infrastructure

2.1 Satellite Communication Programme

Indian National Satellite (INSAT) system, established in 1983, is the largest domestic communication satellite system in the Asia Pacific Region with several communication satellites in operation including the commercial communication satellites like INSAT-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, GSAT-19, GSAT-29 and GSAT-11.

SATELLITES IN SERVICE

INSAT-4 Series

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 for supporting various telecom services over India.

GEOSAT Series

GSAT-8

GSAT-8 is a communication satellite configured around 3000 Kg class (I-3K) bus with a lift-off mass of 3093 kg 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 1000 Kg class (I-1K) bus with Extended C-band Solid State Power Amplifier (SSPA) based commercial transponders. The satellite was successfully launched onboard PSLV-C17 on July 15, 2011 with a lift-off mass of 1410 kg.

GSAT-10

GSAT-10 was successfully launched by Ariane-5 from Kourou, French Guyana on September 29, 2012. Weighing 3400 kg at lift-off, GSAT-10 commercial payload includes communication

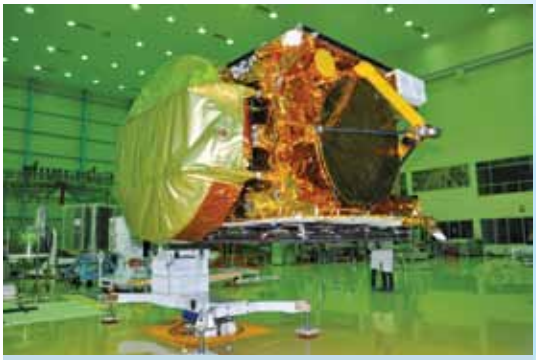
transponders in normal C-band, Extended C-band and Ku-band as well as a GAGAN payload operating in L1 and L5 bands. GSAT-10 is the second satellite to carry GAGAN payload after GSAT-8. GSAT-10 also carries a Ku-band beacon to help in accurately pointing ground antennas towards the satellite.

GSAT-14

GSAT–14 spacecraft 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 2600 W and a lift off mass of 1982 kg. GSAT-14 was successfully launched on January 05, 2014 on-board GSLV-D5 Mission, the second development flight of GSLV with indigenous Cryogenic stage.

GSAT-16

GSAT-16 is a communication satellite configured around I-3K Extended bus with a lift off mass of 3150 kg with a mission life of more than 12 years. The spacecraft's payload includes transponders in Ku-band, C-band and Extended-C band. The satellite was launched by Ariane-5 from Kourou, French Guyana on December 06, 2014.



GSAT-16-launch-test

GSAT-6

GSAT-6 Spacecraft is configured based on ISRO's I-2K Bus. This communication satellite was launched onboard GSLV-D6 on August 27, 2016 with a lift-off mass of around 2117 kg. The spacecraft provides communication through S-band payload with five spot beams covering whole India for user links and C-band with one beam. It carries a 6 m diameter S-band unfurlable antenna.

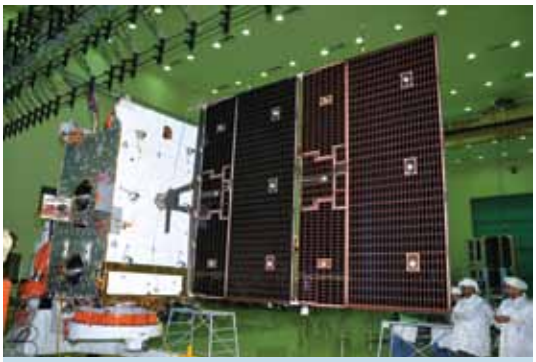
GSAT-15

GSAT-15 is a communication satellite configured around I-3K bus with 3164 kg lift-off mass and 6200 W power generation capacity. It is designed for a mission life of more than 12 years. The spacecraft's commercial payload includes Ku-Band transponders and a two channel GAGAN payload. The satellite was launched by Ariane-5 from Kourou, French Guyana.

GSAT-18

GSAT-18 is a communication satellite configured around I-3K extended bus with a lift off mass of 3404 Kg. The spacecraft carries Ku, Normal C & Extended C band transponders. It also carries Ku-band beacon to help in accurately pointing ground antennas towards the satellite. 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

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 2230 kg. It is configured around the ISRO's standard I-2K bus. The satellite is designed for a mission life of 12 years.

GSAT-19

GSAT-19 satellite with a lift-off mass of 3136 kg is a communication satellite configured around ISRO's standard 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 Mk III-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 3477 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 transponder 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-29

GSAT-29

GSAT-29 Spacecraft is a communication satellite configured with ISRO's enhanced I-3K Bus launched on-board second developmental flight of GSLV MK-III D2 on November 14, 2018 with lift-off mass of around 3500 kg. It is configured with payloads to provide spot beams in Ku and Ka band covering North East and Jammu & Kashmir regions. The satellite also carried Q/V band payload, optical communication payload and geo high resolution camera as technology demonstrators. The designed in-orbit operational life of GSAT-29 is about 10 years.

GSAT-11

GSAT-11 is a communication satellite launched on December 5, 2019 from Kourou, French Guiana onboard Ariane-5 VA-246 with a lift-off mass of 5854 kg. GSAT-11 is a multi-beam high throughput communication spacecraft 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 designed in-orbit operational life of GSAT-11 is about 15 years.

GSAT-11

SATELLITES UNDER DEVELOPMENT

GSAT-31

GSAT-31 spacecraft is configured with enhanced I-2K bus. It is a communication spacecraft carrying Ku-band transponders with 36 MHz and 225 MHz bandwidth and providing coverage over Indian mainland or oceanic region.

GSAT-20

GSAT-20 Spacecraft is configured based on ISRO's standard I-3K Bus. It is a communication spacecraft to be launched onboard GSLV Mk-III. It has Ka x Ka high throughput payload. Presently, the satellite subsystems are under realization.

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 realization.

2.2 Satellite Navigation Programme

Satellite Navigation (SATNAV) is one of the important programmes of the Department. There are two main components of this program

- GAGAN &
- Navigation with Indian Constellation (NavIC).

GPS Aided Geo Augmented Navigation (GAGAN)

GAGAN is a joint project of ISRO and Airports 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 30 December 2013 and later

it was certified by DGCA for precision approach services APV-1.0 (Approach with Vertical guidance) over Indian landmass on 21 April 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 (Space Based Augmentation System) in the world to serve the equatorial region. The GAGAN system was dedicated to nation on 13 July 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 IndianAirspace. With the certification of GAGAN system for APV-1.0 service levels, procedure development and aeronautical surveys at select airports are under progress.

Navigation with Indian Constellation (NavIC)

NavIC is the Indian Regional Navigation Satellite System (IRNSS) developed by Indian Space Research Organization (ISRO). It is an independent regional navigation 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.

Space Segment

The Space Segment consists of eight satellites with three in geostationary orbit and five 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 eight 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 realized and launched onboard PSLV C39. However, the mission was unsuccessful, as the satellite could not be placed in proper orbit. The second ground spare satellite, viz., IRNSS-1I was successfully launched onboard PSLV C41 on 12 April 2018 and is currently operational.

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.

The ISRO Navigation Centres (INC) are operational at Bangalore (INC-1) and Lucknow (INC-2). Seamless switch over operations between INC1 & INC2 have been successfully demonstrated.

IRNSS Network Timing facility is operational at Bangalore (IRNWT-I). The IRNWT-II established at Lucknow, is made operational since February 2018. Time scales are maintained within 20ns (2σ) with respect to UTC. Time traceability service has been signed with National Physical Laboratory, India (NPLI) on 01 June 2018. 16 IRNSS Range & Integrity Monitoring Stations (IRIMS) are operational with 15 of these stations located within the country and one at Mauritius. The IRIMS at Biak, Indonesia is yet to be established. The IRNSS Data Communication Network (IRDCN) is operational with redundant communication links (Terrestrial & VSAT) between all the ground elements.

The IRNSS Spacecraft Control Facility (IRSCF) that monitors and controls the IRNSS spacecraft is operational at Master Control Facility (MCF), Hassan. The IRSCF also uplinks the navigation data to the satellite in addition to its regular TT&C operations. Master Control Facilities at Hassan and Bhopal are configured with complete redundant stations for IRNSS TTC operations.

User Segment

With the satellite constellation established, NavIC system is now fully available for position, navigation and timing solution and for derived location based services.

NavIC can be extensively used for positioning, navigation and timing applications in a variety of civil and commercial activities related to land transportation, aviation, maritime; mapping, surveying and geodesy; scientific research; timing and telecommunications.

IRNSS Follow On Satellites (1J/1K/1L/1M/1N)

The currently deployed IRNSS Satellite constellation comprising of seven satellites provides SPS and RS services over the Indian Region in L5 and S bands. In order to ensure continuity of services, it is planned to realize five navigation satellites as replacement to the satellites in the current constellation viz., IRNSS-1J/1K/1L/1M/1N. These satellites shall be located at the existing orbital slots for ensuring continuity of NavIC (IRNSS) services.

2.3 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-2, Oceansat-2, Megha-Tropiques, SARAL, Cartosat-2 Series Satellite, HysIS 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, INSAT-3D and INSAT-3DR are providing meteorological data to the user community.

Earth Observation Satellites in Service

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

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.

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).

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.

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 360m spatial resolution of 1420km swath with two-day repetivity. The data is used to generate Local Area Coverage(LAC) product of 360m resolution (2-daycoverage 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.

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 20^{o} 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.

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^{o} along as well as across track to obtain stereoscopic imagery and achieve a four to five-day revisit capability.

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: Four Cartosat-2 series satellites were launched on June 22, 2016, February 15, 2017, June 23, 2017 and January 12, 2018 aboard PSLV-C34, PSLV-C37, PSLC-C38 & PSLV-C40 respectively. These satellites are similar to the earlier Cartosat-2, 2A, 2B, etc. The Cartosat-2 series satellites are placed inorbit 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 upto ± 45^{o} providing spot images in continuous imaging mode.

SCATSAT-1: The satellite was launched on September 26, 2016 onboard PSLV-C35. 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.

Microsat: PSLV-C40 carried a Microsat built by ISRO as a co-passenger payload. Microsat is a small satellite in the 100 kg class that derives its heritage from IMS-1 bus. This is a

technology demonstrator and the fore runner for future satellites of this series. The satellite bus is modular in design and cab be fabricated and tested independently of payload.

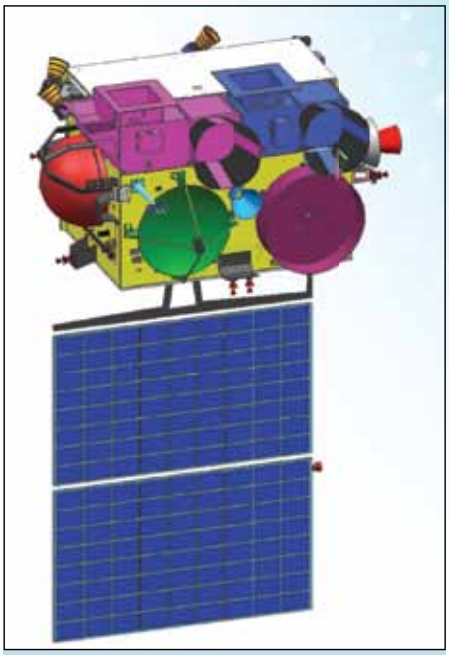
HysIS: Hyper Spectral Imaging Satellite, HysIS weighing 380 kgs was successfully on PSLV-C43 on November 29, 2018 with a mission life of 5 years. This satellite employs Hyper Spectral Imager to take images in Visible and Near Infra Red and Short wave Infra red bands. It provides global coverage on repetitive basis to users and supplementing the data from the existing multi spectral sensors. A wide range of applications in agriculture, forestry, geological environments, coastal zones and inland waters etc are derived from satellite.

HysIS

Meteorological Satellites in Service

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.



INSAT-3DR

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 &

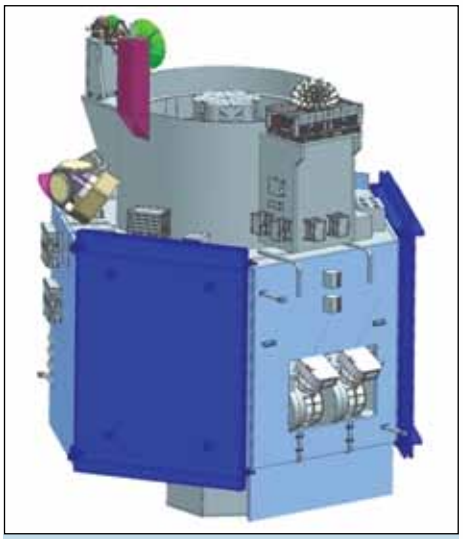
Water), Cartosat (Cartography), Oceansat (Ocean & Atmosphere) and INSAT (Meteorology). It is also envisaged to realise Geo Imaging Satellites (GISAT) in geostationary orbit to enable near real time imaging. The overall aim is to maintain the continuity of services and carryout enhancements in technological 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 here under:

RISAT-2B:

The Satellite is realized with new technologies to provide continuity of services to RISAT-2 in a fast track mode. The primary objective of the mission to provide X band SAR Services with an average daily revisit capability over the areas of interest providing maximum number of spot images in a given orbit. The spacecraft is built around New Hexagonal structure with separate payload module. It carries X Band SAR witha Payload Radial Rib Reflector 3.6 m mesh antenna.

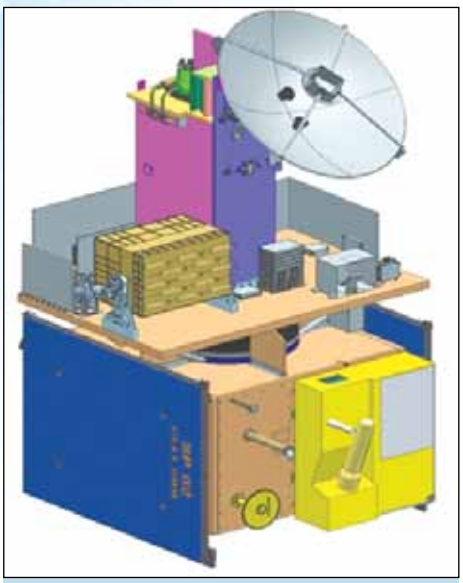
CARTOSAT-3:

Cartosat-3 spacecraft is an advanced High resolution 3 axis stabilized agile satellite to obtain imageries with spatial resolutions of 0.25 m in Panchromatic, 1.13m resolution in 4 band multi spectral; and MWIR Camera with 5.7m resolution. The satellite will be injected into a 505 km sun synchronous orbit with a mission life of 5 years. The total mass of the spacecraft is ~1560 kg generating ~ 2000 W of power.



CARTOSAT-3

OCEANSAT 3:



OCEANSAT-3

The prime objective of OCEANSAT-3 is to ensure the data continuity with improved payload specification of Ocean colour and wind vector data to sustain the operational applications. This satellite is expected to improve the applications by providing additional data such as Sea Surface Temperature (SST), with more number of bands in Optical region and in Infrared region for atmospheric corrections.

Oceansat-3 satellite is envisaged to carry Scatterometer (Similar to Oceansat-2/Scatsat-1), OCM 3 with 13 Bands, SNR >1000, Spectral

BW 10-20nm. Sea Surface Temperature monitor (SSTM-1) with 2 long wave infrared (LWIR) bands with sensitivity >150 mK and an ARGOS-4 of CNES under international co-operation.

RISAT-1A:

RISAT-1A is a repeat satellite of RISAT-1 configuration, to ensure continuity of C-Band (5.35 GHz) Microwave data to the user community for operational services. The mission is envisaged to fly a SAR payload in C-band and has the capability to operate in day, night and all weather conditions with a Mission life of 5 years.

RISAT-2A:

The primary objective of the mission is to provide X-Band SAR operating in orbit with an average daily revisit capability over the area of interest and maximizing the number of spot images in a given orbit. The spacecraft is built around Modified I2K structure, Deployable SAR & Solar panels capable of generating Max Power 5.438 kW.

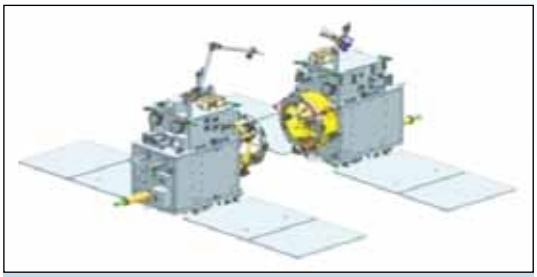
RESOURCESAT-3/3A:

The mission is envisaged to provide continuity of data services on an operational basis in the area of Land and Water resources management with improved spatial resolution, spectral resolution and better revisit frequency. It is planned to enhance remote sensing applications in the areas of agriculture, forestry, water resources monitoring, developmental planning at regional and state level, environmental impact assessment, wasteland and wetland monitoring, land degradation, drought assessment, flood inundation, landslide inventory etc.

RESOURCESAT-3S/3SA: These spacecraft are planned to provide data services for earth resource monitoring with improved resolution and wide swath - Stereo as well as Multi-spectral capability on a single platform and enhance applications in the areas of land and water, large scale mapping, urban planning and infrastructure development, disaster impact assessment. The spacecraft is built around I-1K Bus (MPL + PPL, modular) capable of generating around 3200 W of power. These spacecraft will carry two Panchromatic payloads providing a spatial resolution of ~1.25m and a multispectral payload with spatial resolution of ~2.5m.

Space Docking Experiment (SPADEX):

This project will develop and demonstrate the technologies needed for docking two spacecraft (Chaser & Target) and to control one spacecraft from the Attitude Control System of other spacecraft in the docked condition. Subsequent to docking, the Chaser and Target will be separated so that they would carry-out their designated experiments with payloads. This technology

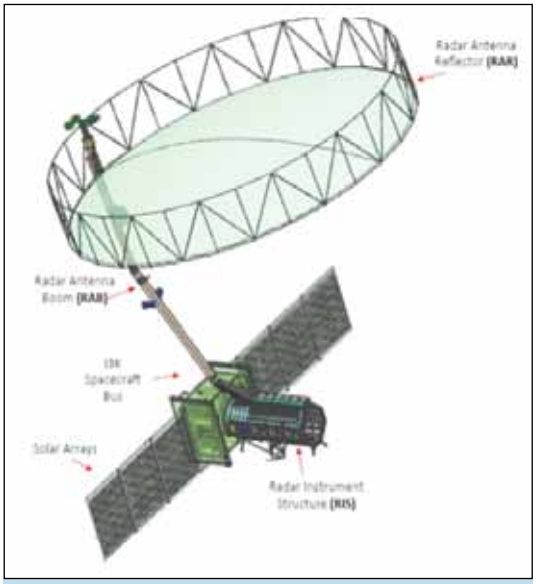


Space Docking Experiment (SPADEX)

will be a forerunner to future planetary missions including crew transfer, international participation etc.

NISAR: This mission is jointly developed by NASA & ISRO. The primary mission goals are for Global coverage of the earth's biomass, cryosphere, for surface dynamics and coastal studies over a period of 3-5 years, Systematic coverage of global environment with 12 days repeat cycle, Interferometry with precision orbit & pointing control.

The mission is built around ISRO's I-3K bus and carries two payloads namely L-band SAR (1260 MHz) and S-band SAR (3200 MHz). The L-band SAR payload is delivered by NASA and S-band SAR payload is developed by SAC, ISRO.



NISAR

INSAT-3DS

This is a follow-on mission of INSAT-3DR and will be used as spare in case of contingency requirement. It is an advanced meteorological satellite configured with improved Imaging System and Atmospheric Sounder. It carries two meteorological payloads viz; 6 channel Imager & 19 channel Sounder. In addition to this, it also carries a Data Relay Transponder (DRT) and Satellite Aided Search and Rescue (SA&R) payload to provide continuity to INSAT S&R services. INSAT-3DS is designed for enhanced meteorological observations, monitoring of land and ocean surfaces, generating vertical profile of the atmosphere in terms of temperature and humidity for weather forecasting and disaster warning.

GISAT-1

GISAT-1 is a Geo Imaging Satellite in Geostationary orbit with a high temporal resolution. It has a Multispectral Imager operating in Visible, Near Infra-Red,Thermal Infra-Red bands and Hyper Spectral Imager operating in visible, near infra-red and short wave infra-red bands. The satellite is primarily meant for near real time imaging of natural resources and disaster management. With a lift-off-mass of 2100 kg, GISAT-1 is aimed at providing fast revisit capability, real time monitoring, high resolution multi spectral and hyper spectral imaging - all on a single, agile, jitter free platform.

3. Space Applications

3.1 Satellite Communication Applications

A fleet of 15 commercial 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 provide, 276.5 operational bent-pipe transponders and 3.5 Gbps high throughput satellite (HTS) capacity, as on 31st Oct 2018, to support the services like television, telecommunication, radio networking, strategic communication and societal applications. The prominent users of the transponders are BSNL, Doordarshan, DTH and TV operators, All India Radio, government and strategic users, public sector units, private VSAT operators, banking and financial institutions, etc. Further, GSAT-29 and GSAT-11 are also launched recently during Nov-Dec 2018. These satellites will enhance the HTS capacity by another 22 Gbps and also augment the transponder capacity over the country.

DOS/ISRO has continued the support for societal programmes like Telemedicine, Tele-education and Disaster Management Support (DMS) Programmes which are solely national development oriented with an aim to address specific requirements at different strata of the society.

In order to meet additional transponder requirements from various users, about 82.4 transponders in C & Ku-band and HTS capacity of 1.5GHz are leased from international satellite operators, through Antrix Corporation Limited on a back-to-back arrangement with users and satellite operators. Thus, satellite communication is playing a major role in the socio-economic development of the country.

Television

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.

Doordarshan is presently operating 34 satellite channels and has a vast network of 67 Studios and 1108 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 1 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 A&N 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 Doordharshan, the public broadcaster, 6 private DTH operators provide service in India. It is estimated that (TRAI Report: Apr-Jun 2018) there are about 69.37 Million active subscribers availing private DTH services. About 867 TV channels are permitted by MI&B.

About 103 Ku-band transponders from both Indian and Leased satellites are catering to DTH television services. Apart from DTH, about 21 C band transponders are used for supporting Television uplink. Doordarshan alone is using a total of 18.92 Transponders (12.25 in C Band & 6.67 in Ku Band) of 36 MHz each on Indian Satellite System.

Satellite News Gathering and Events Broadcasting

Satellite News Gathering using INSAT system enables coverage of on-the-spot real-time news and important events at different locations for transmission to a Central Station. These live coverages are rebroadcast over respective television channels. About 6 transponders are used for DSNG services of various operators.

Majority of the news channels use their own DSNG terminals. Doordarshan alone has 25 C-band and 18 Ku-band Digital Outdoor-Broadcast Digital Satellite News Gathering terminals operating through INSAT satellites.

Radio Networking

Radio Networking (RN) through satellite provides a reliable high-fidelity programme channels for National as well as Regional Networking. Around 472 All India Radio (AIR) stations and about 671 radio transmitters have been equipped with receive terminals. AIR is utilising one C-band transponder for uplinking RN carriers across the country. 39 radio channels of AIR are broadcast through DTH platform of Doordharshan.

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.

1561 Satellite Earth Stations of different size are operating in satellite network of BSNL, Government users, Closed user group, commercial users and broadcasters and are being utilised for telecommunications / broadcasting applications. As per provisional estimates, about 2,75,000 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 16,725 IPSTAR VSATs as well as one by two voice channel connectivity to remote areas through about 4700 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.

Telemedicine

The Telemedicine programme connects remote/rural/medical college hospitals and Mobile Units through the Indian satellites to major specialty hospitals in cities and towns. The telemedicine technology utilises Information & Communication Technology (ICT) based system consisting of customised medical software integrated with computer hardware along with medical diagnostic instruments connected to VSATs. Presently, around 165 Telemedicine nodes are operational across the country.

This year a Telemedicine node was established at Panchtarani, enroute Holy Amarnath cave in Jammu & Kashmir. Six nodes were established in Uttarakhand in Char Dham region. Around 100 nodes are in establishment process countrywide for various users such as Integrated Defence Staff (IDS-Medical), Army, Navy, Air Force, Coast Guards, Indo Tibetan Border Police (ITBP), Employees State Insurance Corporation (ESIC), etc. In Jammu & Kashmir, four TM nodes is established at high altitude region for Defence and six TM nodes in the network is reactivated.

Continuing Medical Education (CME) programmes are conducted on monthly basis from DECU studio. Medical experts/doctors share their knowledge & experiences and interact with the connected remote hospitals. This year, 12CMEs were conducted benefitting more than 2500 users. Feedback from all the participating nodes is taken and a report is prepared.

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 84 networks were implemented connecting around 4700 Interactive (SITs) and 53500 Receive Only Terminals (ROTs), covering 26 States & 03 Union Territories. At present, around 44 networks are operational in various states.

During the year, Tele-education networks of North-East states are revived connecting about 230 satellite interactive terminals (SITs) and work is in progress to operationalize another 120 SITs.

During the year, as a part of revival of North-East States Tele-Education network, seven Hubs were reactivated and 316 SITs made operationalised, efforts are on to reactivate the remaining SITS by this year end. A new TE network was commissioned in Manipur with 25 new SITs. As a part of revival of Jammu & Kashmir Tele-Education network, 64 SITs were activated. Uttarakhand TE network was revived with 42 SITs.

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 & 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 used from data collections, tracking and reporting applications.

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 99% operation efficiency (24x365 bases). 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 the major weather events particularly major cyclones Ockhi in November 2017, Sagar in May 2018, Mekunu in May 2018. Cyclones warnings were disseminated to all stake holders which resulted in minimum loss to human life.

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 & Information Dissemination (RAPID) which is a web based quick visualization 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 & Advanced Visualization Application that touch the life of common man in one or other way ranging from weather events to atmospheric phenomenon. This has capability to visualize the fog presence over railway track and highways & a pilot can see the position of clouds and fog of the entire route in real time basis interactively.

Satellite technology is of great use in meteorology and plays a very significant role in the improvement of weather forecasting and dissemination. In fact, the improvement in weather forecasting is mainly attributed to increasing use of satellite data.

Satellite Aided Search and Rescue (SAS&R)

India is a member of the international COSPAS-SARSAT programme for providing distress alert and position location service through Low Earth Orbit (LEO) & Geo-stationary 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 Center (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 companies, etc benefit from the SAR service.

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 2017-18, INMCC provided search and rescue support to 6 distress incidents in Indian service area through Indian system and contributed to saving 33 human lives. About 1383 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 924 registered user agencies (Maritime & Aviation) in India with an Indian beacon population of more than 16,355 in the database. The next generation system MEOSAR is under implementation phase and is expected to operate under early operations capability (EOC) by end of Year 2019.

High Throughput satellites

The demand for bandwidth catering host of new age applications is exponentially growing. Embracing new technologies both in terrestrial and satellite communication there has been a paradigm shift in the delivery bandwidth from the past one decade. The satellites are becoming bigger and powerful to provide the coverage using multiple spot-beams operating in Ku and Ka bands. The throughput derived from such satellites is of several order higher compared to traditional satellites.

The first in this series GSAT-19 is in orbit. GSAT-29 satellite is launched during Nov 2018 and is in orbit and the GSAT-11 is launched on Dec 5, 2018 and is undergoing in-orbit test. The capacity on these satellites will be used for catering to BharatNet and other VSAT based applications. The gateway facilities for GSAT-19 are made available for immediate use. The full-fledged gateways for all these satellites are in various stages of implementation. These satellites are expected to pave way for greater capabilities in terms of capacity and capability to reach out to people of our country.

South Asia Satellite

Following the announcement made by Honourable Prime Minister of India the South Asia Satellite was realized and launched on board GSLV on May 5, 2017. After the in-orbit tests, sample videos in the native languages of the member countries were uplinked through a hub facility at Delhi.

User terminals (one in each country) were established in the member countries during Sep to Dec 2017 and demonstration of services like TV reception, video conference, data communication, access to Web based weather and geospatial applications was conducted through the Satellite. The demonstration has shown the capabilities of the satellite for the member countries to make use of it effectively.

Installation of a dedicated network in Bhutan is in advanced stage. This network is planned to address telecom back up for critical links, remote village connectivity, disaster management communications, television broadcast and DSNG services. Two television channels of Bhutan BBS1 and BBS2 are uplinked as a single bouquet from March 2018 on trial basis.

Maldives has planned to establish a dedication network for island connectivity and procured 35 terminals for this purpose. Installation is undertaken by Maldives through their internal manpower. Bangladesh has taken the satellite link parameters for their network planning. The plan of utilization by other member countries is in various stages.

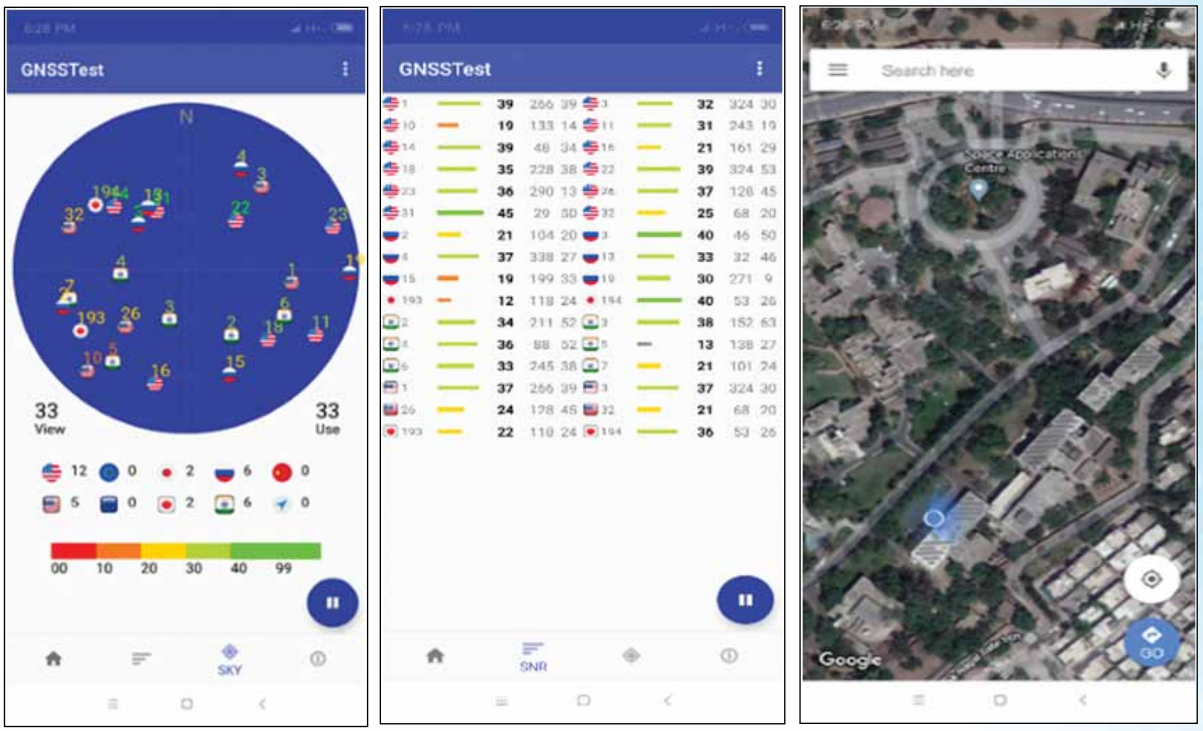
3.2 Satellite Based Navigation Applications

With the satellite constellation established, NavIC system is now fully available for position, navigation and timing solution and for derived location-based services.

NavIC signal can be extensively used for positioning, navigation and timing applications in a variety of civil and commercial activities related to land transportation, aviation, maritime; mapping, surveying and geodesy; scientific research; timing and telecommunications.

The major initiatives by ISRO have been on the following:

1. Initiatives towards introducing NavIC chip onboard smartphones have been undertaken to receive NavIC signals. Discussions with several mobile manufacturers have been initiated with regard to technical support as well as in terms of policy to expedite enabling mobile devices for receiving NavIC signals.



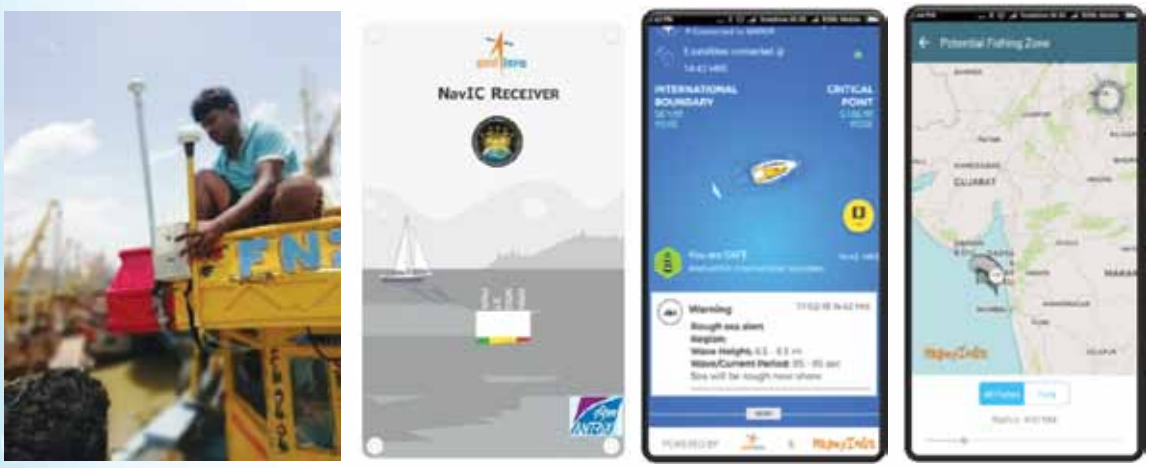
2. ISRO, in conjunction with mobile phone OEM's, is in discussions with major chip manufacturers like Broadcom, Qualcomm etc., to undertake development of chip to add NavIC capability across all ranges of mobile phones.
3. An 11 channel Base Band ASIC, configurable for any one of NavIC L5, S or GPS is designed and developed in-house using 180 nm silicon technology.

4. A Multi Chip Module (MCM) based on 55nm technology developed through M/s. SkyTraQ, Taiwan has been procured by ANTRIX/ISRO in quantity to enable Indian industry in productionisation of NavIC Messaging Receiver

and Vehicle Tracker Units. ANTRIX / ISRO has initiated procurement of single chip module of size <200mm^2 for further optimization in area.

5. A ruggedized version of 36 channel Dual Band NavIC/GPS Receiver, configured for a high-dynamic platform with a rapid refresh rate was successfully used on board PSLV C36, C37, C38, C39, C40, C41 and GSLV MkII & MkIII launch vehicles.

6. A single channel NavIC messaging receivers using IRNSS-1A is designed and developed in-house. These receivers provide alerts messages such as cyclone, high wave etc and information on Potential Fishing Zone for the fishermen venturing into deep sea. INCOIS



(Indian National Centre for Ocean Information Services), Hyderabad is authorized to upload the information. The fishermen in the deep sea can view these messages / information through an App (developed by MapMyIndia) run on any Android based smart phone connected to the receiver through Bluetooth. After pilot field trials with Fisheries department of Kerala, technology is transferred to six industries for mass production. About 1600 units are delivered by two industries. Several hundreds of these units have been distributed to fishermen of two states – Kerala and Tamil Nadu while trials are underway with the other two coastal states of South India.

7. NavIC Timing Receiver with NTP server is disseminating NavIC Time on ISACNET, SACNET, SPACENET. This facility is provided to Centre for Railway Information System (CRIS) on Internet. CRIS has operationalized it to synchronize its systems across the country. Similarly, NavIC Timing receivers have been installed at Northern, North Eastern, Western and Southern region, power grid stations, in the Power System Corporation (POSOCO) for power grid synchronization.

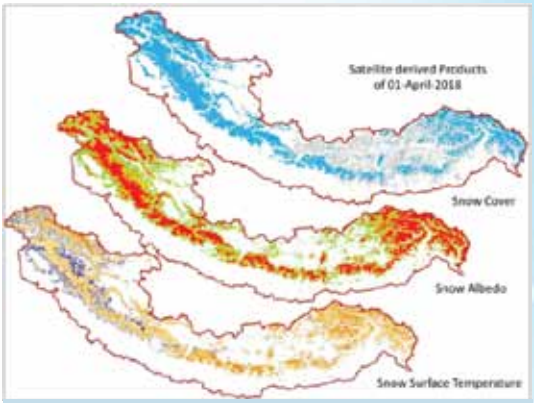
8. ARAI-140 has mandated for fitting NavIC enabled Vehicle Tracking Units in all the commercial vehicles with effect from April 2019. Indian industry involved in the development of Vehicle Tracking Units have approached ISRO for evaluation.
9. ISRO is liaising with various ministries and user agencies to ensure wider adoption of NavIC for position and timing based applications such as sand mining.
10. IRNSS SPS receivers are distributed across various organizations and academic institutions across the country to independently evaluate IRNSS performance from the user perspective. These are located in North, South, East, West and Central regions of the country to carry out detailed performance evaluation. Data collection, evaluation and post processing are carried out from these locations.
11. The IRNSS Signal In Space (SIS) Interface Control Document (ICD) for SPS has been updated and released to the public in ISRO website to facilitate research and development and aid the commercial use of the IRNSS signals for navigation based applications.

3.3 Remote Sensing Applications

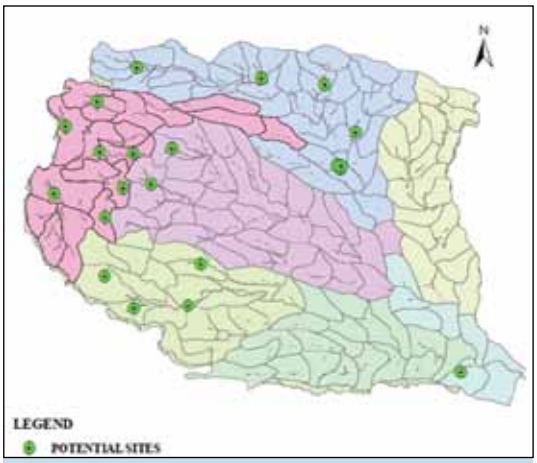
3.3.1 Land and Water Resources

a. National Hydrology Project (NHP)

As an implementing Agency under the National Hydrology Project of MoWR, RD & GR, NRSC/ ISRO is entrusted with the responsibility of generation of geo-spatial products & services pertaining to the water resources sector. Development of real-time operational spatial flood early warning system for Godawari & Tapi basins; Satellite data-based regional evaporative flux monitoring system; Glacial Lake Outburst Flood (GLOF) risk assessment; Spatial Snow-melt Runoff Forecast for Indian River basins of Himalaya and Development of an operational National Hydrological modelling system for the entire country etc. have been initiated under NHP.



Satellite derived snow products for snowmelt runoff estimation



Map displaying suitable locations for a region in Telangana for water harvesting structures

b. Site suitability analysis for planning water harvesting structures

Drainage, slope, land use/ land cover and soil layers were used to identify suitable sites for check dams in Telangana, considering the proximity to agriculture fields, slope of

the terrain and soil permeability. The output shows suitable locations for installing water harvesting structures.

c. Monitoring of Watersheds using Geospatial Technologies:

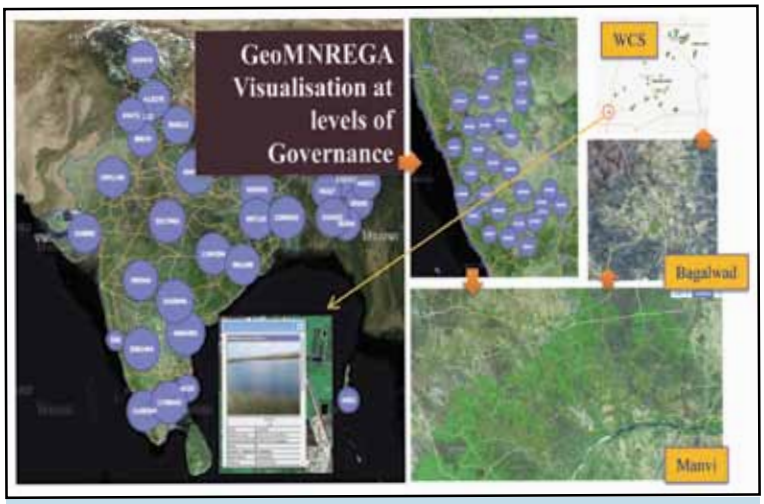
Integrated Watershed Management Programme (IWMP) is a flagship programme of Department of Land Resources (DoLR), MoRD, GOI. Using multi-temporal IRS high resolution (Cartosat-2 and Resourcesat) data, the monitoring of IWMP Projects is being carried out for 6850 projects at National level. Bhuvan based GIS tool, called SRISHTI is used for monitoring and evaluation of the watersheds whereas, a smart phone application named DRISHTI was developed for uploading Geo-tagged ground information onto Bhuvan. A total of 9.68 Lakh geo-tags of the ground activities have been created using Bhuvan-Drishti and uploaded onto the Bhuvan-Srishti platform.

Construction of Farm ponds under IWMP-1 2009-10. Anantpur District, A.P.

Monitoring of about 500 watershed projects sponsored by NABARD is also being carried out across different states using high resolution IRS images, by assessing the changes in vegetation and water resources.

d. GIS Implementation of MNREGA (GeoMNREGA)

Bhuvan based application (GeoMNREGA), is being employed for monitoring of rural development activities under major schemes of the Ministry of Rural Development. Geo-MNREGA has entered second Phase wherein asset implementation is monitored using Bhuvan app for site selection, during asset creation and also after the creation of the asset. Nearly 3.2 crore assets covering 155 sub-categories of activities have been Geotagged and accepted under Phase-1 whereas, about 1.6 lakh completed assets and 15.4 lakhs under-construction assets are geotagged in Phase-II. Figure alongside shows MNREGA activity in Karnataka

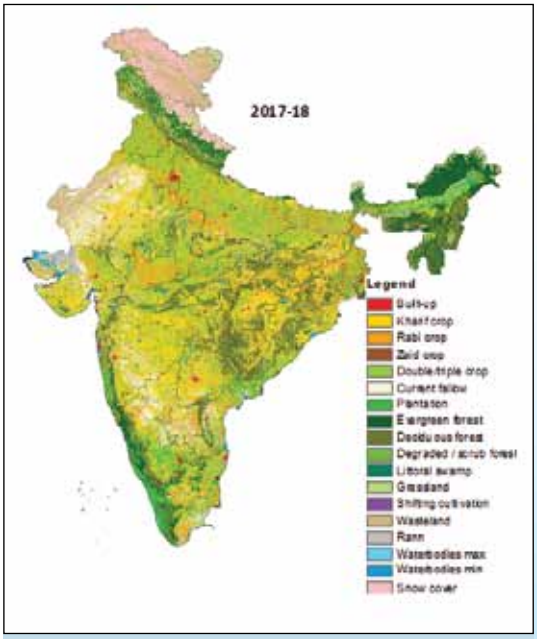


Bhuvan-GeoMNREGA

(Manvi taluk, Bagalwad village) for desilting of a pond which created employment for villagers, on Bhuvan.

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

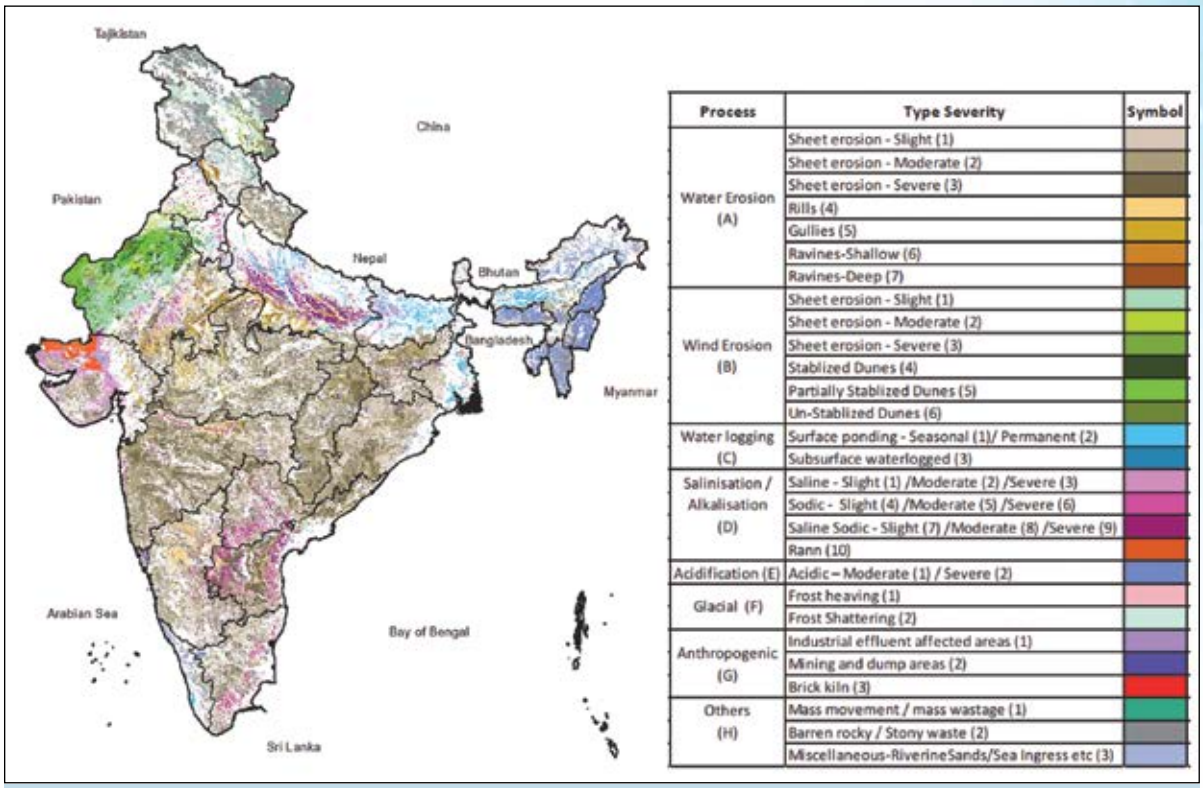
Mapping of Land Use / Land Cover (LULC) using multi-temporal satellite data, was initiated in the year 2004-05 and 14 annual cycles of assessments at 1:250,000 scale have been completed till 2017-18. During 2017-18, it was noticed that the single season crop area has substantially increased during both Kharif and rabi seasons, while double / triple cropped area has marginally decreased by 3.95% as compared to previous year (2016-17). The extent of current fallow has also decreased by nearly 18%.



LULC map of India (2017-18) generated using multi temporal AWiFS data

f. Land Degradation (2015-16) mapping at 1:50,000 Scale

National land degradation mapping has been taken up by ISRO along with partner institutions, for generating information on land degradation at 1:50,000 scale using



Process	Type Severity	Symbol
Water Erosion (A)	Sheet erosion - Slight (1)	
	Sheet erosion - Moderate (2)	
	Sheet erosion - Severe (3)	
	Rills (4)	
	Gullies (5)	
	Ravines-Shallow (6)	
	Ravines-Deep (7)	
Wind Erosion (B)	Sheet erosion - Slight (1)	
	Sheet erosion - Moderate (2)	
	Sheet erosion - Severe (3)	
	Stablized Dunes (4)	
	Partially Stablized Dunes (5)	
	Un-Stablized Dunes (6)	
Water logging (C)	Surface ponding - Seasonal (1)/ Permanent (2)	
	Subsurface waterlogged (3)	
Salinisation / Alkalisation (D)	Saline - Slight (1) /Moderate (2) /Severe (3)	
	Sodic - Slight (4) /Moderate (5) /Severe (6)	
	Saline Sodic - Slight (7) /Moderate (8) /Severe (9)	
	Rann (10)	
Acidification (E)	Acidic – Moderate (1) / Severe (2)	
Glacial (F)	Frost heaving (1)	
	Frost Shattering (2)	
Anthropogenic (G)	Industrial effluent affected areas (1)	
	Mining and dump areas (2)	
	Brick kiln (3)	
Others (H)	Mass movement / mass wastage (1)	
	Barren rocky / Stony waste (2)	
	Miscellaneous-RiverineSands/Sea Ingress etc (3)	

Land degradation map of India (2015-16)

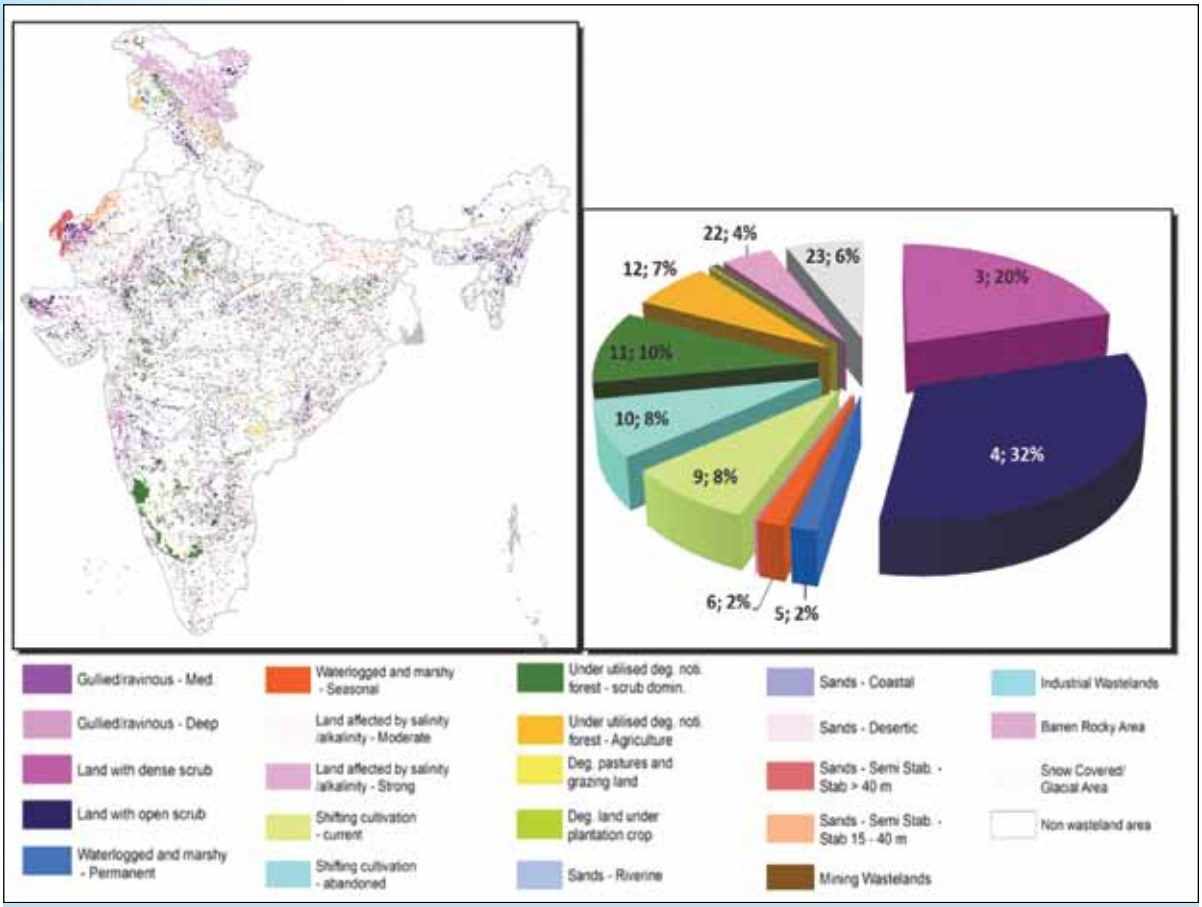
multi-temporal satellite data of 2015-16. Land degradation processes addressed are water erosion, wind erosion, waterlogging, salinisation / alkalization, acidification, glacial, anthropogenic and others. The maps were finalized with adequate ground truth and soil analysis results of nearly 2900 soil samples, collected exclusively under this project. The output comprises of land degradation status of 2015-16 and decadal changes with reference to the 2005-06 data. The land degradation map of India during 2015-16 is given in previous figure.

Land degradation maps are being used for planning various programmes such as soil and water conservation, watershed development, prioritization of watersheds, climate change studies, carbon sequestering studies, etc.

g. National Wastelands Monitoring - Multi temporal satellite data based change analysis

At the behest of Dept. of Land Resources (DoLR), Ministry of Rural Development (MRD) wastelands mapping for the entire country has been carried out on 1:50,000 scale, using remote sensing data (Kharif, rabi and zaid) for the year 2015-16. The mapping also brought out changes in wasteland distribution with respect to the 2008-09 database.

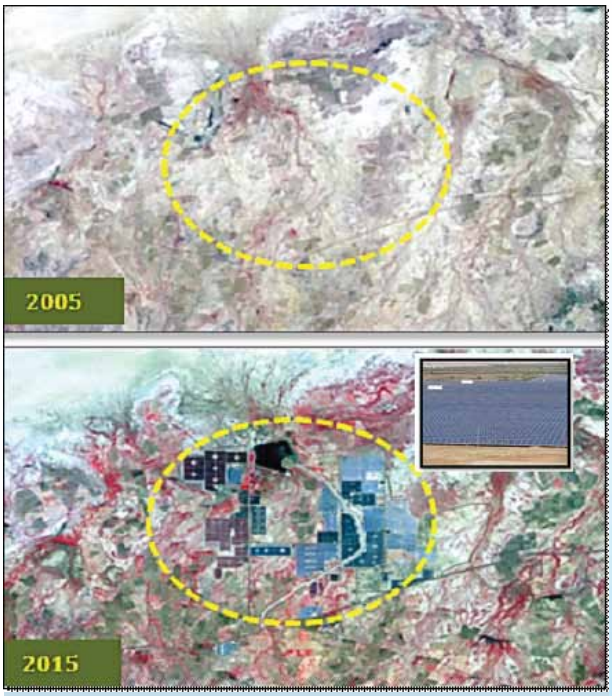
The total wastelands in the country in 2015-16 are 3,96,728.02 sq.km (12.98% of total geographical area) compared to 4,03,925.91 sq.km (13.21% of total geographical area)



Wastelands Map (2015-16)

in 2008-09. The trend indicates overall decrease in Wastelands by 0.24% from 2008-09 to 2015-16.

Wasteland data has been used under various programmes like Crop Intensification, Perspective planning, Renewable Energy prospecting, Site suitability for Industries etc., including reclamation of wastelands for agriculture, plantation, industry etc. In many parts of the country, wastelands have been used for development of solar power plants.



Solar Power Plant development in Wasteland Area, Solar Plant, Charanka, Gujarat

h. Monitoring & Assessment of Ecosystem Processes in North-West Himalayas

In order to understand various processes related to mountain ecosystem, remote sensing based assessment of various components comprising of forests & its climate change induced impacts, mountain agriculture, water resources, habitations, weather & its extremes and geodynamics & seismicity, is being carried out in North-West Himalayas (NWH), in collaboration with nearly 10 research organisations. Under this, species association was modelled and the nitrogen dynamics was computed for three representative ecosyst-ems. One seismological station is being set up for detection of early arrival of P-waves in IIRS campus. Climate change impact on productivity of horticulture crops, establishment of surface runoff & soil erosion measurement site, setting up of hydrological model for entire NWH basins at 2.5 km grid size etc. are other highlights.

3.3.2 Urban Studies

AMRUT Cities' Large Scale Urban GIS Database creation

Large scale (1:4,000 scale) Urban GIS database creation using Very High Resolution Satellite (VHRS) data for formulation of GIS based Master Plans, being carried out for 242 AMRUT cities.

(a) Satellite Image (0.5m) of Kochi town (b) Base details, Building footprints and land use

GIS database of 19 AMRUT cities is provided to the respective Urban Local Bodies (ULBs) for ground verification, attribute data collection and

formulation of GIS based Master Plans. VHRS data showing small portion of Kochi town along with corresponding pre-field map is given in figure for illustration purpose.

3.3.3. Agricultural Sciences & Applications

CHAMAN Programme: Phase I of the national level project; *Coordinated programme on Horticulture Assessment & Management using Geoinformatics (CHAMAN)* has been completed, achieving area assessment of major horticultural crops in selected districts in India (7 horticultural crops, across 185 districts in 12 states). CHAMAN app has been used for faster and efficient collection of ground information, as well as in building up a geodatabase through Bhuvan platform.

Department of Agriculture, Cooperation & Farmers' Welfare (DAC&FW) has approved the implementation of CHAMAN Phase-II under the Mission for Integrated Development of Horticulture (MIDH) and was formally launched at Krishi-Bhavan.

3.3.4 National Carbon Project

a. Soil-vegetation-atmosphere flux studies over different agro-ecosystems of India: This project aims towards quantitative assessment of carbon/moisture fluxes and energy balance components over the different agro ecosystems. Four eddy covariance towers were established till now to assess the carbon and moisture fluxes and up-scaling of it using remote sensed proxies. The agro ecosystems targeted are as below:

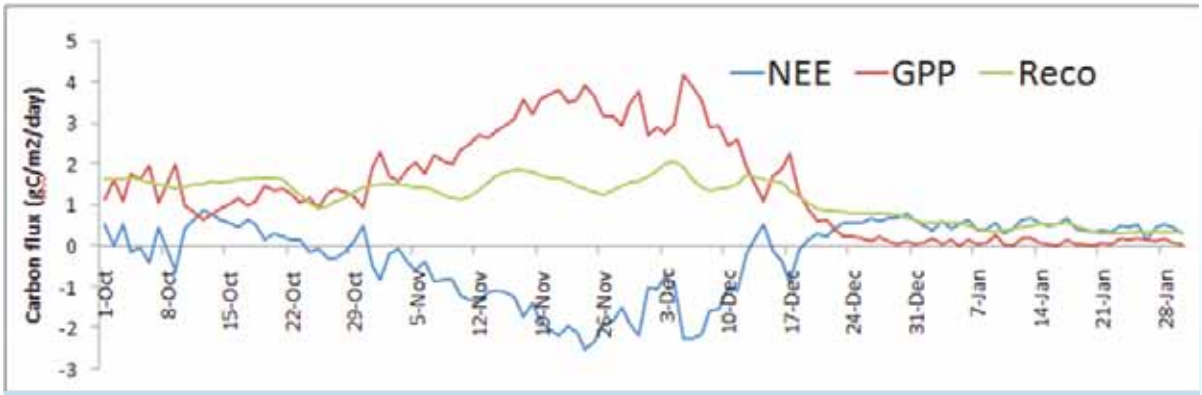
- Tropical flooded rice agro-ecosystem at Regional Agricultural Research Station, Maruteru, West Godavari, Andhra Pradesh
- Rain-fed pulse (gram) agro-ecosystem at Central Seed Farm, National Seed Corporation, Jawalgera, Raichur
- Rain-fed cotton agro-ecosystem at research farm of Central Institute of Cotton Research, Nagpur
- Jute-based agro-ecosystem in the research farm of Central Research Institute for Jute and Allied Fibre, Barrackpore, West Bengal

Brief results of pulse-based agro-ecosystem study carried out this year are discussed below.

Carbon fluxes from rain-fed pulse (Chick pea/ Bengal gram) at Raichur: The mean Net Ecosystem Carbon Exchange (NEE), Gross Primary Production (GPP) and Ecosystem Respiration (Reco) were found to be 0.64 gC/m^2/day, 0.94 gC/m^2/day and 1.58 gC/m^2/day. The net carbon sequestrate was found to be -35.68 gC/m^2. From flowering to harvesting stage the mean NEE was -0.03 gC/m^2/day, GPP 1.05 gC/m^2/day, Reco 0.96 gC/m^2/day. The net carbon sequestrate was found to be -3.39 gC/m^2. During the total season the net carbon sequestrate over the rainfed chick pea based agro-ecosystem was found to be 0.314 ton/ha. The Reco to GPP ratio was found to be very high as 77%.

b. Soil-Vegetation-Atmosphere Flux Studies over Forests

The objectives of the study are (a) Analysis of atmospheric CO_2 patterns to study spatio – temporal Carbon source-sink relations over India, (b) Establishment of network of eddy



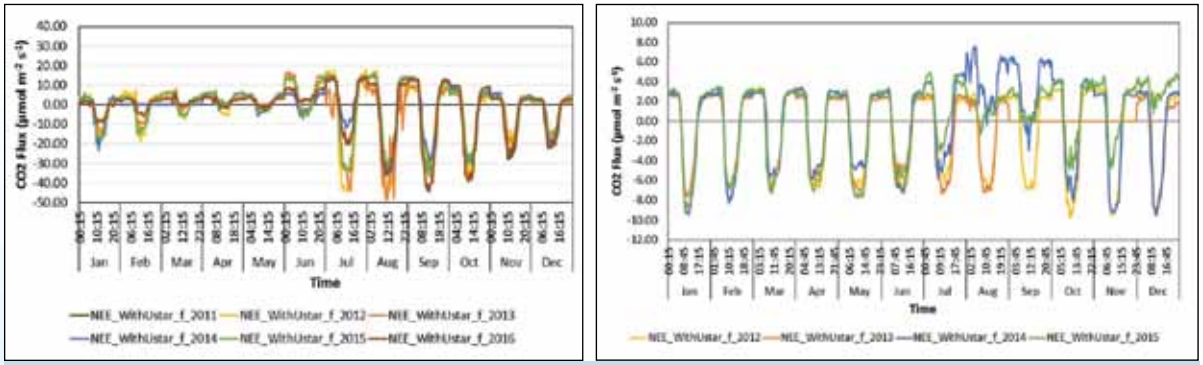
(a) Dynamics of mean daily carbon fluxes in terms of Net Ecosystem CO_2 Exchange (NEE), Gross Primary Production (GPP) & Ecosystem Respiration (Reco) over rain-fed chickpea crop season

(b) Flux tower

(c) Chickpea grown over fetch area of tower

covariance flux towers for measurements of mass and energy exchange, (c) Measurements and spatial modeling of soil CO_2 fluxes and (d) Integration of observations and component – wise modeling for conducting full carbon balance accounting of India and estimation of net carbon balance. A network of eddy covariance flux towers was established in forests of (a) Betul (teak mixed forests, MP), (b) Sundarbans (mangroves, West Bengal) and (c) Kanha, (Sal forest, MP).

Salient findings: Annual estimates of net CO_2 sequestered in teak mixed forests of Betul was 2148 ± 973 g m^{-2} yr^{-1} for NEP, 7688 ± 852 g m^{-2} yr^{-1} for GPP and 5539 ± 552g m^{-2} yr^{-1} for Reco. Annual estimates of net CO_2 sequestered in Sundarban mangroves was observed to be in the order of 914 ± 74g m^{-2} yr^{-1}NEP, 4465 ± 360g m^{-2} yr^{-1}GPP and 3750 ± 312 g m^{-2} $yr^{-1}{}_{Reco}$. Temperature-Greenness (TG) model was used to up-scale the tower based GPP for teak mixed deciduous forests of central India using eddy flux data and Moderate Resolution Imaging Spectroradiometer (MODIS) based EVI (MOD13A2) and Land Surface Temperature (LST – MOD11A2) data. Eddy flux tower data based GPP estimates were analyzed as a function of scaled LST and scaled EVI derived from MODIS data for Betul tower site (coefficient of determination, R2 = 0.9) to generate spatial GPP estimates. Results suggested good agreement of tower based GPP with TG-model based GPP estimates for the study areas.



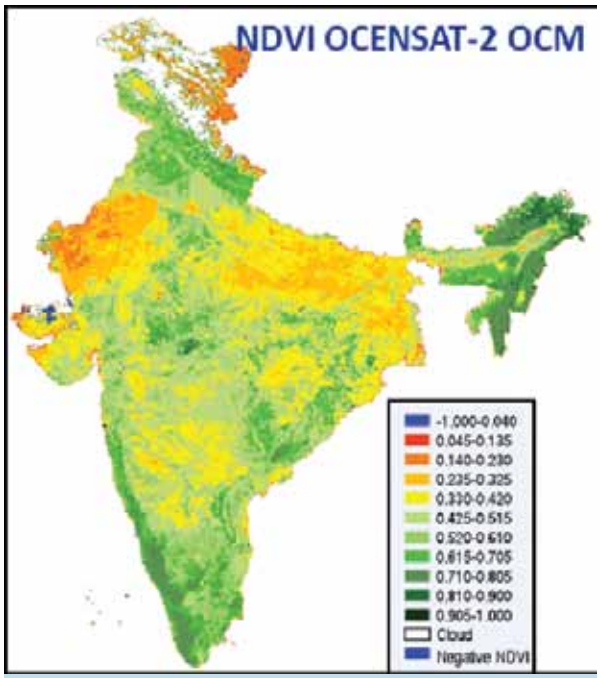
Monthly diurnal average NEE at Betul, MP and at Sundarbans, West Bengal

3.3.5. Climate and Atmospheric Science Studies

a. Arctic expedition: Measurements on Greenhouse gases and reflectivity from the vegetation were carried out during the Arctic expedition during August 2018. Preliminary observations show arctic soil acting as source and sink for CH_4 depending upon soil moisture and source for CO_2. The Carbon stored in the permafrost soil will be emitted during the thawing process in the summer season.

b. National Information System for Climate and Environment Studies (NICES)

National Information System for Climate and Environment Studies (NICES) was setup during 2012 to generate various bio-geo-physical products relevant to climate change studies (fig. 3.3.5.b1). Products for 64 bio-geophysical variables are being generated among which, 13 are qualified to be Essential Climate Variables (ECVs).



NDVI product from Ocenasat-2 data, from NICES

c. Air quality monitoring using INSAT-3D data

An operational web-based Air Quality Monitoring System, using Space based inputs, mainly from Indian EO sensors such as INSAT-3D/3DR & OCEANSAT-2 OCM, other global sensors such as MODIS, SUOMI NPP, in-situ data from Central Pollution Control Board (CPCB) and modelled Air Quality parameters, has been developed. This information is being regularly disseminated through VEDAS Web portal (fig. 3.3.5.c1) for use by CPCB, IMD etc. for Air Quality Monitoring.

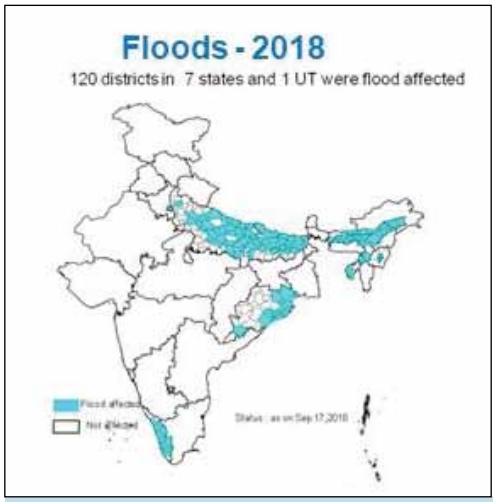
Snapshot of Air Quality Monitoring application at SAC VEDAS web portal

3.3.6. Disaster Management Support Activities

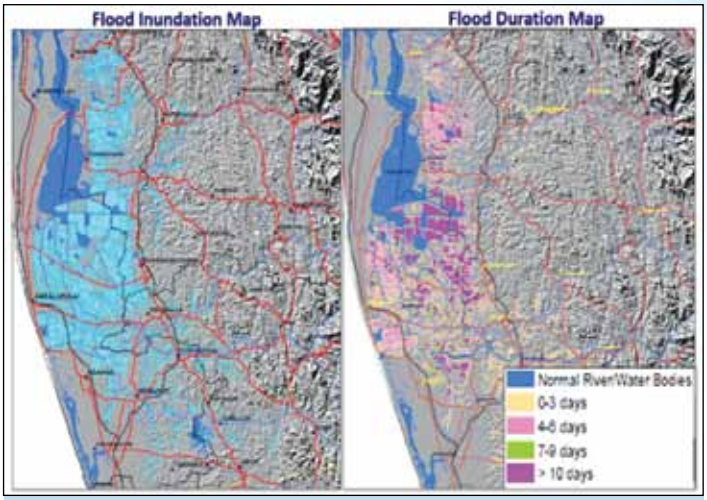
A. Floods

During 2018, India witnessed major floods during June to September in 120 districts spread across Assam, Bihar, Manipur, Odisha, Uttar Pradesh, Kerala, Tripura and Delhi.

Very devastating floods occurred in Kerala State during second week of August, and 10 out of 14 districts were affected very severely. The floods were monitored and inundations mapped using Indian and foreign satellite datasets on a regular basis. Flood inundation maps at State and District level were generated and disseminated to Kerala State Disaster Management



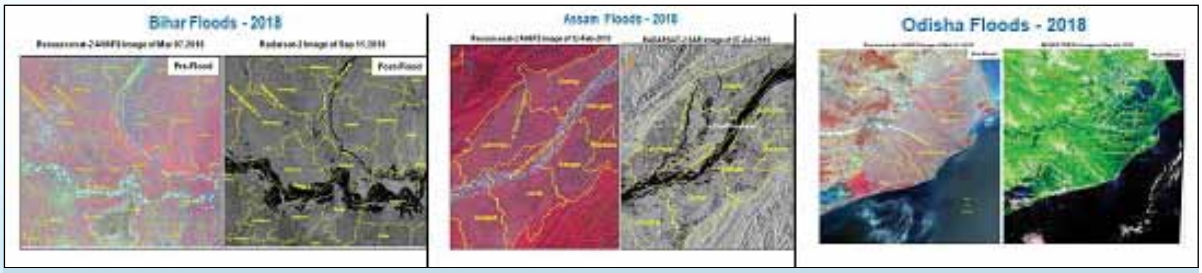
Flood affected districts in India during 2018



Images showing the severely flooded areas in Kerala during August, 2018

Authority (KSDMA), KSREC and Central departments. Products were also disseminated through Bhuvan and NDEM web-portals in near real-time.

In addition to Kerala floods, all the major flood events in the country were monitored and about 75 flood maps were disseminated to the concerned departments for use in relief and rescue planning activities.

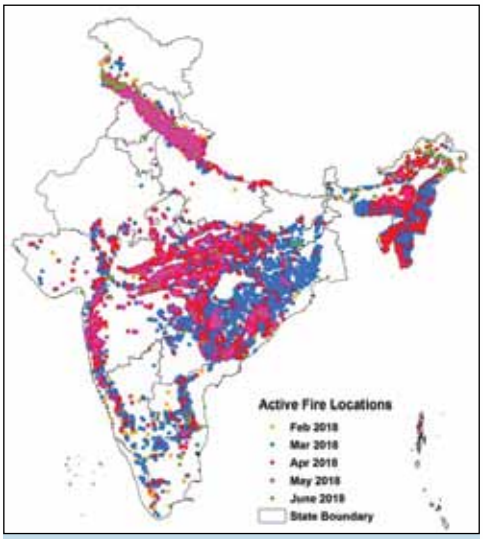


Flood scenario in Bihar, Assam & Odisha

Kerala Floods - Support from International Charter & Sentinel Asia: International Charter and Sentinel Asia were activated for high resolution satellite datasets for detailed damage assessment for Kerala floods. More than 98 satellite datasets comprising both optical and microwave data were provided by the International Charter. The satellite datasets from NRSC/ISRO, CNSA, CSA, DLR, DMCII, ESA, JAXA, KARI, ROSCOSMOS, etc and from sentinel Asia JAXA datasets were acquired and analysed. More than 13 value added products were generated and disseminated to concerned users.

b. Forest Fires

During 2018, Active forest fire monitoring was carried out using satellite data during Feb-Jun period. About 38,900 active fire locations were identified during this season. This information was shared with Forest Survey of India (FSI), Dehra Dun in near real time mode. Additionally, fire alerts are published on Bhuvan and sent as SMS to selected State Forest Departments.



Active forest fire locations during 2018 generated from Terra/Aqua of MODIS satellite data

Fire events: The fire event in Kurangani hills of Tamil Nadu (11th March 2018) was monitored using medium resolution multi spectral satellite data from the 11th to 13th March, 2018. Fire events in the vicinity of the Vaishnodevi temple were monitored from 22nd to 26th May, 2018.

c. Landslides

Kerala and Karnataka landslides: Kerala and Karnataka witnessed widespread occurrence of landslides due to heavy rainfall in August, 2018. RS2/RS2A LISS-IV Mx Satellite data were analysed to identify landslides in Kerala.

A total of 5130 landslides have been mapped. Similarly, Kodagu and Dakshina Kannada districts of Karnataka state also witnessed landslides due to the same rainfall. A total of 120 landslides were mapped using high resolution satellite data.

Mangalore-Bangalore Rail line affected by Landslide

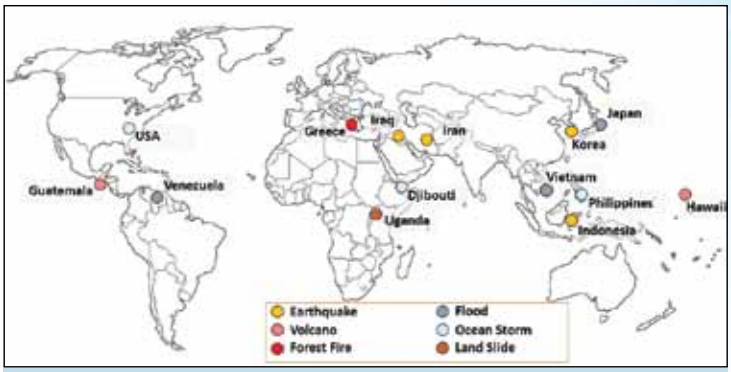
d. National Database for Emergency Management (NDEM) Services

Disaster Services: Value added products such as flood inundation maps, forest fire hotspots, damage assessment maps, drought indices maps, earthquake locations etc., were hosted on NDEM portal for all major disaster events during 2018. So far, 1335 disaster specific products/ maps/reports were disseminated to the users through the NDEM platform, which also include daily/seasonal products from various sources for assessing the overall weather situation across the country.

e. Capacity Building: 6 regional training programmes were conducted at Nagpur, Delhi, Kolkata, Shillong, Bangalore & Jodhpur during May-June 2018 covering 375 officials from district disaster management department to increase the outreach of NDEM services at district level.

f. IRS Data Support for International Disasters

Under Sentinel Asia framework, more than 36 IRS satellite datasets were provided for 14 disasters in 2018 which include floods in Sri Lanka, Japan, Myanmar, Vietnam, Thailand, Taiwan and LAOS, earthquake in Indonesia and Japan & Oil Spill in Thailand.



IRS Data Support

Similarly, under the framework of International Charter, about 69 IRS satellite datasets were provided for 12 disasters in 11 countries during 2018, which include USA, Indonesia, Philippines, Vietnam, Venezuela, Greece, Japan and others.

3.3.7 Satellite Data Reception

NRSC Ground Station - IMGEOS: About 9365 satellite data passes were acquired from IMGEOS facility at an average of 51 passes per day with station efficiency better than 99% using its four 7.5 m S/X band antenna terminals for Earth observation data from the ongoing Indian Remote-Sensing missions including Resourcesat-1, Resourcesat-2&2A, Cartosat-1, Cartosat-2, Cartosat-2A/2B, Cartosat-2S, Oceansat-2, SCATSAT-1, Microsat-1 and SARAL. Also data is acquired from few foreign satellites viz., AQUA, TERRA, LANDSAT-7, LANDSAT-8, SNPP, NOAA-19 & METOP-A/B satellites.

AGEOS Activities: "Antarctica Ground Station for Earth Observation Satellites (AGEOS)" facility was established at Bharati (Research base of NCAOR), Antarctica to acquire IRS data and transferring the data to IMGEOS facility for processing. This Ground station being located in South Polar Region is capable of acquiring 10-11 passes from a mission per day maximizing global coverage for IRS missions. A total of 4,273 payload passes were acquired successfully at AGEOS during April 2018 to Sep 2018. C-band Communication systems are established at Antarctica, NRSC & NCAOR for data transfer (40 Mbps), and other services like VOIP, Video Conference, Internet, Monitor & Control (M&C) from NRSC & ISTRAC TTC.

Antarctica Ground Station for Earth Observation Satellites (AGEOS)

AGEOS-II: NRSC/ISRO has established a second Antenna system (DRS-2) at AGEOS with tri-band (S, X and Ka bands) reception capability, towards equipping the facility to receive satellite data from upcoming Cartosat-3 mission. Establishment of S/X/Ka band Data reception Terminal is a carried out during Jan to Apr, 2018 as part of 37th Indian Scientific Expedition to Antarctic. The system is ready to receive the data from Cartosat-3 series of satellites in Ka-band. Also, the new terminal is capable of supporting TTC services from the station.

IGS & User Stations: SVALBARD and TROMSO Stations: Payload data dump of Scatsat-1 at these stations is being transferred through Network to IMGEOS, Shadnagar and Ancillary Data Processing is being carried out to generate Level-0 Products. During April 2018-Sep 2018 period, about 1,641 Scatsat-1 data passes were acquired through these stations and processed as per TAT requirement.

3.3.8. Other Developments

Antenna Control Servo System for Ka-Band Data Reception System: 3-axis Antenna Control Servo System is being developed to meet satellite tracking requirements for Cartosat-3 series satellites. As part of the development, a two axis Antenna Control Servo System was developed and successfully tested on 4.5 M X-band antenna system to verify X-band auto track performance.

S & Ka Band Data Reception System: Towards meeting Cartosat-3 data reception requirements, development of Ka Band Data Reception system using 7.5 m Antenna with Cassegrain feed to provide 37 dB/ °K G/T has been taken up. The design, specifications and configuration of down link systems are finalized and the development is under progress.

New S/X Band Feed for 7.5 m Antenna System: 7.5m Antenna System X band feed is designed using Five element feed. The new feed consists S and X band feed elements kept at cassegrain focus. Design, Simulation and fabrication of S/X Band feed is completed and will be used in future 7.5 m Antenna Systems for data reception in S/X Band from LEO satellites.

S/X Band Feed

Jodhpur Station X/S –BAND 3-Axis Antenna: A 7.5 m S/X Band antenna system is being established at CAZRI Campus Jodhpur, which will have better visibility for north western region of Indian subcontinent and will enable coverage for SAARC countries. Noise survey, Elevation profile, identification of ACP and marking of True north are completed.

3.3.9. Data Processing, Products, Archival and Web Applications

Satellite Data Processing: During the period, about 1,48,223 data sets were processed for optical and microwave satellite remote sensing missions including processing for global acquisitions. A total of 1180 geophysical products were also generated.

Satellite Data Dissemination: A total of 53,462 products were supplied during the period to various users. Besides, Foreign high resolution data for nearly 46 lakh sq km was disseminated to users.

Web Download: About 4,28,888 products were downloaded by users including 3,48,033 through Oceansat-2 web portal and 80,855 through Bhuvan-NOEDA portal (satellite data coarser than 23m resolution).

Indian and Global Archives: Over India, systematic collections of satellite data from RS-2, RS-2A, Cartosat-1 & Oceansat-2 is being carried out and archived. Also, Global archives are being enhanced using Antarctica station (AGEOS, Bharati) for downlinking the data.

Bhuvan

Bhuvan [http://bhuvan.nrsc.gov.in] is ISRO's Geoportal providing visualization services and Earth observation data to users in public domain. Bhuvan provides continuous services to wide array of users for visualization of EO and their remote sensing application needs, besides servicing free remote sensing data through NOEDA.

a. **Bhuvan Web Services:** During the period, 7 new application releases, 51 product updates (for 15 NICES products), new development & support for 11 national level projects, 6 state level applications, support for Disaster Management (national & international) & SAARC portal were carried out.

b. **High Resolution data update on Bhuvan:** Bhuvan was updated with 5m resolution Resourcesat-2/2A LISS-IV FMX satellite data (2017). A total of 11,728 tiles were made available for free download of satellite Orthorectified images through Bhuvan-NOEDA portal.

Snapshot of Bhuvan Portal

c. **Infrastructure and Networking:** Operationalization of Bhuvan scale-up infrastructure at Shadnagar with 100 live servers and 150 TB of online storage unit along with networking devices with High Availability mode realized. Bhuvan Data centre at Shadnagar was made operational with High availability along with 103 Bhuvan Web applications.

d. **Support to National events through Bhuvan:** *International Day of Yoga:* NRSC/ISRO in co-ordination with Ministry of Aayush, has come out with Android based Mobile app for image collection with location information for the International Yoga day-2018 (21-06-2018) events and made them available on Bhuvan portal for visualization in real time.

f. **Information Products:** Following new products were operationalized during the period.

Synthetic L4MX Data generation using Spatio Temporal Fusion method: Generation of 2deg * 2deg area covering Haryana state @ 5m resolution with better than 5-day temporal resolution using RS2-AWiFS, LISS_III & LISS-IV, RS1-AWiFS, LANDSAT-8 OLI sensors.

Active fire alerts generation: Active fire alerts generation using S-NPP and MODIS data sets are being carried within 15 minutes of data acquisition at Shadnagar. Daily alerts are being generated for 4 passes of each satellite during day and night.

g. **Bhuvan Outreach:** During this period, Bhuvan conducted 7 training programs and trained more than 200 participants. Bhuvan Exhibition was conducted on 26th September 2018 and witnessed participation of 7000 students.

MOSDAC LIVE

3.3.10. MOSDAC

Web based visualization and analysis system, LIVE (Let's Interactively Visualise Earth) is implemented which provides NRT

access for Earth observation, Meteorological & Oceanographic products derived from satellite & Model forecast and ground observations. VARSHA and SCAT, two new visualization software was configured in LIVE.

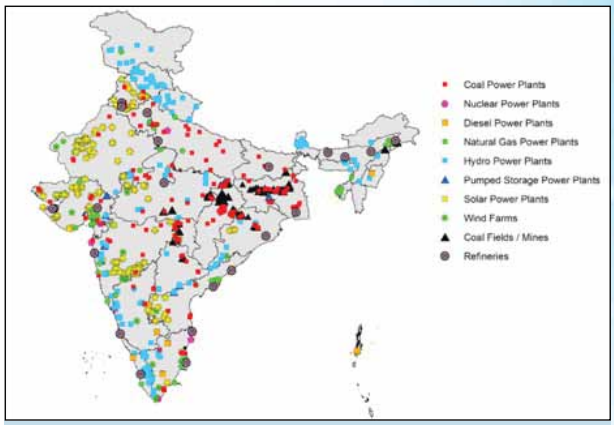
Summary of achievements of MOSDAC is shown in figure below.

MOSDAC	Total	New in 2018
Registered Users	4493	1022
Data Volume	170 TB (Available in Archive)	116 TB (Disseminated to Users)
Information Services	17	3
Data products	189 (8 Satellites)	32 (3 Satellites)
Number of Personnel Trained (SMART Programme)	312	132
Number of Research completed by Students (SMART Programme)	77	34
Outreach (SMART Programme)	530 Students (6 University)	230 Students (3 University)

Summary of achievements of MOSDAC

3.3.11. Visualization of Earth observation Data and Archival System (VEDAS)

During the year 2018, five applications were developed and deployed on VEDAS. (i) Prototype of the GIS based energy map of India for NITI Aayog (ii) Solar Calculator for Africa (iii) A multilingual Android App for wetland information data collection and dissemination (iv) A dashboard for monitoring vegetation Condition for Rajasthan, and (v) Tool for dissemination of L & S band SAR data. Nearly 3000 Web-map products were disseminated through VEDAS.



GIS based energy map of India

The Geospatial Energy information system (developed for NITI Aayog) provides static data on 22 thematic layers related to energy map of India. It hosts data of all types of conventional power plants, including Thermal (Coal, Diesel & Natural Gas), Hydro and Nuclear Power plants, locations of Refineries, LNG terminals, etc. It also provides 15 reference layers, including Bhuvan WMS for village boundaries and satellite images up to 1.0 m spatial resolution.

Enhancements and enrichments of existing web services and functionalities have been done on VEDAS. For example, the Vegetation Monitoring module now has options for temporal

NDVI generation & visualization, long term statistics generation for NDVI data sets etc. Automatic processing chain of INSAT-based fire product is also enabled.

During the year, 214 participants from various organizations / institutes have undergone training (10 training programmes). Under research initiative of TREES, 36 students have worked on research initiative in various fields of EO applications such as Urban Applications, Hyperspectral analysis, Water Resources, Image Processing and Machine Learning.

3.3.12. Aerial Services and Digital Mapping

Aerial Projects

a. AVIRIS-NG Airborne Campaign: ISRO executed airborne campaign under ISRO-NASA collaboration programme, with advanced Airborne Visible Infrared Imaging Spectrometer-Next Generation (AVIRIS-NG) sensor of JPL-NASA, to develop in-depth science models, algorithms, atmospheric correction methods which will be helpful for future programmatic goals of ISRO in developing space based Hyper spectral sensor systems.

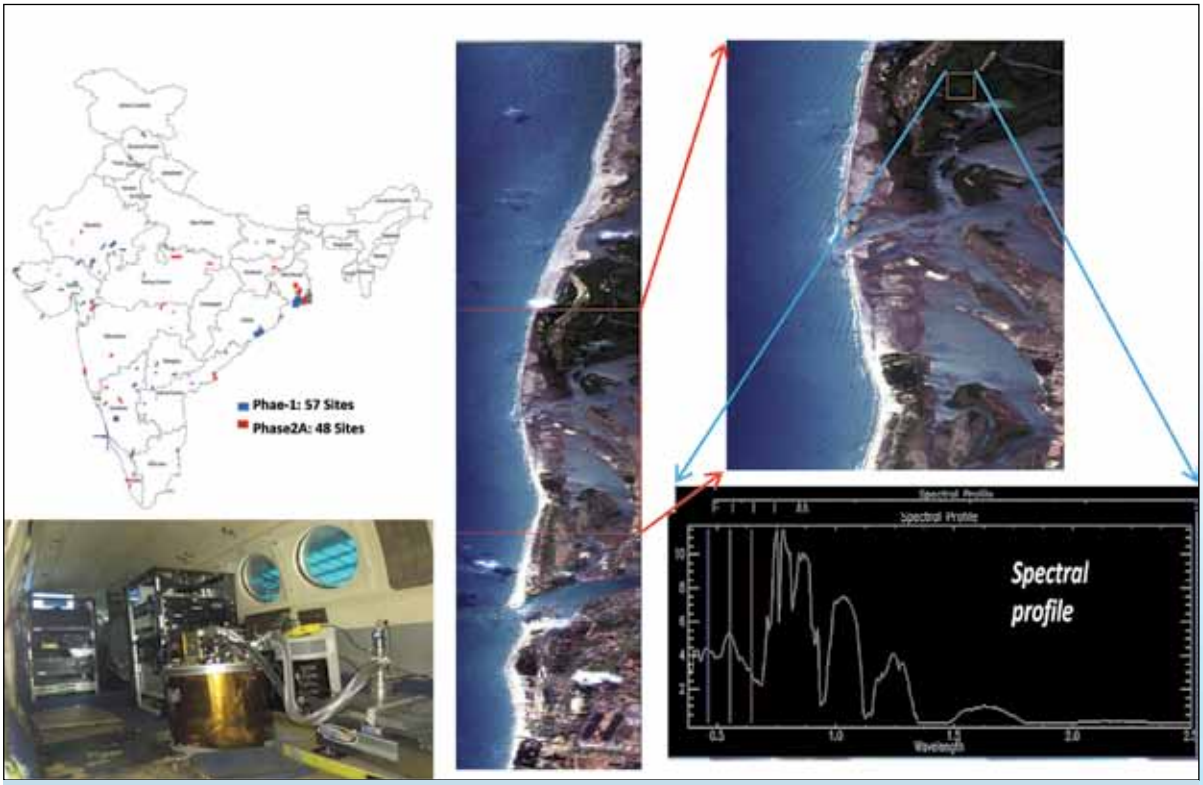
During 2018, campaign was conducted for 80 days, covering 15634 sq.km over 48 sites with 158 flying hours and collected 11.25 TB Aerial data with spatial resolution varying from 4m to 8m of data. Science teams from various research institutions and academia carried out ground truth data collection synchronizing with the aerial survey operations.

b. Geospatial Database Generation and Extraction of Building Heights Using LiDAR- DC for Coastal Stretch from Cochin to Gujarat: Airborne LiDAR data acquisition, geospatial database generation and extraction of building heights have been carried out along west coast (Cochin to Gujarat) up to 2 km inland, covering 11687 sq.km. It is being used for generating Digital Elevation Models (DEM) with sub-meter height accuracy in MSL datum, 0.5m interval contours, ortho-photos with 50 cm GSD and geo-database compatible to 1:5000 scale.

c. UAV Remote Sensing: North Eastern Space Applications Centre (NESAC) has undertaken major expansion of UAV (Unmanned Aerial Vehicle) activities and supplied UAVs to all State Remote Sensing Application Centres in the NER.

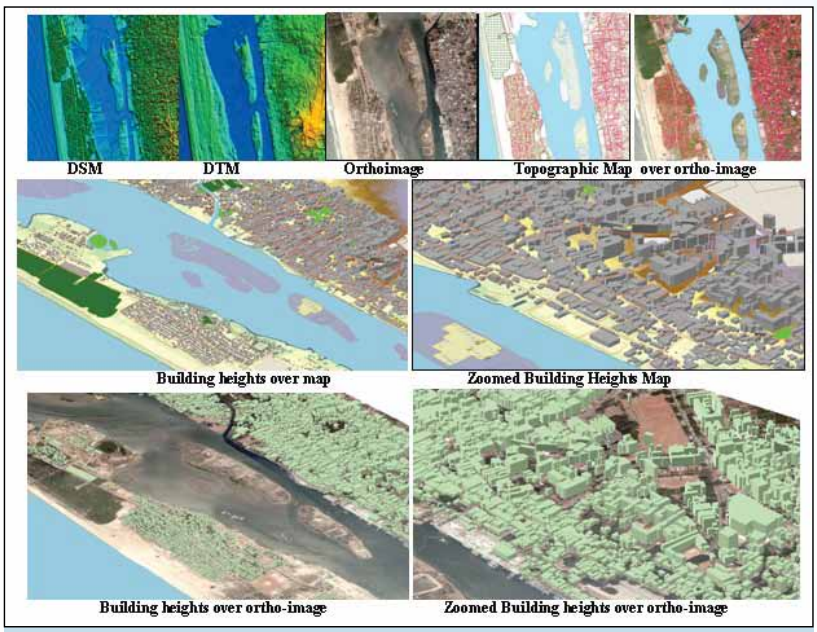
c. Establishment of Continuously Operating Reference Stations (CORS): ISRO has established 12 Continuously Operating Reference Stations (CORS) covering select transects of the Himalayan Thrust Systems and an intra plate seismic zone (The Kutch rift zone); to understand the Geodynamics. Six more CORS are under installation.

The CORS are equipped with geodetic choke ring antenna capable of tracking GPS, GLONASS, GALILEO, BEIDOU, NAVIC, QZSS and GAGAN SBAS constellations. The connectivity to the server is established through GSM and Broadband mode for real time data transfer to the server through built-in /external router.



Sites covered under AVRIS-NG campaign (left top); also shown is AVIRIS-NG sensor and associated racks installed in NRSC aircraft (left bottom). Part of AVIRIS-NG data acquired over Pichavaram (Tamilnadu) and the spectral profile of a section of the study area (right side)

Preliminary results indicate crustal shortening of the order of ~ 10.5 mm/yr across the major thrust systems (MBT and MCT) in the Himalaya.



DEM and other Geospatial products using airborne LiDAR data

3.3.13. National Meet Projects

158 Space Application projects were initiated, in 58 Ministries/Departments, as an outcome of the National Meet held in September 2015. These projects are in the areas of earth observation & geospatial technology, satellite communication & navigation, meteorology, technology diffusion and capacity building.

Horticulture Crop mapping under CHAMAN project for Ministry of Agriculture.

Among these, 90 projects/ pilot studies have been completed by meeting the requirements projected by the respective Ministries. 39 projects are in progress. Some of the significant outcomes include

i. Fodder crop assessment for dairy industry (M/o Agriculture & Farmer's Welfare)

Remote sensing based technique developed for assessing the fodder crops and assessment carried out in Uttar Pradesh, Bihar, Rajasthan, Gujarat and Haryana. The output is published in VEDAS geoportal. Also, the technology is transferred to AMUL with the establishment of remote sensing cell at GCMMF, Anand, for carrying out the activity on its own.

ii. Fibre Crop Information System for Cotton and Jute (M/o Textiles)

Web-based Geospatial information system has been established for centralized monitoring and assessment of Cotton & Jute crops towards informed decision making. Mobile apps for field data collection, geo-tagging of the offices / establishments / centres of the Cotton & Jute Corporations, reporting of crop condition based on the compilation of the field based crop conditions and in-season assessment of area under the Cotton & Jute crop and its yield etc. are enabled.

iii. Geospatially enabled Urban Frame Survey (UFS) for National Sample Survey Office (NSSO) (M/o Statistics and Programme Implementation)

The study used Geospatial technology in place of sketch maps for Urban Frame Survey. Pilot studies carried out in Bodhan, Bhongir, Dehradun and Manglaur using satellite image and Mobile application. Based on the results, the standing committee of UFS, NSSO has taken the decision to operationalize the UFS 2017-22 and ISRO is developing enterprise geo-web application to carryout survey for 8000 cities across India.

iv. Mapping of surface exposures of rock-phosphate using Earth observation, geochemical and field data (M/o Chemicals & Fertilizers)

Methodology developed for mapping rock phosphate outcrops using satellite data, through a pilot study carried out in Jhamar Kotra, Rajasthan. Rock phosphate was delineated using the

spectra of phosphate and host rock (dolomite) using advanced image processing technique. Based on the pilot study, a national project is initiated for mapping the surface exposures of rock phosphate in different promising areas of exploration in India, in association with Geological Survey of India (GSI) and Atomic Minerals Directorate (AMD).

v. Telangana Water Resources Information System (Govt. of Telangana)

Telangana Water Resources Information System (TWRIS) was developed as a geospatial solution on Bhuvan, for comprehensively addressing the water resources of the state to provide online information and decision making parameters for the decision makers. It has datasets on Natural Resources, Water Resource Projects, Surface Waterbodies, Irrigation Projects, Cropping Pattern and Groundwater level data. Information on 23 major & 52 medium projects, 45,100 water bodies including minor irrigation tanks, Cropping pattern & statistics, Monthly groundwater level for 750 observation wells etc are available on TWRIS and are regularly updated.

Towards execution of various space technology related projects, 130 MoUs have been signed including 78 MoUs with Central Ministries/ Departments/Institutes and 52 with State Governments/Departments/Institutes. Nearly 500 officials from various government departments have been trained in geospatial technology applications in 2018. Since 2015, nearly 11,000 officials have been trained.

For promoting space technology applications in the State Government Departments, 18 State Meets have also been conducted.

3.4 Space Science and Planetary Research

India's first inter-planetary mission "Mars Orbiter Mission (MOM)" completed four years in Mars Orbit in Sept 2018. AstroSat, the first Indian multi-wavelength space observatory, completed three years in orbit in September 2018 and is providing researchers both in India and abroad with excellent data on a variety of astrophysical objects in our Milky Way galaxy to those far away sources external to our galaxy. India's second mission to the Moon, *Chandrayaan-2*, with an indigenous Orbiter, Lander, and Rover, is being prepared for an early 2019 launch. Aditya-L1, India's first dedicated solar exploration mission, and X-ray Polarimeter Satellite (XPoSat) mission, a dedicated mission for polarization studies, are near-term upcoming space science missions.

Space science research activities are being pursued at premier research laboratories of ISRO/DOS viz., the Physical Research Laboratory (PRL), the National Atmospheric Research Laboratory (NARL), the Space Physics Laboratory (SPL) at VSSC and the Space Astronomy Group at URSC. In addition to ongoing approved programs, feasibility studies of experiments for future missions are also undertaken at several ISRO/DOS centers.

Novel research projects in the field of atmospheric science, astronomy and planetary exploration are technically and financially 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 the Advisory Committee for Space Science (ADCOS).

The major activities carried out under space science and planetary research during 2018-19 are summarized below.

Mars Orbiter Mission

Mars Orbiter Mission (MOM), the first interplanetary mission of ISRO, completed four years in its orbit on September 24, 2018 well beyond its designed mission life of six months. The satellite is in good health and continues to work as expected and continues to yield interesting results on Mars and its environment.

Scientific analysis of data being received from the Mars Orbiter spacecraft is in progress. Twenty four scientific papers have been published so far in peer-reviewed journals. The Mars Colour Camera (MCC), one of the payloads onboard MOM, has produced 1000+ images so far. It offers the unique capacity to image the full Mars disk with a single exposure. The third year of MOM operation has been marred by the serious dust storm that covered the whole of the Martian disk preventing access to useful images from the MCC. The storm has shown signs of subsiding in late August 2018 and we anticipate new images when solar illumination of the disk, turn favourable. Some of the processed MCC images generated during this period, are shown below.

Flood carved channel system of Kasei Valles imaged on January 12, 2018.

Third year data release of MOM

On the occasion of four years completion of MOM in its orbit, Dr. K. Sivan, Chairman, ISRO, released third year (24th Sept 2016 to 23rd Sept 2017) data of MOM to public through ISSDC website: https://mrbrowse.issdc.gov.in/MOMLTA/. More than 2200 users have registered and downloaded more than 625 GB data so far.

Martian disc imaged on 18th March, 2018 showing cloud formation around Olympus Mons.

Olympus Mons imaged on 17th February 2018 showing water ice clouds aligned along the Olympus Mons in the lower left part of the image.

AstroSat Mission

AstroSat is India's first observatory class mission dedicated to multiwavelength astronomy. AstroSat was launched on 28th September 2015 from Sriharikota. AstroSat has a unique capability of observing the cosmos from Ultra-Violet (UV) to high energy X-rays with four co-aligned payloads. A fifth experiment complements these co-aligned experiments by continuously scanning part of the sky for x-ray transients.

The satellite observations are driven based on proposals submitted by a large user community. Observation times are allotted to selected science proposals made through a

Opening page of Long Term Archive of MOM data

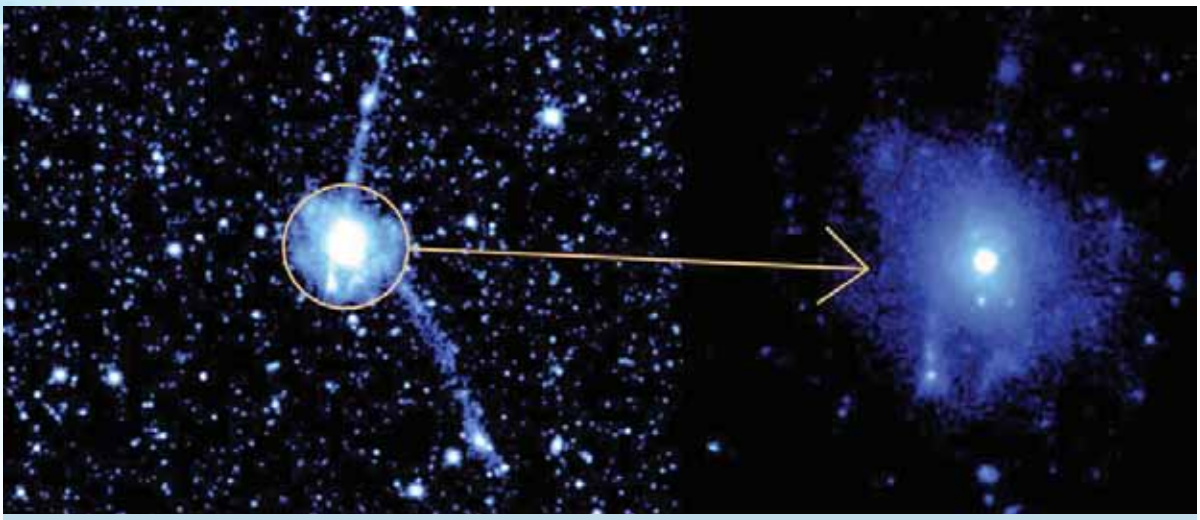
custom-designed proposal submission and evaluation system. On 26th of September, 2018, data was made opened to public. As of October 2-18, AstroSat has a total of 917 registered users from 24 countries.

AstroSat has produced a total of 86 publications in refereed journals in the first three years of operation; 24 publications during this reporting period. Inclusive of all conference proceedings, astronomy telegrams and circulars issued, this number is in excess of 250. Selected results highlighting AstroSat capabilities, are listed below.

Ultra-Violet Imaging Telescope (UVIT) provides the highest spatial resolution imaging capability over a wide field (~0.5 deg) in space today. This high spatial resolution imaging with a wide range of selectable filters, has resulted in many important findings. An example is discussed below.

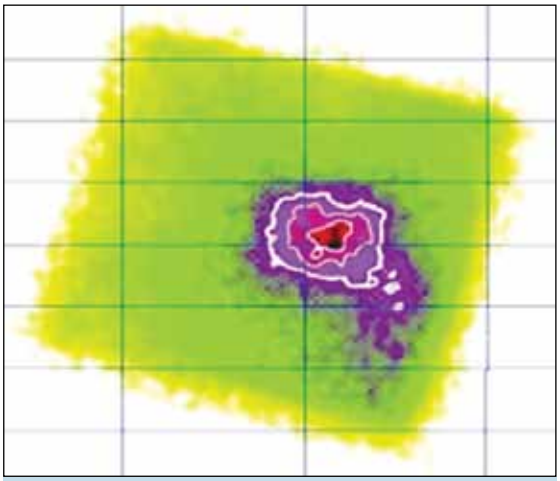
NGC7252 was formed from the merger of two massive galaxies which collided billions of years ago. The merged galaxy show stars and gas twirling around a bright central core which resembles a picture of electrons going around the central nucleus. Hence, NGC7252 was named as “Atoms for peace” galaxy highlighting the use of nuclear energy for peaceful purposes.

The effects of the violent collision resulting in the single galaxy are evident from the furious star forming activity going on in the two tails of the galaxies. Since ultraviolet light traces young hot stars, **Ultraviolet Imag-ing Telescope** (UVIT) of AstroSatis used to trace the locations of ongoing star formation along the tidal tails. Using these data, the rate at which new stars are being formed is measured in addition to changes in the star formation rate along the tail.

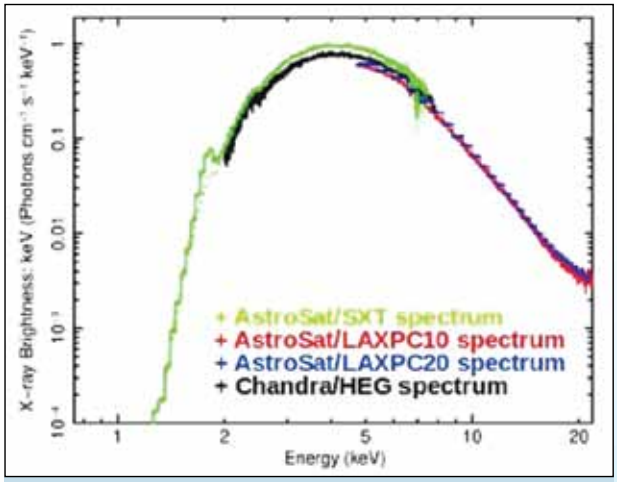


Dissecting star-formation in NGC7252 galaxy, also known as “Atoms for Peace” galaxy . Image credit: Koshy George et.al.

Soft X-ray Telescope (SXT) has measured the spin of blackhole in the binary system 4U 1630-47. This discovery is very interesting as the blackhole is spinning very close to the maximal spin possible for blackholes.

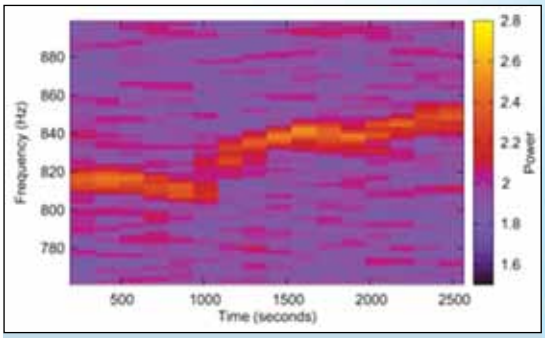


SXT image of the binary system 4U 1630-47.



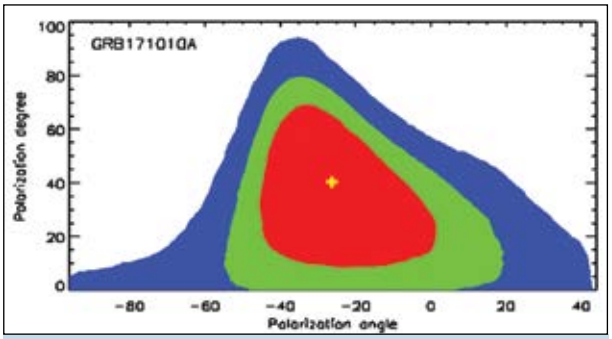
Broad band X-ray spectrum of 4U 1630-47

Large Area X-ray proportional Counter (LAXPC) for the first time has detected quasi-periodic oscillations (QPO) in the neutron star binary 4U 1728-34 above 20 keV energies. Within 2000 seconds, the data also revealed that the QPO frequency changes from 820 Hz to 850 Hz.



QPO evolution in LAXPC data of 4u 1728-34. The evolution is clearly seen as orange-yellow band.

Though **Cadmium Zinc Telluride Imager (CZTi)** is not designed for X-ray polarization measurements, CZTi is giving polarization measurements of several objects, specially gamma ray bursts (GRB), the most energetic events observed on Earth today. Recently, data of GRB 160802A taken from CZTi helped in narrowing down of the emission mechanism and also helped to infer the jet geometry of the GRB.



X-ray polarization angle versus degree of polarization plot for GRB 171010A in 100 - 300 keV.

CZTI has also detected variable prompt emission polarization in GRB 171010A.

Scanning Sky monitor (SSM) has observed the Crab pulsar repeatedly and found that the flux variations are confined to within 10%.

The success of AstroSat has prompted ISRO to start working towards future Astronomy missions. An Announcement of Opportunity was published early 2018 which attracted around twenty proposals from different scientific institutions/IITs and universities from all over India. An initial review of these proposals is over and short listing of mature proposals are in progress.

CHANDRAYAAN-2 MISSION

India's second mission to the Moon, Chandrayaan-2 is a major science mission with a fully indigenous Orbiter, Lander and Rover, now scheduled for an early 2019 launch from Sriharikota.

It is planned to have an Orbiter in 100 km x 100 km lunar orbit, Vikram Lander which separates from Orbiter and lands at a pre-identified site. The Pragyaan Rover rolls out from the Lander soon after landing for investigations on the lunar surface. The Orbiter has number of payloads for remote-sensing the Moon. The Lander and Rover also have science payloads to carry out in-situ analysis in the vicinity of landing site.

The scientific objective is to expand the current lunar scientific knowledge base through detailed studies, leading to an improved understanding of the origin and evolution of the Moon. Specifically, it will address investigations of

i) Extent and quantification of water in various forms by Imaging IR Spectrometer, Dual Frequency SAR, Chandra's Atmospheric Composition Explorer-2
ii) Topography by Terrain Mapping Camera-2, Orbiter High Resolution Camera
iii) Mineralogy by Imaging IR Spectrometer
iv) Surface Composition by Chandrayaan-2 Large Area Soft X-ray Spectrometer, Alpha Particle X-ray Spectrometer, Laser Induced Breakdown Spectroscope
v) Thermo-physical characteristics by Instrument for Lunar Seismic Activity, Chandra's Surface Thermo-physical Experiment
vi) Lunar atmosphere by Chandra's Atmospheric Composition Explorer-2, Langmuir Probe, Dual Frequency Radio Science experiment

In order to maximize the science outcome from Chandrayaan-2, a Lunar Science Meet was organized at ISRO HQ on Sept 27th to bring together scientists from various research institutes, colleges and ISRO centers in the country, who are involved or associated with Science of the Moon and Science on the Moon. Nearly 70 scientists / technologists from ISRO/ DOS centres/laboratories, IITs, Institutions, Universities and Colleges actively participated in the science meet. Sessions on Lunar Volatiles, Lunar Surface Evolution, Mineralogy and Volcanism, Lunar Ionosphere, Science from Vikram Landing site and Going beyond Chandrayaan-2 were organized.

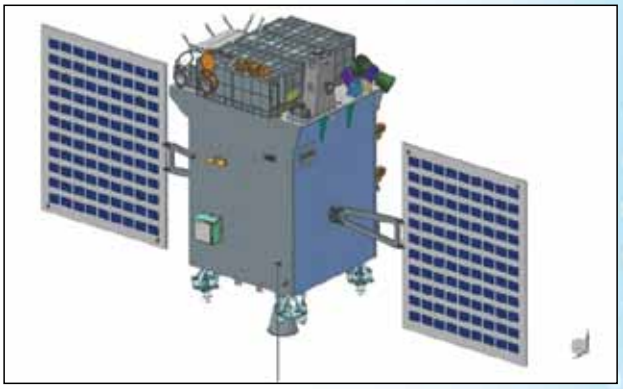
Orbiter in thermo-vac

The Orbiter is fully integrated and is undergoing Thermo-vac tests. Lander integration is in progress. Rover flight model integration is under progress. Orbiter and Rover payloads are ready. Lander payloads are in advanced level of testing.

ADITYA-L1 MISSION

Aditya L-1 is the first dedicated Indian solar mission to study the various dynamics of solar atmosphere and the puzzling phenomena of coronal heating. The spacecraft will be placed at the Sun-Earth Lagrangian point (L1) for the uninterrupted monitoring of the Sun. The Lagrangian point L1 is at about 1.5 million kilometres from the Earth and spacecraft would take about 109 days to reach from the Earth. The orbit around L1 will have an orbital period of about 178 days.

Aditya L1 will carry seven payloads for scientific observations of photosphere, chromosphere and the corona. Four payloads will carry out direct observation of the Sun and the remaining three will provide in-situ measurements of particles and fields at L1. The mission is being designed to meet the following objectives:



- Study of Solar upper atmospheric dynamics
- Study of chromospheric and coronal heating, physics of the partially ionized plasma, initiation of the coronal mass ejections, and flares
- Observe the in-situ particle and plasma environment providing data for the study of particle dynamics from the Sun
- Development, dynamics and origin of CMEs
- Magnetic field topology and magnetic field measurements in the solar corona (not planned by any mission so far)
- Drivers for space weather (origin, composition and dynamics of solar wind)
- Solar spectral irradiance (UV) variations and dynamics of chromosphere

To meet the above mission objectives, the spacecraft is configured with seven payloads. Visible Emission Line Coronagraph **(VELC)** for the study of Solar Corona. The Solar Ultraviolet Imaging Telescope **(SUIT)** will study the lower and middle solar atmosphere. The two X-ray payloads namely Solar Low Energy X-ray Spectrometer **(SoLEXS)** and High Energy L1 Orbiting X-ray Spectrometer **(HEL1OS)** will study broadband spectrum of X-ray flares and dynamic events in the solar corona. AdityaSolar wind Particle Experiment **(ASPEX)** and Plasma Analyser Package For Aditya **(PAPA)** will provide in-situ measurements of solar energetic particles and their energy distributions. A Magnetometer on a deployable boom will provide a measure of the local Interplanetary Magnetic Field.

X-ray Polarimeter Satellite (XPOSAT) MISSION

XPoSat is a dedicated Indian polarimetry mission to study various dynamics of astronomical sources in extreme conditions. The spacecraft will carry two scientific payloads in a low earth orbit with preference for a low inclination orbit. The primary payload POLIX (Polarimeter Instrument in X-rays) will measure the polarimetry parameters (degree and angle of polarization) of astronomical sources in medium X-ray energy of 8-30 keV photons. The XSPECT (X-ray Spectroscopy and Timing) payload will give spectroscopic information of soft X-rays in the energy range of 0.8-15 keV.

Development of payloads for future planetary missions

A dozen of scientific payloads are under various stages of development in view of a future mission to Mars. This mission is expected to conduct in-depth studies to explore Martian surface, subsurface, exospheric and ionospheric features. Selection of scientific payloads for the future Venus mission is underway.

Projects under Announcement of Opportunity (AO) programme:

ISRO/DoS has been supporting 45 proposals which are selected under specific AOs by extending funding support for a duration of three years. Main objective of this programme is to expand the Indian scientific community with access to data and can analyse data from Chandrayaan-1 and MOM missions.

ISRO's Space Science Promotion Scheme: ISRO-SSPS

The basic aim of this scheme is to strengthen research activities in Space Science at Universities. ISRO-SSPS aims to meet the demand/requirement for trained human resources to address future space science programs and attract more faculty and student participation in space science research at the national level. Five Universities are provided funding support under phase-II activities of this scheme. Funding support consists of a recurring grant for a period of five years which includes M.Sc fellowships to meritorious students and honorarium and travel support to guest faculties.

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. This year the International Olympiad in Astronomy and Astrophysics will be held at Beijing in November 2018.

4. Human Space Programme

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. Indian Manned Spaceflight Programme – GAGANYAAN was officially announced by the Honourable Prime Minister of India on August 15, 2018 on the occasion of 72nd Independence Day celebrations and approved by the Government.

In this regard, a new ISRO Centre namely Human Spaceflight Centre is formed to implement Gaganyaan Programme. HFSC shall also be responsible for the development of the engineering systems related to the orbitor module, the human centric technology domains of bioastronautics, crew training and life support, basic and applied space sciences, human and robotical space exploration etc. In addition HSFC shall also play the role of a technology aggregator to bring together the national expertise in diverse disciplines for multi directional growth and capacity.

As part of development of critical technologies, Crew Escape System (CES) Pad Abort Test flight (PAT) was successfully demonstrated. It is a major technology that will safely Parachute future astronauts down, in case of any exigency at the Launch pad while taking off and India has become the fourth country in the world to acquire this technology after USA, Russia and China. PAT flight was successfully conducted on 05th July, 2018 with the simultaneous firing of Low-altitude Escape Motor (LEM) and High-altitude Escape Motor ([HEM) from the sounding rocket complex at SDSC. CM separated from CES at an altitude of 2.9 km. The spent CES was jettisoned away and descended with a pair of 31 m diameter parachutes which were later recovered and brought back to shore.

Pad Abort Test (PAT)

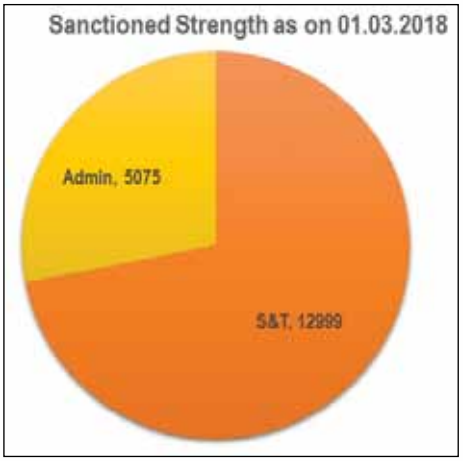
CM Separation & descending

This test also demonstrated several new technology elements for future ISRO programmes like Radar Altimeter that will be used in Chandrayaan II, NavIC for position information and linking it with GSAT-6 to get real time data, wireless telemetry system for eliminating the need for massive harnessing and low power data transmitter with turbo coding.

5. Capacity Building

5.1 HUMAN RESOURCES

The total approved sanctioned strength of the department as on 01.03.2018 is 18,074, out of which 12,999 are in Scientific and Technical (S&T) category and 5,075 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 provide 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 realisation of the organisational goals and resulting achievements. Hence stringent recruitment process is adopted to ensure 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 and 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 recruitment of Officers in Administrative area, Office Assistants and Junior Personal Assistants during the year. Further, specialised recruitments, based on the Centres's requirements, are made by respective Centres/Units. In order to induct quality manpower into the systems, the campus recruitments at IITs are continued and selections are under process.

ISRO/DOS has been absorbing bright graduates from the Indian Institute of Space Science and Technology (IIST) on successful completion of the B.Tech programme, meeting the benchmark set. The eighth batch of students, who were admitted to B. Tech during September 2014 at IIST have graduated during June 2018. A total of 69 eligible students are inducted in all DOS/ISRO 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/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 up on the suitability and recommendations of Centres. Till date opportunity has been extended to more than 250 candidates.

Training:

Training & Development activities are envisaged through both, Centralised and Decentralised systems. The scheme of Centralised Induction Training Programme for newly joined scientist/ 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 given to Office Assistants and Junior Personal Assistants in Administrative areas, conducted by different Centres/Units on a rotational basis. With regard to induction training programmes for other category of manpower, specific modules are designed and training is imparted at respective Centres.

Other programmes such as; Refresher courses for knowledge enhancement for technicians, technical assistants and technical support staff; Special training programmes for Administrative staff covering rules, procedures, systems and covering latest changes in the system; Training programmes for scientific/technical staff on specific technical topics of relevance in specific centres/units; Programmes on other relevant topics for other personnel, depending upon their specialization; General training programme to improve soft skills, computer skills, management & leadership aptitude, etc. are conducted as part of cadre training requirement. These training programmes are implemented both through centralised and de-centralised training programmes. Customised, exclusive management development training programmes for S&T personnel at middle level & executive level are organised through leading academic institutes.

The employees are also provided opportunity to attend international trainings suitably.

HRD programmes at different Centres

At URSC

A total of 35 In-House Programmes were conducted and 926 participants participated in various In-House training programmes. Around 249 People were nominated for external training programmes. A total of 113 employees were sponsored for various Conference / Seminars / Workshops / Training Programmes / Symposiums organized by reputed institutes / organizations. The centre also supported for Academic project training and all together 447 students from PG (ME/M.Tech/MS/ MSc) and UG (BE/B.Tech) were benefitted.

At VSSC

Conducted ISRO Induction Training Programme (IITP-30) for 280 Scientist/Engineers, 6 training programmes under management development, skill development, technology

update and computer related, and one structured training programme on “Cost Effective Space Transportation System”. 217 employees were nominated to external training programmes/seminars/workshops etc. Provided training for trade/technician/graduate apprentices and facilitated academic project work for B.Tech, M.Tech and M.Sc students. ISRO Induction Training Programme (IITP-31), structured training programme on “Advanced AvionicsSystems – Design towards Miniaturization and Advanced Production Techniques” and 36 in-house training programmes were planned.

At SAC

During the period, four Training & Development Programmes were conducted at ISRO level. 12 in-house programmes/workshops,13 lectures, 309 personnel were deputed to various conferences /Seminars & 14 educational visits were facilitated/coordinated at SAC. About 27 candidates have been recommended for higher studies.

At SHAR

HRDD has organized 52 training programmes during 2017-18 and a total 1575 participants were trained in various technical & managerial topics. Structured Training Programme on “Safety in Realizing Space Systems” was organised during 03rd to 07th July 2017.

STP at SDSC SHAR

Similarly, about 29 training programmes are organised in 2018-19 as on date with a total 634 participants. Structured Training Programme on “Project Management and Systems Engineering” is organised recently during 24th to 28th September 2018. A detailed training calendar is drawn and being implemented every year as per the identified training needs of the Centre Employees.

At LPSC

20 nos. of major in-house training programmes were conducted during the period. These include Structured Training Programme on Manufacturing of Space Systems for Sci./Engr. SG/SF/SE of various centres of ISRO, 2 batches of ISRO Level one month long Mandatory

training programme for promotion to the post of Assistant Engineer (Mechanical discipline), Executive Development Programme (EDP) for senior most engineers of both units of LPSC, Hands-On Training programmes on AutoCAD & AutoDeskInventor, ANSYS and Advanced Excel for nominated personnel of LPSC-V, Budget Preparation Training Program for all budget coordinators of both units of LPSC and many other programmes were conducted.

At ISTRAC

ISTRAC has total sanctioned manpower strength of 555 + 3 (CED posts) personnel consisting of 377 Scientific & Technical and 178 + 3 (CED posts) administrative personnel. Timely action is being taken to keep the vacancies at the barest minimum.

At IPRC

HRDTD being the agency for the skill and knowledge development of employees of IPRC, it regularly nominates personnel to attend training programmes (including STP, ASCI, Space Studies Programme organized by International Space University etc.), seminars, Short term courses, Conferences and Workshops conducted by various agencies. In this respect 46 personnel were nominated for training in 7 external agencies, 31 personnel for four conferences / seminars, 14 personnel for STP in seven ISRO centres. Through IPRC In-house Training Programme (IITP), five training programmes were organized and 185 employees from different levels and categories have participated.

I APPRENTICE TRAINING

Under the Apprentices Act, 1961, training has been imparted to 1,850 apprentices in Centres/ Units of the Department in the Technical and Commercial Trades.

II RESERVATION IN SERVICES:

i) SCHEDULED CASTE AND SCHEDULED TRIBES

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

ii) PERSONS WITH DISABILITIES

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

iii) EX-SERVICEMEN

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

iv) OTHER BACKWARD CLASSES (OBCs)

At present, 4,478 persons belonging to Other Backward Classes are employed. Out of the 4,478 OBCs, 242 persons have been appointed during the current year.

v) WOMEN EMPLOYEES:

There are 2,069 Women Employees in the Scientific and Technical categories and 3,285 Women Employees in Administrative categories in the Department as per the details given in Table IV. They represent 20% of personnel in the Department.

vi) JOINT CONSULTATIVE MACHINERY (JCM)

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

vii) CONFERENCES AND WORKSHOPS:

a) National Conference for ISRO Women

National Conference for ISRO Women Employees was organised at U R Satellite Centre (URSC) at Bangalore on March, 2018. Women employees from various DOS/ISRO establishments participated in the Conference as delegates and presented papers.

b) International Day of Yoga

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

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

127th Birth Anniversary of Bharat Ratna Dr. Bhimrao Ramji Ambedkar was celebrated in DOS/ISRO establishments in 2018.

STATUS OF SCHEDULED CASTE/SCHEDULED TRIBE PERSONNEL IN DOS/ISRO

TABLE - I

Sl No	Centre/Unit	Total Strength of Employees 2018-19	Strength of SC Employees 2018-19	Strength of ST Employees 2018-19
1	DOS/ISRO HQ	443	57	25
2	VSSC	4632	352	63
3	URSC	2662	296	104
4	SDSC-SHAR	2152	338	128
5	SAC & DECU	2090	190	139
6	LPSC	1265	139	29
7	NRSC	822	103	32
8	ISTRAC	434	64	15
9	MCF	326	39	15
10	ADRIN	163	18	5
11	IIRS	118	12	5
12	PRL	255	9	2

13	SCL	579	108	6
14	NARL	66	9	1
15	NESAC	41	2	4
16	IIST	97	4	0
17	IPRC	670	137	12
	TOTAL	**16815**	**1877**	**585**

STATUS OF PERSONS WITH DISABILITIES IN DOS/ISRO

TABLE - II

Sl No	**Centre/Unit**	**Total Strength of Employees 2018-19**	**Strength of Persons with Disabilities**	**Classification of Employees with Disabilites**			
				Deaf & Dumb	Blind	Partially Blind	Orthoped-ically Handi capped
1	DOS/ISRO HQ	443	7	0	0	1	6
2	VSSC	4632	103	19	1	13	70
3	URSC	2662	62	14	5	0	43
4	SDSC-SHAR	2152	56	2	2	0	52
5	SAC & DECU	2090	45	5	3	0	37
6	LPSC	1265	30	10	0	0	20
7	NRSC	822	16	2	0	0	14
8	ISTRAC	434	11	0	0	0	11
9	MCF	326	4	1	0	0	3
10	ADRIN	163	3	0	0	0	3
11	IIRS	118	6	0	1	0	5
12	PRL	255	6	1	0	0	5
13	SCL	579	3	0	0	0	3
14	NARL	66	1	0	0	0	1
15	NESAC	41	1	0	0	0	1
16	IIST	97	1	0	0	0	1
17	IPRC	670	13	0	0	0	13
	TOTAL	**16815**	**368**	**54**	**12**	**14**	**288**

STATUS OF REPRESENTATION OF EX-SERVICEMEN IN DOS/ISRO

TABLE - III

Sl No	Centre/Unit	Total Number of Employees in Group - C 2018-2019	Total Number of Ex-Servicemen in Group - C 2018-2019
1	DOS/ISRO HQ	71	4
2	VSSC	667	114
3	URSC	354	10
4	SDSC-SHAR	645	23
5	SAC & DECU	322	7
6	LPSC	195	51
7	NRSC	84	0
8	ISTRAC	32	1
9	MCF	46	2
10	ADRIN	20	1
11	IIRS	14	0
12	PRL	15	0
13	SCL	55	0
14	NARL	5	0
15	NESAC	0	0
16	IIST	0	0
17	IPRC	102	17
	TOTAL	**2627**	**230**

WOMEN EMPLOYEES IN DOS/ISRO

TABLE - IV

Sl No	Centre/Unit	Total Number of Employees 2018-2019	Number of Women Employees 2018 - 2019	
			Scientific & Technical Staff	Administrative Staff
1	DOS/ISRO HQ	443	26	120
2	VSSC	4632	547	433
3	URSC	2662	568	129
4	SDSC-SHAR	2152	130	131
5	SAC & DECU	2090	272	86
6	LPSC	1265	87	107
7	NRSC	822	147	54
8	ISTRAC	434	72	36
9	MCF	326	37	12
10	ADRIN	163	31	10

11	IIRS	118	17	7
12	PRL	255	22	19
13	SCL	579	35	16
14	NARL	66	5	6
15	NESAC	41	8	4
16	IIST	97	19	6
17	IPRC	670	46	40
	TOTAL	**16815**	**2069**	**1216**

5.2 Technology Transfers

The current year saw some notable technologies being licensed to Indian industries for commercialization and regular production. The primary one among these was the **NavIC messaging receiver**, which has been developed specifically for fisherman community for navigation and receive broadcast messages on fishing potential and disasters. Considering the societal application of the same, it was decided to distribute the technology, without any licensing fee or royalty loading. 700 nos. of the device have already been realized from M/s ADTL and further, 900 nos. from KELTRON are in progress. Additionally, 5 companies, including M/s BEL have been shortlisted for further production.

Besides above, two vital technologies for strategic users – **IRNSS (restricted services) receiver and Personnel Tracker (restricted services)** were also matured for technology transfer and were licensed to M/s BEL and M/s ITI, for former, and M/s BEL for latter. IRNSS–RS provides location navigation service with anti-spoofing technology for authorized users. Personnel Tracker gives position information in TDMA / ALOHA mode of operation. It supports small message as well as data transfer through satellite and USB/Bluetooth user data Interface. This tracker will be used to track the person in the field of operation in situations like disaster rescue operation, surveillance, etc.

Developed by Space Applications Centre(SAC), **two-way MSS terminal** is intended to be used for tracking small boats and trigger disaster warning dissemination, using in-house developed modem ASIC. Also of note is the **Mini-SAR: X band Airborne SAR** – a miniaturized airborne synthetic aperture radar of X band. Applications include high-resolution imaging, disaster management, urban planning, etc. Both the technology transfers have been to M/s BEL.

From Vikram Sarabhai Space Centre, the notable development of the year was the technology transfer of **Li-ion** to Indian industries. Around 119 firms attended the pre application conference held at VSSC on 17th Aug, 2018.

Additionally, technology transfers of **epoxy adhesive EPG 2601[M] and polymer resin PF-106** was approved by the Centralized technology transfer committee, with a detailed review of costing and adhering to the policy guidelines. Further, several proposals in various stages of centre-level TT approvals viz. **CASPOL**, low modulus flex seal rubber compound, radiometer, etc. are being processed. Further, collaborations with different academic and

central agencies to utilise **FEAST** – the in-house developed structural analysis software are being discussed.

5.3 Indigenisation

Launch vehicles and satellites use various critical materials and components which are space qualified. Even though Indian industry is supplying majority of the materials, few critical materials and electronics component and packages are still being imported. The import component is around 9.4% for launch vehicles and around 50 – 55% for satellites. To be self reliant ISRO, along with industry and other institutes, is constantly exploring the avenues for indigenizing the materials & alloys and electronics for space programmes.

Indian industry is able to supply commercial grade electronic components for ground systems and few packages for avionics. But there are no major production facilities for semiconductor components and devices across India for producing space qualified components. SCL, Chandigarh is producing some of the critical devices and packages in a phased manner based on the priority.

First Divergent Inner Shell

SE Inner Shell Forging

Combustion Chamber Inner Shell

Besides technology development activities, ISRO has also provided thrust for the Indigenisation in specific activities particularly, Components development, DC-DC Converter developments, Thermal Heat pipes, Mechanical, avionics systems, Integration & Checkout systems etc. Some of the major Indigenization efforts are listed below.

Sl. No.	Item	Brief Description
1.	Aluminium alloy rods, flats, plates, forgings	Used for brackets, structural angles, inserts.
2.	Adhesives, Primers, Ecobond, RTV, Kapton	qualification done
3.	TTCP	To support TC uplink and TM downlink
4.	TCXO -Centum	18,38.556, 50&75 MHz
5.	Clock Oscillator - Centum	256 kHz to 12 MHz (10 types)
6.	VCXO -Centum	38 – 40 MHz
7.	BE103MT –BEL	Relay Driver Bipolar ASIC for 70V Bus
8.	BE104MT –BEL	Magnetic Torquer Bipolar ASIC
9.	Clock Oscillator - Centum	52.5 MHz

10.	TCXO - Centum	42.8 MHz
11.	Wires & Cables	Polyimide Insulated wires
12.	Thermo foil Heater - Thakarsons	3.5W/sq.in

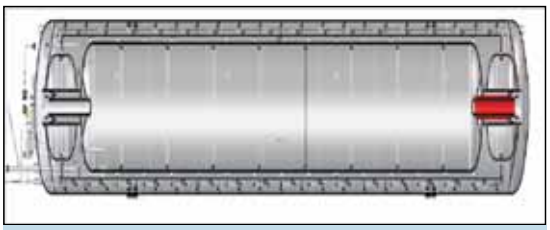
Indigenous development of Doppler Weather Radars (DWR)

Indigenous development of S, C and X band Doppler Weather Radars (DWRs) for meteorological observations are going on at radar Development Area (RDA), ISTRAC. A C-band DWR at TERLS and three S-band DWRs are operational at Cherapunji, Gopalpur and Kochi. Fourth in this series was made operational at SDSC, SHAR on September 16, 2018. This dual polarimetric S-Band DWR continues the services provided by the Mark-1 non-polarimeteric Radar at SHAR. RDA has also established a magnetron based X-band polarimetric DWR at NARL Gadanki. Indigenous development of X-band Solid State Power Amplifier (SSPA) based DWR is progressing in association with M/s Data Patterns, Chennai.

Indigenous development of LH2 Tank

Indigenous Development of Liquid Nitrogen (LIN) Shielded LH2 Tank: SDSC SHAR team has developed through Indian Industry a Liquid nitrogen shielded LH2 Tank to meet the future requirement of storage tanks for LH2 & LHe. First two tanks with 15 Kl and 40 Kl capacity are realized to meet transportation requirements of Liquid Hydrogen for ISRO.

Based on this, development work is taken up for realization a 120 Kl LH2 Tank, to meet bulk storage requirements for the ISRO launch vehicles as per manifest.



Schematic configuration of Tank

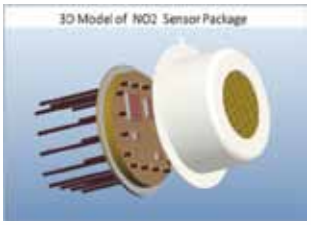
Fabrication works at factory

Total design activities completed. Fabrication of Inner vessels (LH2 & LIN) including Pneumatic, Helium & Vacuum qualification completed. Integration of sub-assemblies, inter space piping & stage-wise qualification works are in progress. Performance evaluation of the integrated vessel and delivery are targeted for Dec 2018.

Indigenous development of Pollution Sensors: Gas sensors are required in launch complex operation continuously as part of the Safety System. Efforts are taken to indigenously develop these sensors through academia – IISc, Bangalore.

- NO_2 sensors: Fully packaged NO_2 sensors are tested continuously for 0-3 ppm in lab level. Testing the sensors for higher concentration is planned at SDSC SHAR. Parallel action initiated for productionisation of sensor with SCL,Chandigarh.

- Oxygen sensors: Testing with electronics module completed from 0 to 100% concentration. Testing of five numbers of integrated sensors in the field condition is planned at SDSC SHAR.
- Hydrogen sensors: Sensor with electronics tested for 0.25 % to 1% concentration at lab. Testing the sensors for higher concentration is planned at SDSC SHAR.
- Hydrazine sensors: Deposition of copper oxide material on IDEs and testing with gas concentration completed. Packaging of sensors with electronics & testing at field is planned.



NO2 Sensors – Schematic & Actualrealised

Indigenous development activities are in progress for Cryo & High pressure components such as Cryo valves, UCU Adapters etc, being used in ground systems.

As an effort towards indigenization, some of the important items indigenized are listed below:

a. **Indigenous Copper Alloy Induction:** CUS Steering engine realised and tested (200s & 1060s) as part of qualification. CUS A13 Engine and CE20 (E6) Engine realised and acceptance tested successfully for flight.

b. **Aluminium Alloy (AA 2219) Tank for PS4:** Two PS4 tanks L1.6 & L2.5 designed and realised and design validated

c. **Materials/ Elements Indigenised:**
   a. Semi-cryo engine bearings (6 types-dia 75, 65, 55, 50, 40, and 35) tested successfully in LN2/ Isrosene.
   b. Forgings for Semi cryo engine (biggest -290kg & complex shape) developed.
   c. SS rings (15-5PH& 15-5W PH) developed for HTVE and Semi-cryo engines.
   d. Al-Bronze and M3 (Pure Copper) for Semi cryo engine bushes and gaskets developed

d. **NO_2 & Hydrazine sensors:** Developed. Packaging & Productionisation of sensor with SCL,Chandigarh.

e. **Bunched Passage Orifice Flow Meter (BPOFM):** Design validated by calibration in water & LH2. Flight Electronics package developed; Qualification trial with LH2 planned and inter centre expert committee has reviewed.

f. **DC-DC Converter:** Built-in EMI Filter, Triple output and Regulation is better than imported. Proto HMC fabrication in progress for L/V & S/C packages.

g. **Rotary Transducer:** Accuracy less tha + 3 arc. To be used in high speed scan mechanisms and Robotics.

h. **Optical Encoder:** 16 bit resolution demonstrated and to be inducted in Cortosat-3A.

i. **ABEC 9 Bearings:** Pilot sample evaluation in progress and Heat treatment optimisation in progress. 2 Indian manufacturers identified.

j. **Components:** Cell Balancing HMC, VCXO 18-20 MHz, TCXO 14-20 MHz, Development

of 5 ASICs/ 7 IC's, Thermo foil Heaters, CDR Capacitor, D-Sub Connectors, Thermistors, Relay Driver ASIC has been developed.

k. **Digital Electronics:** Flash based SSR, Advanced OBC: SPARC - V8 architecture-LEON 3, DWT Based Image Compression ASIC has been developed.

l. **Communication:** Circular grid array antenna, Synthesizer based X-band Data transmitter, Frequency programmable C and Ku-Band TT&C has been developed.

m. **Avionics Production:** Adaptable DC-DC converters (8W/ 16W/ 48W), Automation in Fabrication & Testing -Faster turn-around time has been developed.

n. **Mechanical Systems:** 2m Scaled down Static Model for 18m UFA, Regular Hexagonal CFRP Core, Heat Pipe Embedded Large Panels has been developed.

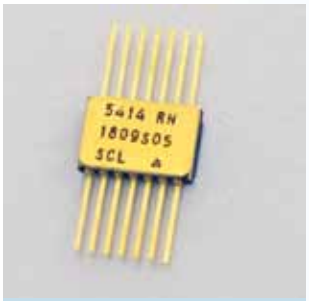
o. **Thermal Systems:** Pulse Tube Cryo Cooler, Phase Change Material coupled Heat pipe and Thermal control coatings has been developed.

p. **Power Systems:** 100V Regulated Bus, All electric propulsion, Stackable Battery Non-Switching silent Power Bushas been developed.

q. **Space Craft Systems:** Indigenous TMTC Processor (TTCP), Indigenous Waveguide components.

Indigenisation of VLSI Components

Six types of devices have been screened and delivered for Spacecraft Bus application including Flight Model (FM) Units of Hex Schmitt Trigger Inverter and FM Quad Two Input NAND Gate. Chip-On-Board (COB) based Hyper Spectral Image Sensor (HySIS) has been realized for HySIS Spectrometer for Remote Sensing applications.



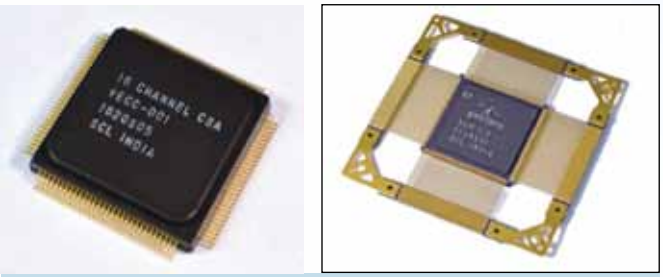
Hex Schmitt Trigger Inverter

Quad Two Input NAND Gate

High Frequency Reconfigurable Data Acquisition System (RDAS) and Multicore RDAS have been developed for use in Launch Vehicle application. Digital ASIC for NavIC (Indian Regional Navigation Satellite System – IRNSS) has been provided for use.

16-Channel Charge Sensitive Amplifier (CSA), to be used as first stage pre-amplifier with detector arrays in strategic applications, has been successfully realized.

64-bit RISC-V Shakti Processor with Indian Institute of Technology (IIT) Madras and 32-bit SPARC-V8 Ajit Processor with IIT Bombay have been successfully developed for

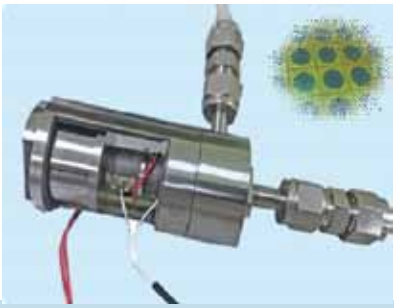


16 Channel CSAMIDU

advanced computing applications as part of National effort on indigenous Microprocessor development.

MEMS based Piezoelectric Acoustics Sensor (IMAS), Micro-valve for Electric Propulsion System and Pressure Sensor (Oil Filled, Compensated) have been developed for Launch applications.

Acoustic Sensors (IMAS) Micro-Valve



Oil Filled Pressure Sensor

5.4 Partnering with Industry

- As per the manifest and projection for the future, ISRO is gearing up for enhanced Launch frequency in coming years. In addition, GSLV Mk III is entering into operational phase from developmental phase. The semi-cryo project is approved and stage systems and facilities for ground testing and launch pad are in realization to support the increased demand for satellites. Towards this, new contracts have been signed for building the satellites with private parties. Exclusive facilities are created at IPRC for PS2 and PS4 stage and engine integration through GOCO (Government Owned and Company Operate) model.
- In case of producing solid propellant motor production, one private industry is qualified for producing PSOM-XL motors and capacity within ISRO is being augmented for production of solid motors.
- Private industry is developed for producing Composite motor cases and additional sources are being explored for supplying carbon-carbon cloth and other input materials.
- In order to meet the increased launch demand, it was planned to increase the participation of Indian industries in the realization of PSLV systems through a suitable mechanism.
- Constantly exploring aven-ues for indigenization of electronic components, materials and alloys used for space programme is a major activity os all Centres. Hafnium Sponge production plant (320 kg per year) has been established at CMET, Hyderabad. Portescap, Mumbai make DC motors qualified towards import substitution for RMSA.

Hafnium Sponge Production Plant at CMET, Hyderabad

Realised powder coated metal film resistors thro' M/s Omega Products, Mumbai and 6 core and 10 core cables through M/s Flu-Tef, Ahmedabad and M/s Garg Associates, Ghaziabad.

- More than 100 Indian Industries to participate in satellite realization activities, in light of the enhanced satellite manifest, demanding inceased number of satellites for various user based services, there is an urgent need to augment capacity, not only in terms of satellite building but also for the Assembly, Integration and Testing (AIT) & in enhancing the participatory effort with industries. In this regard, various efforts undertaken during the year are outlined below:
- As part of Capacity Building Activity, URSC has taken up lot of initiatives for the participation of Indian Industries from spacecraft subsystems to spacecraft Assembly, Integration and Testing. In order to strengthen the industry participation in spacecraft AIT, URSC-ISRO has entered into contract with three industry partners from private & public sector. It is planned to provide adequate training, both theory and hands-on, to the partners from the industry. While this activity will scale up the industry participation and eventually strengthen the trained resources for satellite AIT, this is expected to accelerate the pace of satellite building activities, so as to meet the increased demands outlined in the launch manifest.
- Solar panel and battery fabrication and testing contract is in place with M/s BHEL till February 2019. Necessary action for the extension of contract till Feb 2020 at same rates and terms initiated. Selection of alternate vendor development for solar panel and battery activities is in progress.
- Production of Vikas engines, Cryogenic engines, PS4/RCT engines, PS4 RCS thrusters, propellant tanks, water tanks and stage interface elements continued through industry to meet the mission requirements. Aluminium alloy (AA2219) PS4 propellant tanks (2 nos.) were realized & qualified for use in PS4 stage as part of reducing the cost as well as meeting the enhanced launch frequency.
- Integration & testing of PS1–RCS packages through M/s. BATL is initiated. for PSLV C43, one number each of PS1 RCS packages were successfully realized through GOCO mode at In-house facility and M/s. BATL.
- Production of pressure vessel parts for spacecraft propellant tanks, spacecraft propulsion components continued through industry. Long term contract established and being operated with M/s.CTTC, Bhubaneswar for sourcing machined parts for spacecraft propulsion system components. Qualification requirements of 9 types of propulsion components completed.

5.5 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 & 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.

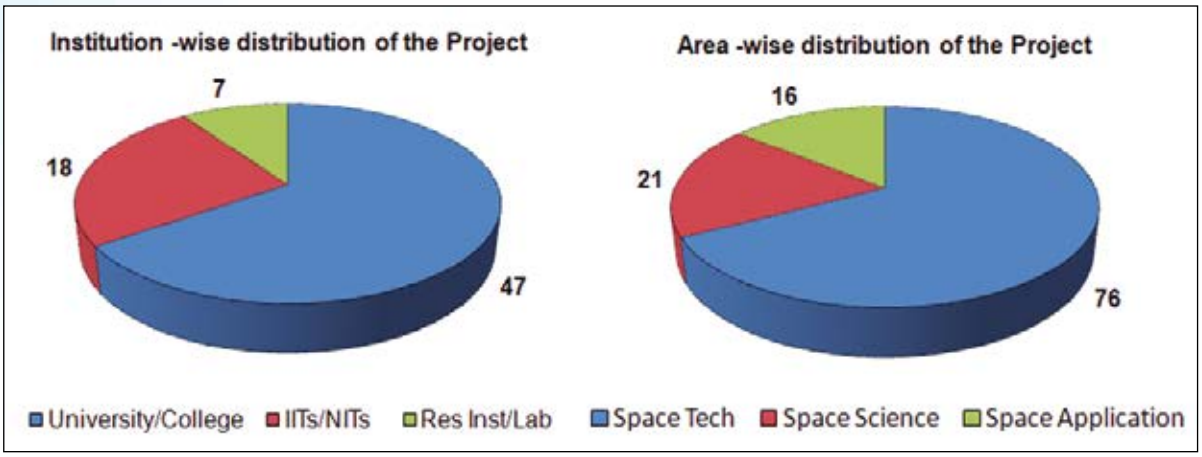
The main objective of the RESPOND Programme is to establish strong links with academic institutions in the country to carry out research and developmental projects which are of relevance to space programme. The major activity under RESPOND is to provide support to research projects in wide range of topics 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).

Considering the requirements of ISRO in the areas of nanotechnology and nanoscience, an MoU has been entered into with Centre for Nano Science and Engineering (CeNSE) at IISc. The scope of the MoU includes R & D activities, utilization of nanofabrication and characterization facilities by the various centres of ISRO, in addition to training/capacity building.

Further, In order to enhance greater participation and contributions from academia in addition to the ongoing Respond activities, a Centre of Excellence (CoE) on Advanced Mechanics of Materials" has been set up at IISc. The Centre aims at pursuing advanced research in the areas of relevance to the future technological and programmatic needs of Indian Space Research Organisation.

Activities

During the year, RESPOND supported 59 New Projects and 54 Ongoing Projects and five Space Technology Cells and Joint Research Programme with Savitribai Phule Pune University. In addition, 5 ISRO Chairs, 88 conferences/symposia/ publication and other scientific/promotional activities have been supported. During the year, 32 sponsored projects



have been successfully completed. Scientific publications have emerged out of these projects apart from fulfilling the objectives.

During the year RESPOND has supported 47 Universities/Colleges, 18 IITs / NITs and 7 Research Institutes / Laboratories to take up Projects both new and ongoing (Figure-1). Further, during the year, large number of projects have been supported in the area of Space Technology (76) followed by Space Science (21) and Space Application (16) and (Figure-2).

Projects at Space Technology Cells (STC): During the year RESPOND has supported 66 new projects, 148 ongoing projects of five Space Technology Cells and Joint Research Programme at Savitribai Phule Pune University. Under STCs 76 projects have been completed during the year. Details are given in the table below:

Sl. No	Name Of The STC/JRP	No. of Projects		
		New	Ongoing	Completed
1.	IISc Bengaluru	19	19	29
2.	IIT Madras	5	21	5
3.	IIT Bombay	11	16	8
4.	IIT Kanpur	13	39.	11
5.	IIT Kharagpur	7	36	9
6	SP Pune Uni.	11	17	14
	Total	66	148	76

The projects are reviewed by domain experts in ISRO and later by Joint Policy Committees consisting of experts from ISRO and the academia.

Highlights of Some of the RESPOND Projects

- **Study of timing properties of a few out-bursting black hole candidates:** Under this project, PI has successfully studied and selected 6 black hole candidates and monitored the temporal behavior of their x-ray spectra in order to investigate the accretion flow properties during the x-ray active phase of the outburst transients. The observed spectra were fitted to a model developed based on the so-called 2 component advective flow mechanism. It was successfully concluded that the timing and spectral properties conform to the model well.
- **Studies related to coronal heating and solar wind turbulence:** Under this, the project has successfully carried out the study of the waves and instabilities in solar plasma in relation to structures and turbulence in solar wind and coronal heating. The findings of the proposal have scope in the future space mission of ISRO-Aditya dedicated to solar coronal and space plasma experiments.
- **Multi-frequency microwave scintillation studies with specific emphasis to navigation over the Indian Latitude:** The project aimed at studying the occurrence

features of unexplored S band scintillations around the EIA crest of the Indian zone at three frequencies and to develop model of fade margin at L5, L1 and S band frequencies under different geophysical and geomagnetic conditions. The observations were recorded during April, 2015–April, 2017. The results have got useful applications in satellite communication like IRNSS, GAGAN satellite.

- **Growth and Characterization of pure & substituted Langasite crystals for development of high temperature SAW devices suitable for space applications:** The project has successfully achieved growth and characterization of LGS crystal and extraction of important electrical, optical and electro-mechanical properties of the growth crystals. Under this project, new process is optimized for the growth of LGS crystal.
- **Coking in Semi-Cryogenic Engines: Studies on predicting the onset of coking in a heated tube with Isrosene/Kerosene:** The model developed under this project predicts the increased rate of surface deposition with increase in fluid temperature. The result will be used for predicting the coking phenomenon in coolant channels using Isrosene.
- **Development of Ultra Fine Grained Super High Strength Aluminium Alloys (7xxx series) by cryo rolling:** The project aimed at developing super-high strength aluminium alloys. The project has succeeded in development of ultra fine super high strength Aluminium alloys (7xxx series) by cryo rolling.
- **Development of nanostructured / amorphous SiGe Thermoelectric materials by high energy ball milling and spark plasma sintering:** The n and p type (Si80Ge20) thermoelectric alloys have been synthesized through high energy ball milling and spark plasma sintering at optimized processing conditions. SiGe phase, structural and chemical features were obtained by the XRD and transmission electron microscopy results. SEM-EDAX studies confirmed the structural homogeneity and uniform distribution of doping elements. The results obtained will be useful in the realization of thermoelectric converter of RTG.
- **Development of tools for hybrid-Polarimetric SAR data analysis and applications:** The project was primarily aimed at developing analysis techniques and tools for RISAT -1 hybrid polarimetric data. Under this project, five different methods were developed for decomposition of scattering mechanism and analysis techniques for hybrid polarimetric data with special reference to RISAT-1. The project has successfully developed a GUI based tool in MATLAB for RISAT-1 hybrid polarimetric data analysis.
- **Development of a catalyst for reduction of Carbon Dioxide to Methane and Water:** The project aimed at synthesis, characterization and testing of commercial catalyst for Sabatier reaction. The project has successfully synthesized more than 20 catalysts and tested their catalytic activity for CO_2 hydrogenation to methane, focused on Ru catalysts.
- **Free Space Optical Communication with Acousto-Optic Modulator based Transmitter:** The project aimed at Acousto-Optic Modulator based shaped programmable pulse shaping (b) Demonstrated rapid rate of new set of pulse shape generated (c) Generation and investigation of wide coherent communication source. The project has successfully developed Programmable MHz Rate Shaped Pulse technology.

- **Development of Bi-metallic joining techniques and realization of bi-metallic adaptors for Launch Vehicle:** The Proposal aimed to identify alternative methodologies to fabricate/manufacture bimetallic adaptors for satellite launch vehicles in lap and butt configurations with cost efficient and better mechanical properties. Under this project, two alternative approaches to fabricate AISI321/AA2219 bimetallic adaptors were identified and their respective welding procedures were also optimized.
- **Rare-earth Silicate Environmental Barrier coatings for SiC Based High Temperature Materials:** Under this project, Yttrium silicate environmental barrier coatings on SiC were developed by a novel technique of slurry spray deposition followed by in-situ reaction. The novelty of the present approach is that the spraying infrastructure is simple and economical. Also, the raw material does not need elaborate pre-treatment for preparing free flowing powders. This project contributed to understanding the fundamental causes for the difficulty of synthesizing phase-pure yttrium silicates.
- **Study on improvement of adhesion of EPDM based nano-composites in solid motor thermal insulation:** This project has brought out the formulation based on EPDM-RiCon/ Polyimide/Kevlar- nano silica composite, along with parameter optimization for better adhesion. This material has proved to be technically suitable candidate to be used for solid rocket motor thermal insulation applications.

5.6 Infrastructure

SDSC SHAR is realizing a Second Vehicle Assembly Building facility along with necessary systems for integration of Launch vehicles for meeting the future requirements for ISRO Space Programme. SVAB civil works are completed in all aspects and the facility is ready in its final configuration.

SVAB – External & Internal views

Autoclave at SPROB and Raw material Storage Facilities operationalised at SDSC, SHAR.

Autoclave & Raw Material storage facility

Centralized high performance computing system is established at LPSC Valiamala to cater the computational needs of the center in the area of computational fluid dynamics and structural mechanics. The facility was inaugurated on 28th July 2018.

Chairman, ISRO inaugurating the HPC facility

Computer/ Server Racks of HPC

Spacecraft Propulsion System Component Assembly & Testing Facility is commissioned and facility is operationalized. Thermo-vacuum facility and LN2 storage facility used for carrying out thermo-vacuum testing of IRS/GEOSAT propulsion system components were installed and commissioned.

SPS-CAT: 4 Tonne Vibration shaker facility

SPS-CAT: Thermo vacuum facility

Mechanical Systems Area (MSA) Building comprising of 7 blocks (A to G) has been established at ISITE in order to meet the additional area requirements of Mechanical system Area which comprises of Structures Group, Thermal Systems Group and Spacecraft Mechanisms Group. The facility was inaugurated by Chairman, ISRO on 27th April, 2018.

11 metre Antenna at Bhopal TTC station has been installed and commissioned.

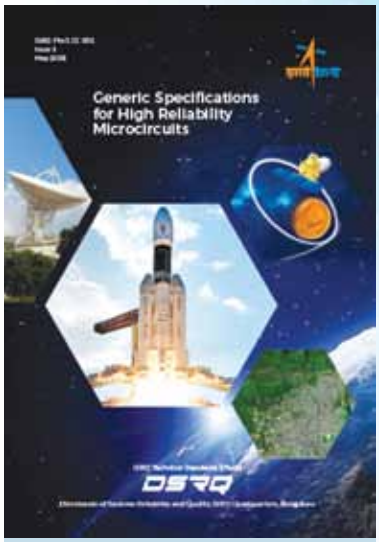
Inauguration of Bhopal-2 Terminal

5.7 Quality practices at ISRO

The quality practices at ISRO Centres/Units towards identification of systemic quality issues in their functioning were reviewed. Specific areas for improvement were identified and the quality teams at few Centres/Units have already been restructured and suitable re-organisation for the remaining Centres/Units is in the pipeline.

The IPAB functions as an ISRO-level nodal agency towards formulating policies in the area of quality and reliability of space systems. This is a think-tank forum with representation of the systems reliability and quality chiefs of all ISRO Centres and Units.

Follow up of the Non-conformances, changes and pending actions identified by major review fora towards ensuring the quality and reliability of GSLV Mk III D2 mission is done. Follow up on the implementation of Lessons Learned from the previous missions namely GSLV Mk III D1 and LVM3-X has also been taken up. Active follow up is also ON towards the implementation of Lessons Learned from previous spacecraft missions towards improvement in quality and reliability of future spacecraft missions. DSRQ is also keeping a close tab on the Quality Assurance aspects of Chandrayaan 2 mission as well as the other forthcoming spacecraft missions of ISRO.



ISRO Technical Standards

Generated 39 ISRO Technical Standards towards documenting the best practices in the various disciplines of engineering for standardizing the practices and for the benefit of future generations.

Sharing of best practices among ISRO Centres and Units as well as between ISRO and other agencies, academia, etc is also pursued. Exclusive sessions were held towards this with IBM DOORS (Dynamic Object Oriented Requirements System), IIT Bombay, etc. DSRQ has

also been assessing the international best practices towards Human-rating of the upcoming Gaganyaan mission and an exclusive report is under preparation.

The highlight of this year's outreach initiatives has been a pan-ISRO competition, inviting proposals for innovative ideas towards improving the quality and reliability of space systems. This competition was open to all employees of ISRO and a grand collection of 193 proposals were received. The proposals were evaluated by a high level team led by a senior Centre Director and the top five teams were awarded during a ceremony at ISRO Headquarters. Several innovative ideas resulting in increased accuracy, speed, easy availability of technical data, etc. by making use of advanced technologies like 3D Printing, Artificial Intelligence, Automation and other digital platforms have emerged during this exercise. A summary report capturing the best of the best ideas that came up during the competition has been prepared and provided to the Centres/ Units for absorption into the QA practices across ISRO Centres/Units.

Chairman, ISRO, Director, URSC and Director, DSRQ along with the top five teams- winners of the Pan-ISRO competition.

5.8 International Cooperation

Indian Space Research Organisation (ISRO) is pursuing its bilateral and multilateral relations with International Space agencies with the aim of strengthening ties between countries and for taking up new scientific and technological challenges. It includes carrying out cooperation activities of mutual interest; sharing expertise in the applications of space technology, organising international events in India and participation in international events. The scope of international cooperation has become wider and diverse, as ISRO has made tremendous progress in multitude areas in recent time.

Space Cooperative documents are signed with space agencies of 50 countries and 5 multinational bodies namely Afghanistan, Algeria, Armenia, Argentina, Australia, Bangladesh, Brazil, Brunei Darussalam, Bulgaria, Canada, Chile, China, Egypt, European Centre for Medium Range Weather Forecasts (ECMWF), European Commission, European Organisation for Exploitation of Meteorological Satellites (EUMETSAT), European Space Agency (ESA), France, Germany, Hungary, Indonesia, Israel, Italy, Japan, Kazakhstan, Kuwait, Mauritius, Mexico, Mongolia, Morocco, Myanmar, Norway, Portugal, Peru, Republic of Korea, Russia, Sao-Tome and Principe, Saudi Arabia, Singapore, South Africa, South Asian Association for Regional Cooperation (SAARC), Spain, Sultanate of Oman, Sweden, Syria, Tajikistan,

Thailand, The Netherlands, Ukraine, United Arab Emirates (UAE), United Kingdom (UK), United States of America (USA), Uzbekistan, Venezuela and Viet Nam.

In order to intensify space relations with partnering countries and establishing new relations with other nations in the peaceful uses of outer space, 20 Space cooperative documents with Space agencies of 15 countries and one multinational body are signed this year, viz., (1) Agreement between India and Uzbekistan on cooperation in the exploration and uses of outer space for peaceful purposes; (2) Memorandum of Understanding (MoU) between ISRO and Russian Federal Space Agency (ROSCOSMOS) on Joint Activities under Human Spaceflight Programme (HSP); (3) MoU between India and Tajikistan on cooperation in peaceful uses of Space technology for development; (4) Agreement between India and Algeria on cooperation in the field of space sciences, technologies and applications; (5) MoU between India and Morocco for cooperation in peaceful uses of outer space; (6) Agreement between India and Sao-Tome and Principe on Space cooperation; (7) MoU between India and BruneiDarussalamon cooperation in the operation of telemetry tracking and telecommand station for satellite and launch vehicles and for cooperation in the field of space research, science and applications; (8) MoU between ISRO and South African National Space Agency (SANSA) on cooperation in the exploration and uses of outer space for peaceful purposes; (9) Implementing Arrangement (IA) between ISRO and Japan Aerospace Exploration Agency (JAXA) concerning collaborative activities on improved rainfall products using satellite images and ground measurements; (10) MoU between Indian Institute of Space Science and Technology (IIST) and Nanyang Technical University (NTU), Singapore for cooperation in Space education; (11) Framework Agreement between India and Indonesia on cooperation in peaceful uses of outer space; (12) IA between ISRO and CNES for Pre-Formulation Studies of Maritime Domain Awareness mission; (13) Agreement between DOS and the European Commission on Cooperation in access and use of Sentinel data of the Copernicus programme; (14) MoU between India and Sultanate of Oman on cooperation in peaceful uses of outer space; (15) IA between ISRO and National Remote Sensing Department, Viet Nam on the establishment of tracking and data reception station and data processing facility; (16) MoU between the IIST and the Technion – Israel Institute of Technology for cooperation in the field of Space; (17) ISRO-NASA Space Act Agreement for DSN support for Chandrayaan-2; (18) IA between ISRO-JAXA concerning Pre-Phase-A Study & Phase-A Study of Joint Lunar Polar Exploration Mission; (19) IA between ISRO and CNES Concerning Exchange

Chairman,ISRO President CNES exchanging IA for cooperation on maritime domain awareness

of Personnel; (20) IA between ISRO and CNES for cooperation in Geodesy activities and applications.

India and USA intensified its Space cooperation and carried out many activities in this year. Significant progress has been made in the joint realization of microwave remote sensing satellite mission, 'NASA-ISRO Synthetic Aperture Radar (NISAR)'. The NISAR Critical Design Review was successfully carried out at JPL in October 2018. The Phase IIB of Airborne Campaign with NASA's hyperspectral instrument and ISRO's aircraft was carried out in selected sites over India in March-May 2018 to collect valuable data for earth science research activities. ISRO and NASA have also conducted Balloon campaigns to measure aerosol. Both agencies are also discussing on: NASA's Deep Space Navigation support for ISRO's future missions, cooperation in lunar exploration, mars exploration, Heliophysics and HSP. As part of ISRO and United States Geological Survey (USGS) cooperation in earth observation data sharing, LANDSAT Technical Working Group meeting was organised at Hyderabad in May 2018. Discussions are also in progress between ISRO and NOAA on cooperation in SCATSAT-1 data reception at NOAA's ground station.

India-Russia space cooperation made significant progress in 2018 mainly in the field of Human spaceflight programme. Apart from signing a MoU for cooperation in HSP, ISRO and ROSCOSMOS have formed joint working group exclusively on HSP and had series of discussion on many areas including Environment Control and Life Support System, Radiation shielding solutions, Micro particle impact mitigation, Astronaut training, Medical system for Astronauts, Personal hygiene and waste management system, View port, Space suit, Human rating guidelines for crew module. ISRO and ROSCOSMOS are also working towards establishing ground stations for each other's satellite navigation systems (NavIC station in Russia and GLONASS station in India).

As part of Indo-French space cooperation, ISRO and CNES have made significant progress in conducting feasibility study to realize an earth observation satellite mission with thermal infrared imager, *'TRISHNA'*. Both sides had Mission Definition Review and discussed on scientific needs, mission requirements, data policy, work share and plan for this mission. ISRO and CNES have finalized all interface control documents for accommodating CNES's ARGOS instrument in ISRO's OCEANSAT-3 satellite. ISRO and CNES have formed joint working group in Earth observation, Planetary exploration, Launch vehicle development, Communication and Navigation and Human spaceflight programme to further explore cooperation opportunities. A vision document, detailing the areas of cooperation in the future has been released by MEA during the visit of French President to India in March 2018. The space agencies are also working towards establishing ISRO's ground station for satellite navigation in France and CNES's geodetic receivers in India.

Under India-Japan space cooperation, ISRO and JAXA scientists are currently working on sharing of earth observation data and to carry out calibration/ validation experiments towards developing rainfall products with improved accuracy and are also carrying out a feasibility

study to realise a joint satellite mission to explore moon. It is also proposed to establish ISRO's ground station for satellite navigation in Japan. The ISRO-JAXA Joint working group has reviewed the cooperation in September 2018 and agreed to initiate discussion for cooperation in human space flight programme and X-ray astronomy.

The 3rd ISRO-German Aerospace Centre (DLR) Technical meeting was organised at Bengaluru in January 2018. ISRO-DLR teams discussed on Remote Sensing, Earth Observation and Applications, Space Exploration and Space Technologies and Space Missions. Both sides agreed to enhance cooperation in optical, microwave and hyperspectral remote sensing, disaster management support, data processing, wind tunnel testing, flight dynamics, robotic exploration, navigation, TTC, space debris and data reception facilities.

The 2nd Technical meeting between ISRO and Korea Aerospace Research Institute (KARI) was organised at Bengaluru in June 2018, wherein both sides discussed on cooperation opportunities in earth observation satellite navigation and space exploration.

The 5th meeting of ISRO –LAPAN, Indonesia was organised at Jakarta in December, 2018.

ISRO has organised an exclusive sounding rocket launch for UAE Space Agency (UAESA) officials at Vikram Sarabhai Space Centre on October 24, 2018.

ISRO has announced an 8-week capacity building programme on nano satellite development, named as **UNNATI** (**UN**ispace **N**anosatellite **A**ssembly & **T**raining by ISRO) as an initiative to commemorate the 50th Anniversary of the First United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE+50). The Programme will be conducted by U.R. Rao Satellite Centre (URSC) of ISRO at Bengaluru every year for next 3 years. Candidates from more than 40 countries have submitted their applications for the first batch, starting during January 2019. The programme provides opportunities to the countries for strengthening their capabilities in assembling, integrating and testing of nano satellites.

Chairman ISRO is making announcement on UNNATI programme at UNISPACE+50 event

ISRO hosted the 46th Plenary of the Coordination Group for Meteorological Satellites (CGMS-46) at Bangalore. The plenary had discussions under five working groups namely Satellite system and operations, Satellite data and products, Operational continuity and contingency planning, Global data dissemination and Space weather coordination group. The meeting was attended by 86 participants from 14 different Space agencies.

Prominent visitors to ISRO Centres in 2018 includes French Minister of Higher Education, Research &

Innovation; UAE Minister of foreign affairs and International Cooperation; Brunei Minister of communication; Members of the European Parliament; Japanese parliamentarians; Chief of Staff of Brazilian Air Force, Chairman of Algerian Space Agency, Chief of Air Staff of Bangladesh Air Force; and Ambassadors of USA, France, Sweden and Uzbekistan.

In the field of capacity building, ISRO continues to share its facilities, expertise in the application of space science and technology by conducting short-term and long-term courses through Indian Institute of Remote Sensing (IIRS) and the United Nations (UN) affiliated Centre for Space Science and Technology Education in Asia and the Pacific (CSSTE-AP) at Dehradun. As of now, there are more than 2668 beneficiaries from 108 countries.

A workshop on South Asia Satellite (SAS) ground segment, applications and utilization was organised at New Delhi in December 2018 with anticipation of technical experts from Afghanistan, Bangladesh, Bhutan, Maldives, Nepal and Sri Lanka.

Two senior ISRO officials have been bestowed with International Awards during this year. Dr. B.N. Suresh, Chancellor, IIST & Honorary Distinguished Professor received '2018 INCOSE Pioneer Award' and Shri A.S. Kiran Kumar, Vikram Sarabhai Professor and former Chairman, ISRO/ Secretary, DOS was conferred with the '2018 International Von Karman Wings Award'.

Prof. Satish Dhawan, former Chairman, ISRO/Secretary, DOS was honoured by Graduate Aerospace Laboratories at California Institute of Technology (GALCIT) as one of the "Legends of GALCIT".

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).

5.9 ISRO, Legal Affairs and Policy

- Department is in the process of enacting a legislation to support overall growth of the space activities in India with higher order of participation of various agencies including public/ non-governmental/private sector stakeholders, in compliance with the obligations underinternational treaties on space activities.
- The proposed legislation upon enactment through Parliament, would support the pursuance of space activities by various agencies in India including private sector & start-up companies in aerospace sector, under due authorization by the Central Government.

5.10 Indian Institute of Space Science and Technology (IIST)

Indian Institute of Space Science and Technology (IIST), a 'Deemed to be University' under Section 3 of the UGC Act 1956, established by the Department of Space (DOS), Government of India, in 2007, is in its twelfth year of existence. It offers undergraduate, post-graduate, doctoral and post-doctoral programmes in broad areas of space science, space technology and space applications. The Institute continues to be ranked as one of the top universities of the country. The year 2017-18 saw IIST improving its NIRF ranking, set up by the Ministry of Human Resource Development (MHRD), Government of India, by five places to be ranked 23rd among all Engineering institutions in the country. IIST is also ranked in the top 10 among these institutions for 'Teaching and Learning Resources'. The institute went through the AICTE approval process 2018 and in this connection an AICTE team visited IIST on 2 March 2018. The institute has been duly recognized by AICTE. AICTE has approved all the B.Tech as well as M.Tech programmes of the institute, on 29 May 2018. The faculty strength in the Institute as on 1st October 2018 is 96.

A total of 140 students were enrolled in to the Undergraduate programme in July 2018. A total of 77 students were enrolled for M.Tech. and Master of Science programmes in this academic year (July 2018 batch). A total of 26 scholars were admitted to PhD programme in July 2018 which includes 2 sponsored candidates from ISRO.

The cumulative enrolment of the institute as on October 1 2018 stands at 2267 with program-wise distribution as: Undergraduates 1724, Post Graduates 506 and Doctoral enrolment 268. The total degrees awarded by the institute are 1452, comprising of 1042 B.Tech., 353 M.Tech. / Master of Science and 57 Ph. D.

The Sixth convocation of IIST was conducted on July 18, 2018. Degrees were awarded to 111 B.Tech. graduates, 63 Master of Technology/Master of Science and 19 Ph.D. degree recipients. Gold medals were also awarded to top performer of Undergraduate and Postgraduate programmes. Cash certificates were given to best all rounder and best academic performers in each of the Undergraduate programmes. Out of successful B.Tech. students, 69 (out of 111 conferred degrees) were offered placement in ISRO in 2018. Thus, a total of 845 BTech graduates from the institute have been placed in ISRO.

With facilitation and coordination support by Research Council and Advanced Space Technology Development Cell (ASTDC), IIST faculty members are currently engaged in 39 projects in collaboration with various ISRO centers.

5.11 Occupational Health & Safety Programmes

Space program calls for presence of varieties of hazardous operations and it needs utmost precaution to avoid an accident or a mishap. In order to achieve high occupational health and safety standards for every operation in ISRO Centres/Units and to take care of statutory obligations with external agencies, the erstwhile ISRO Safety office was reconstituted and renamed as Directorate of Occupational Health and Safety (DOHS) on 19th May 2018 vide office order of Chairman, ISRO.

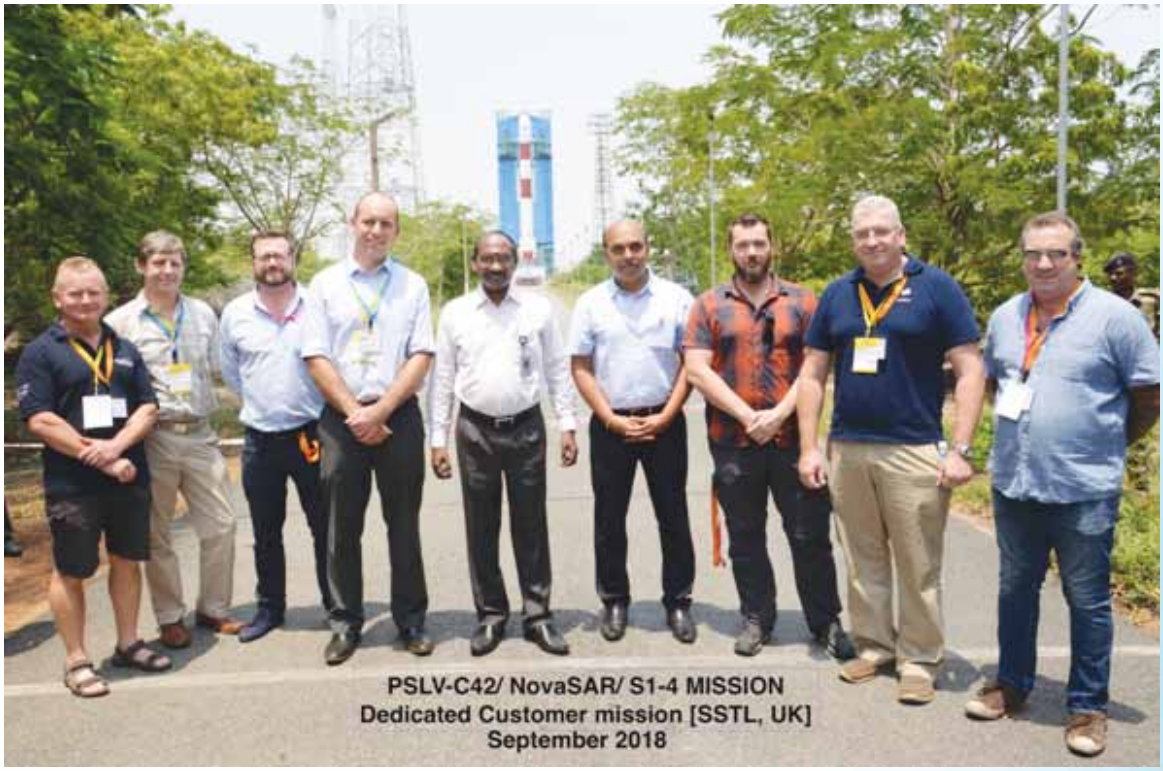
- 3-day Safety audit and Safety inspection was done at MCF, Hassan and Bhopal, and presented the recommendations to Director, MCF. It was carried out as part of Inter-Centre external safety audit programme.
- Assessed the adequacy of manpower for Fire services at ISRO Centre/Units and submitted an assessment report to DOS for necessary action.
- Held discussions with Chief Controller of Explosives (CCoE), PESO, Nagpur regarding modalities in conforming to the requirements recently introduced Explosive Rules 2008 for production, use, storage and handling of propellants in ISRO.
- Disseminated 'World Environment Day' messages to all Centre/Units and encouraged Centre/Units to celebrate World Environment Day 2018 through various programs and also distributed reusable and recyclable cloth bags to all in ISRO HQ./DOS to spread the awareness.

- Prepared and provided emergency evacuation guidelines to all ISRO Centres/Units to conduct Fire Emergency Mock drill and closely monitored the Safety non-conformances in various ISRO Centres/Units and ensured their completion. Inspection of all higher capacity UPS in ISRO HQ was carried out and also took action to relocate the same as per the ISRO Safety guidelines.

5.12 SPACE COMMERCE (ANTRIX)

1. **Transponder Leasing:** Through INSAT/GSAT fleet of satellites, Antrix enables Satellite Communication based services predominantly covering the Indian mainland and its islands. The services are provided for a variety of SATCOM applications like Television Broadcasting (TV), Direct to Home (DTH), Digital Satellite News Gathering (DSNG) and Very Small Aperture Terminal (VSAT) in 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, government and strategic sectors. Additionally, transponders on foreign satellites operating over India are being provisioned on a short term lease basis, primarily to meet the requirements of DTH and VSAT customers. All DSNG users and some VSAT users have been migrated from foreign satellites to INSAT/GSATs. With upcoming HTS class of satellites, Antrix is looking forward to cater to broadband connectivity demands arising from Government flagship programs like Digital India, BharatNet etc.
2. **Mission Support Services:** Antrix is recognised as one of the prominent service provider from this part of 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. ANTRIX is continuing to provide long term TTC support for a prestigious international customer from Europe. There has been a growing demand from customers and new business opportunities are being constantly explored including providing TTC support from newer ground stations.

3. **Launch Services:** As part of PSLV launch services to international customer satellites, during the year, Antrix undertook dedicated customer satellite mission for Surrey Satellite Technology Limited (SSTL), UK. PSLV-C42/ NovaSAR/ S1-4 Mission during September carried 2 primary satellites viz. NovaSAR a 450 kg S-Band Synthetic Aperture Radar satellite and S1-4, a 450 kg optical imaging satellite.



PSLV-C42/ NovaSAR/ S1-4 MISSION
Dedicated Customer mission [SSTL, UK]
September 2018

4. **Small Satellite Launch Vehicle**

   Antrix has taken-up the task of producing ISRO's new Small Satellite Launch Vehicle (SSLV) partnering Indian Industries in the near future, to capture a fair share of the growing global small satellite launch market.

5. **Remote Sensing Data and Services:** The global marketing of IRS data is being pursued in collaboration with its international partners. Currently, Antrix markets IRS data and services from Resourcesat-2, Cartosat-1, Cartosat-2S and Oceansat-2 satellites. Antrix is in the process of expanding the IRS ground segment and Reseller Network to promote IRS data products and related services across the globe.

6. **New business opportunities:** Company has taken up the task of building & marketing NaVIC receivers for various user segments utilizing ISRO's technology. Fishermen across Indian coastline are expected to benefit from this activity. The requirement of better managing sand mining activities in various states using NavIC is also being addressed.

7. ANTRIX is establishing the Multi Mission Meteorological Data Reception and Processing Facility for a national user. The work is progressing well and the system is expected to be commissioned during 2019.

8. Bengaluru Space Expo (BSX) 2018

- The 6th edition of Bengaluru Space Expo (BSX-2018) was held during 6th-8th September 2018. It is a biennial event organized with the intent to bring together Indian industries, ISRO and various stake holders in the space domain for the common benefit of improving space productivity and commerce. The theme for BSX-2018 was **"Creating Dynamism in Indian Space Ecosystem" with specific focus on "Enabling New Space in India"**. The BSX-2018 has enabled Indian industries to get exposed to the growing business environment, various business opportunities and technologies, to spur the growth of space commerce in India.

- During this event, there were nearly 740 delegates from 21 participating countries. The event witnessed participation of more than 120 industries. About 50 eminent professionals delivered talk on several aspects related to increased industry participation in the areas related to launch vehicles, satellites, applications. Space Exhibition was organized with nearly 100 stalls depicting the space products and services from India and abroad.

104 Exhibitors showcasing their products and Services

Dr. K. Sivan, Chairman, ISRO & Secretary, Department of Space, delivering the inaugural address during BSX-2018

5.13 ISRO Public Outreach Programme

To tap the potential of the scientific and engineering fraternity, ISRO under its Outreach policy expands its horizon to provide a suitable platform to these youths by establishing Space Technology Incubation Centres (S-TIC). In line with this, the first S-TIC at National Institute of Technology–Agartala in the state of Tripura was inaugurated on September 18, 2018. Second S-TIC was inaugurated on January 17, 2019 at NIT, Jalandhar, Punjab.

S-TIC NIT-Agartala inaugurated by Sri Biplab Kumar Deb, CM-Tripura

Satish Dhawan Centre For Space Science was established on October 11, 2018 at Central University of Jammu, Jammu & Kashmir which will have facilities for Geospatial data analysis,

Satish Dhawan Centre for Space Sciences Central University of Jammu

ground based observation for atmospheric studies, research lab for astrophysics, material lab etc.

Organised the 4th India International Science Festival (IISF) during September 2018 at various ISRO Centres, under the banner of IISF and VIBHA. During this event the labs of SAC, NRSC, ISTRAC, SCL, NESAC were open to students, public and local media to showcase our achievements and research facilities to them, to get an insight of work life of researchers.

4th IISF being celebrated at NRSC, Hyderabad

4th IISF being celebrated at SAC, Ahmedabad

Area Specific Intensive Module Training for new recruited Engineers was conducted on 27.12.2018

VSSC Organized 20 field exhibitions at selected educational institutions and public places to create awareness among public about the activities of ISRO. World Space Week celebrated from October 4-10, 2018 was conducted in all ISRO centres.

Inter-Centre Sports meet – ICSM 2018 was organised at SDSC SHAR in two phases during Aug-Sep 2018. In the first phase all the athletic events are conducted and participants from

ICSM 2018 – Inauguration & Address by Chairman, ISRO

ICSM 2018 - a glimpse of events

all ISRO/DOS Centres/Units have participated. During second phase all the indoor games are organised.

A two-day workshop on "Satellite Navigation and Applications of GNSS/NavIC" was organised during April 5-6, 2018 at NARL, Gadanki. The aim of the workshop was to create awareness on the potential and use of Indian Regional Navigation Satellite System (IRNSS) – NavIC.

Many Events, workshops, conferences were organized in different ISRO centre during the period. Some of them include Bharat Ratna Dr. APJ Abdul Kalam Commemoration Day, Hindi Fortnight Celebration, Research Meets, World Space Week Celebrations, International Yoga Day celebrations, SwachhBharath Campaigns National Science Day, etc. Many school children and interested public will be invited to attend some of these outreach programmes.

During the reporting year, for five launches from SDSC, SHAR namely PSLV-C41, PSLV-C42, PSLV-C43, GSLV-F08 and GSLV-Mk- III National level Print and Electronic Media were invited to cover the launches live from Sriharikota. Doordarshan, India's National Television boradcasted the launch of six satellites from SDSC, SHAR during the reporting year incluidng GSAT-11 satellite which was launched from French Guyana. In order to reach maximum pupoluation of the country and across the world ISRO website was regularly updated to desimnate relevant information of ISRO. Even Social media tools like Twitter and Facebook were effecitively utilised as a part of public outreach programme. ISRO also participated in more than 20 exhbitions across different parts of India at local, regionla, National and International level.

6. Space in Parliament

Indian Space Programme continued to attract the attention of both the Houses of Parliament. Questions were answered in Parliament during the year of 2018 as shown below:-

Questions	Budget Session		Monsoon Session		Total	
	14th Session - 16th Lok Sabha	245th Session of Rajya Sabha	15th Session- 16th Lok Sabha	245th Session of Rajya Sabha	L.S.	R.S.
Starred Questions	02	01	0	01	02	02
Unstarred Questions	17	12	16	10	33	22
Total	19	13	16	11	35	24

The Questions were with respect to Space Applications, Space technology, Satellite Launching Stations, Chandrayaan-11, NavIC receivers, Crew Escape System, Flight testing of unmanned crew escape system, Navigation Satellites, Weather Satellites, Reusable Launch Vehicle, Electric Propulsion System, Lithium-ion batteries, Making of Green Propellant, Mission on Moon and Mars, Launching of second Astrosat-2, Framing of National Space Act, ISRO's share in global launch market, 'Make in India' in Space technology, Start-ups in space sector, Project to support ASEAN countries, Village Resource Centres, Social upgradation in rural areas, etc.

During the year 2018, Department-related Parliamentary Standing Committee on Science & Technology, Environment & Forests have visited URSC, Bengaluru and IIRS, Dehradun and held discussions with representatives of Centres/Units of the Department of Space. The Committee on Papers Laid on the Table.

Rajya Sabha is scheduled to undertake a study visit to Antrix Corp. Ltd., Bengaluru on 14th September, 2018.

7. Vigilance

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

Category of Employees	Types of Cases	Cases Pending as on 01.01.2017	Cases received during the Period 01.01.017 to 30.09.2018	Total (Col. 3+4)	Disposed during 01.01.2017 to 30.09.2018	Pending (Col. 5-6)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Group – A & Group – B (Gazetted)	Disciplinary (non-vigilance)	11	1	12	2	10
	Vigilance	7	0	7	0	7
Group-B (Non-Gazetted) Group C	Non vigilance	10	10	20	11	9
	Vigilance	2	0	2	2	0
	Total	**30**	**11**	**41**	**15**	**26**

8. 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 Fourth meeting of Sanyukt Hindi Salahkar Samiti (JHSS) for DOS and DAE under the Chairmanship of MOS, PMO was organized at New Delhi on 07.05.2018. Due to the ensuing elections during 2019, the tenure of JHSS has been extended for one year from July 01, 2018 with the approval of the honorable MOS, PMO, the chairman of the said committee and the Fifth meeting of the Committee was organized at New Delhi on 21.12.2018.

MoS Dr. Jitendra Singh Addressing the Members During the Joint Hindi Salahkar Samiti Meeting on 21st December, 2018 at New Delhi. Secretary DOS & Secretary DAE Seated Either side of MoS.

- The 40th meeting of Central Official Language Implementation Committee held on 27.12.2018 under the Chairmanship of Secretary, DOL, where Joint Secretary, DOS and Joint Director (OL), DOS have participated.
- The 160th meeting of Departmental Official Language Implementation Committee across the table was held on 03.01.2019 under the Chairmanship of Joint Secretary, DOS.
- During the year the second Sub-Committee of the Committee of Parliament on Official Language Inspected. V.S.S.C., Thiruvananthpuram, SCL, Chandigarh, ISTRAC, Bangalore, NARL, Gadanki with regard to the progress made in the implementation of Official Language, which was appreciated.
- 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.4,16,961/- has been spent by the Department and its centre/units for the purchase of Hindi books for Library, which is in accordance with the target set up by DOL i.e. 50% of the total amount allocated for general books.

- During the year, the Department has incurred expenditure in accordance with the target set by the DOL for the publication of advertisement in Hindi in the news papers.
- In order to implement Hindi in more meaningful and effective manner and to evaluate the progressive use of Hindi in DOS/ISRO Centers/Units, an Annual Inspection Programme was drawn up by Department and inspections were carried out. The Officers from Regional Implementation Offices of Department of Official Language have also inspected the various Centers/Units to review the progressive use of Hindi.
- Internal inspections of 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 Vishwa Hindi Divas Celebration organized on 10th January, 2019.
- The training programmes in Hindi through Hindi Teaching Scheme, under Correspondence course are 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 Centers/Units have been requested to prepare an action plan for imparting training to the remaining employees and to complete the training programme at the earliest. Out of the total strength of 18,074 in the department, 16,485 are trained in Hindi and remaining 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 Centers/Units, during which competitions in Essay Writing, Noting and Drafting, typing, quiz, poetry writing, 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 from house-to-house, the family members of the employees were included during Hindi Fortnight celebrations in all Centers/Units of the Department and there was an overwhelming response.
- The children of the employees those secured highest marks in Hindi in class X & XII were awarded.
- With a view to refresh and update the knowledge of Official Language personnel, an 'Official Language Orientation Programme was organized by SCL, Chandigarh on 07.12.2018.
- World Hindi Day was celebrated on 10th January, 2019 in all Centers/Units of the Department by conducting various programmes. In DOS/ISRO HQ, a Poetry Recitation Competition on "Patriotism" was organized on the occasion.
- Department plays an active role in the activities of Town OLIC. It conducts various programmes under the auspices of Town OLIC. Hindi Noting and Drafting competition was organized by the department for the Town OLIC member offices on 24.10.2018. Further, on 04.12.2018 the prize distribution programme under Joint Hindi Day Fortnight was organized by the department.

- DOS/ISRO HQ in-house magazine “Disha”, compendium of technical articles “Antariksh Gyan Sarita” were published during the year.
- Several pamphlets, Panels (More then 50) and stickers/posters on Indian Space Programme, as well as Astrosat; PSLV-C 39, 40, 41, 42, 43; Chandrayan-II, GSLV-F08, GSAT-6A, GSAT-29, GSAT-7A, HySIS Mission, Glimpses Of Indian Space Programme, Gaganyaan brochures 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 conducted several outreach programmes also in order to reach out the space activities to the common man and student community.
- The website of the department is in bilingual and it is regularly updated in Hindi. In addition to Department’s own Website, SAC, PRL, NRSC, URSC and NARL also have their own Websites. DOS/ISROHQ, SAC, VSSC, LPSC, SDSC 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” also continued during the year and employees of DOS/ISRO HQ and its C/Us were awarded Cash Prize and Certificates.
- The Incentive Scheme “Vikram Sarabhai Hindi 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 eight (8) Books in Hindi on Scientific subjects written by the Scientists of Space Applications Centre, Ahmedabad, Satish Dhawan Space Centre UR Rao Satellite Centre and SCL were published by the Department. These books were released by Secretary, DOS/Chairman, ISRO on 24.04.2018. The authors were awarded the Cash Prize and Certificate by Secretary, DOS on 03.01.2019, during the 160th Departmental OLIC Meeting. The Secretary also awarded Certificate to the members of the Vikram Sarabhai Maulik Lekhan Yojana Committee for their commendable work. Publication of Technical Articles by the Scientists of the Department in leading magazines continued during the year. For the year 2018, one technical book written in Hindi by a Scientist of NRSC is selected for publication.
- During the year various centres/units of the department conducted a total of Seven (07) technical seminars in Hindi on various subjects. 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 organizations, Town OLIC and also by Regional Implementation Office.
- A topic on Hindi Implementation as a part of Induction Programme in all the major Centers of DOS/ISRO continued 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.
- In the Department the task of inclusion of Hindi in COINS, the web version of COWAA is underway at SDSC, SHAR Shriharikota.

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AWARD:

National Level -

- For Best implementation of Official Language, Department of Space was awarded the ***"Rajbhasha Kirti Puraskar" (III Prize)*** by the Honorable Vice-President of India in a function organized at Rashtrapati Bhawan, New Delhi on 14.09.2018 and it was received by Shri S. Kumaraswamy, Joint Secretary, DOS.

Shri S. Kumaraswamy, Joint Secretary, Dept. of Space Receiving 'Rajbhasha Kirti Puraskar' For the year of 2017-18 from hon'ble vice President of India Shri Venkaiah Naidu.

Regional and TOLIC Level -

- The following centre/units of DOS were awarded for best implementation of Hindi in their centre/units by respective Town OLICs and at regional level during the year:-

Sl. No.	Centre/Units	Award	Position
1	ILC, Mumbai	Regional Level 2017-18 (Western Region)	First
2	MCF, Bhopal	Regional Level 2017-18 (Central Region)	First
3	SCL	Under TOLIC	First
4	VSSC	Under TOLIC	First
		In-house Magazine-GAGAN Rolling Shield (Chal Vaijanti Puraskar) Joint Hindi Fortnight 2018-19 - for scoring highest marks	First Second
5	URSC	Under TOLIC	First
6	IISU	Under TOLIC	Second

9. Right to Information

Right to Information (RTI) Act 2005 is implemented in this Department as per the mandate of RTI Act. With the increased RTI applications and in order to disseminate the information in time, Department has decided to decentralize the adjudication of RTI applications/appeals at Centres/Units/Autonomous Bodies/PSU level with effect from 01/11/2018. In terms of Section 5 & 19 of the Right to information Act, 2005, all the DOS/ISRO Centres /Units/Autonomous Bodies/PSU (Antrix) have identified and designated the Transparency Officer, Nodal Officer, Appellate Authority and Central Public Information Officer for implementation of RTI Act.

As per Section 4 (1) (b) of RTI Act, Department of Space has published the following information on the web page http://www.isro.gov.in/right-to-information

- Guidelines for submission of application under RTI Act, 2005
- Milestone of the Department of Space/Indian Space Research Organisation
- Annual Report – 2017- 2018 (English/Hindi)
- Human Resources
- Citizen Charter
- Public Grievances
- Suo-Motu disclosure of official tours of Joint Secretary level officials and above
- Suo-Motu disclosure of Directory of employees of ISRO HQ/DOS
- 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
- Budget at a glance 2018-19 & Budget Profile
- Manner of execution of subsidy programmes and details of beneficiaries of such Programmes

- Particulars of recipients of concessions, permits or authorizations 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 Transparency Officers, Nodal Officers, First Appellate Authorities, Central Public Information Officers nominated for the implementation of RTI Act in DOS/ ISRO
- In addition to the above, the following information also uploaded periodically in the website:
  (a) Transfer Policy for the administrative cadre.
  (b) Transfer & Posting of officers in Administrative Cadre
  (c) Status of implementation of RTI Act, 2005
  (d) Audit Report of the DOS/ISRO on proactive disclosure under RTI Act, 2005 (May 2017)
  (e) Detailed Demands for Grants 2018-19
  (f) Output-Outcome Framework 2017-18

During the period January 2018 to October 2018, 1287 applications were received and information were disseminated under the provisions of the RTI Act. 259 Appeals were received by the First Appellate Authority and 17 approached the Second Appellate Authority, i.e., Central Information Commission.

10. 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	Report No. 22 of 2014 Management of Satellite capacity for DTH service	One	Nil	Nil	Nil	Nil
2	Report No. 27 of 2014 (Para No. 4.1) Inordinate delay in realisation of SRE-2 mission	One	Nil	Nil	Nil	Nil
3	Report No. 27 of 2014 (Para No.4.2) Loss in allocation of satellite Capacity	One	Nil	Nil	Nil	Nil
4	Report No. 27 of 2014 (Para No.4.3) Avoidable expenditure due to improper contract management	One	Nil	Nil	Nil	Nil

5	Report No. 27 of 2014 (Para No.4.4) Infructuous expenditure on procurement of components	One	Nil	Nil	Nil	Nil
6	Report No.30 of 2015 (Para No. 5.1) Implementation incentive scheme	One	Nil	Nil	Nil	Nil
7	Report No.30 of 2015 (Para No. 5.2) Irregular payment of service tax	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 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
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	One	Nil	Nil	Nil	Nil
16	Report No.17 of 2017 (Para no.6.1) Management of VSAT Services	One	Nil	Nil	Nil	Nil
17	Report No.17 of 2017 (Para No.6.2) Irregular Expenditure on Pre-Project Activities	One	Nil	Nil	Nil	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	One	Nil	Nil	Nil	Nil

19	Report No.17 of 2017 (Para No.6.4) Infructuous Expenditure in purchase of ecologically fragile land	One	Nil	Nil	Nil	Nil
20	Report No.02 of 2018 (Para No.7.1) Operationalisation of Satellite navigational system	One	Nil	Nil	Nil	Nil
21	Report No.02 of 2018 (Para No.7.2) Infructuous expenditure on Software Development	Nil	Nil	One	Nil	Nil

B. Summary of important audit observations during 2018

1. C&AG Report Union Government, Scientific Departments Report No. 2 of 2018 Para 7.1 titled "Operationalisation of satellite navigational system":

Audit had made observation that NAVIC was approved by the Government of India in May 2006 at a cost of ₹1,420 crore to establish an independent and indigenous satellite based navigation system over the Indian landmass and surrounding region. An expenditure of ₹1,283.93 crore had been incurred on the programme so far. However, the system has yet to be operationalised due to delays in execution of contracts, deficient monitoring of programme and inadequate follow up. In addition, ₹3.57 crore were spent on unnecessary procurement of modems.

2. C&AG Report Union Government, Scientific Departments Report No. 2 of 2018 Para 7.2 titled "Infructuous expenditure on Software Development":

Audit had made observation that failure to implement and properly monitor a project on development of Digital Workflow System by the Department of Space resulted in non-development of the software for more than 11 years since its initiation despite expenditure of ₹2.27 crore.

11. 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)
- 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-C10successfully 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

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.
- GSLV-F08 in its 12th flight of Geosynchronous Satellite Launch Vehicle (GSLV) launched GSAT-6A from the Second Launch Pad (SLP) in Satish Dhawan Space Centre SHAR, Sriharikota on March 29, 2018. However, the ground station lost communication with the satellite.
- India's Polar Satellite Launch Vehicle, in its forty-third flight (PSLV-C41) in launched IRNSS-1I Satellite from First Launch Pad (FLP) of SDSC SHAR, Sriharikota on April 12, 2018. The IRNSS-1I is the eighth satellite to join the NavIC navigation satellite constellation.
- A major technology demonstrator called as Pad Abort Test was successfully carried out at Satish Dhawan Space Centre (SDSC), SHAR, Sriharikota on July 05, 2018. This was one of the tests to qualify a Crew Escape System, which is a critical technology in human spaceflight. The first Pad Abort Test demonstrated the safe recovery of the crew module in case of any exigency at the launch pad.

- PSLV-C42 Successfully Launches two foreign satellites from Satish Dhawan Space Centre (SDSC), SHAR, Sriharikota on September 16, 2018. This mission launched two earth observation satellites, NovaSAR and S1-4 (together weighing nearly 889 kg) of M/s Surrey Satellite Technologies Limited (SSTL), United Kingdom under commercial arrangement with Antrix Corporation Limited.
- PSLV-C43 on November 29, 2018 successfully launched India's Hyper spectral Imaging Satellite (HysIS) and 30 international co-passenger satellites. HysIS, the primary satellite of PSLV-C43 mission, weighing about 380 kg, is an earth observation satellite configured around ISRO's Mini Satellite-2 (IMS-2) bus. The co-passengers of HysIS include 1 Micro and 29 Nano satellites from 8 different countries. These satellites have been commercially contracted for launch through Antrix Corporation Limited, the commercial arm of ISRO.
- PSLV-C44 on January 24, 2019 successfully launched Microsat-R & Kalamsat-V2 (student satellite). The fourth stage of the vehicle was moved for the first time to a higher circular orbit of 453 km, after two restarts, to establish an orbital platform for carrying out experiments.
- ISRO's next generation high throughput communication satellite, GSAT-11 was successfully launched on December 05, 2018 from Kourou launch base, French Guiana by Ariane-5 VA-246. Weighing about 5854 kg, GSAT-11 is the heaviest satellite built by ISRO. GSAT-11 is the fore-runner in the series of advanced communication satellites with multi-spot beam antenna coverage over Indian mainland and Islands. GSAT-11 will play a vital role in providing broadband services across the country. It will also provide a platform to demonstrate new generation applications.
- GSLV-F11 successfully launched GSAT-7A, ISRO's 39th communication satellite, on December 19, 2018 from the Second Launch Pad (SLP) of Satish Dhawan Space Centre SHAR, Sriharikota. GSAT-7A with a lift-off mass of 2250 kg, is a geostationary satellite carrying communication transponders in Ku-band. The Satellite is built to provide communication capability to the users over the Indian region.

Acronyms

AA	Aluminium Alloy
AAI	Airport Authority of India
ABPP	Air Breathing Propulsion Project
ACL	Antrix Corporation Limited
ADCOS	Advisory Committee for Space Sciences
ADRDE	Ariel Delivery Research and Development Establishment
AFC	Autonomous Film Cooling
AFTN	Aeronautical Fixed Telecommunication Network
AGEOS	Antarctica Ground Station for Earth Observation Satellites
AICTE	All India Council for Technical Education
AIT	Assembly, Integration and Testing
AMD	Atomic Minerals Directorate
APEP	Ammonium Perchlorate Experimental Plant
ARG	Automatic Rain Gauge
ASDM	Aerial Services and Digital Mapping
ASIC	Application Specific Integrated Circuit
ASICs	Application Specific Integrated Circuits
ASTDC	Advanced Space Technology Development Cell
AVIRIS-NG	Airborne Visible Infrared Imaging Spectrometer-Next Generation
AWiFS	Advanced Wide Field Sensor
AWS	Automatic Weather Stations
BPOFM	Bunched Passage Orifice Flow Meter
BSX	Bengaluru Space Expo
CATVAC	Comprehensive Assembly and Test Vacuum Chamber
CCoE	Chief Controller of Explosives
CDMA	Code Division Multiple Access
CeNSE	Centre for Nano Science and Engineering
CEOS	Committee on Earth Observation Satellites
CES	Crew Escape System
CFRP	Composite Fiber Reinforced Plastic
CGMS	Coordination Group for Meteorological Satellites
CGMS	Coordination Group on Meteorological Satellites
CHAMAN	Coordinated programme on Horticulture Assessment & Management using Geoinformatics

CME	Continuing Medical Education
CMOS	Complementary Metal Oxide Semiconductor
CNES	Centre National d'Etudes Spatiales
CNES	Centre National d'Etudes Spatiales
COB	Chip-On-Board
CoE	Centre of Excellence
CORS	Continuously Operating Reference Stations
COSPAR	Committee on Space Research
CPCB	Central Pollution Control Board
CSA	Charge Sensitive Amplifier
CSSTE-AP	Centre for Space Science and Technology Education – Asia Pacific
CSSTE-AP	Centre for Space Science and Technology Education in Asia and the Pacific
CUS	Cryogenic Upper Stage
DAC&FW	Department of Agriculture, Cooperation & Farmers' Welfare
DECU	Development and Educational Communication Unit
DEM	Digital Elevation Models
DEM	Digital Elevation Model
DGCA	Directorate General of Civil Aviation
DMS	Disaster Management Support
DOHS	Directorate of Occupational Health and Safety
DoLR	Department of Land Resources
DOORS	Dynamic Object Oriented Requirements System
DOS	Department Of Space
DRT	Data Relay Transponder
DSN	Deep Space Network
DSNG	Digital Satellite News Gathering
DTH	Direct-to-home
DWR	Doppler Weather Radars
ECMWF	European Centre for Medium Range Weather Forecasts
ECVs	Essential Climate Variables
EGC	Engine Gimbal Control
EIA	Equatorial Ionization Anomaly
EIRP	Effective Isotropic Radiated Power
EMA	Electromechanical actuators
ENWi	Electron density and Neutral Wind

EO	Earth Observation
EOC	Early Operations Capability
ESA	European Space Agency
ESIC	Employees State Insurance Corporation
EUMETSAT	European Organisation for Exploitation of Meteorological Satellites
FM	Flight Model
FSI	Forest Survey of India
FSS	Fixed Satellite Services
FTP	File Transfer Protocol
GAC	Global Area Coverage
GAGAN	GPS Aided Geo Augmented Navigation
GEO	Geostationary Earth Orbit
GeoMGNREGA	GIS Implementation of MGNREGA
GHRC	Geo High Resolution Camera
GHz	Giga Hertz
GIS	Geographical Information System
GIS	Geographical Information System
GISAT	Geo Imaging Satellites
GLOF	Glacial Lake Outburst Flood
GNSS	Global Navigation Satellite System
GOCO	Government Owned and Company Operate
GPP	Gross Primary Production
GPS	Global Positioning System
GSAT	Geosynchronous Satellite
GSI	Geological Survey of India
GSLV	Geosynchronous Satellite Launch Vehicle
GSLV-MkIII	Geosynchronous Satellite Launch Vehicle Mark III
GTO	Geosynchronous Transfer Orbit
HAVA	Hypersonic Air Breathing Vehicle with Air frame integrated system
HEM	High-altitude Escape Motor
HMC	Hybrid Micro Circuit
HSP	Human Spaceflight Project
HSP	Human Spaceflight Programme
HTS	High Throughput Satellite
HTVE	High Thrust Vikas Engine
HySIS	Hyper Spectral Image Sensor

IA	Implementing Arrangement
IAA	International Academy of Astronautic
IADC	Inter-Agency Space Debris Coordination Committee
IAF	International Astronautical Federation
ICC	INSAT Coordination Committee
ICD	Interface Control Document
ICD	Interface Control Document
ICG	International Committee on GNSS
ICG	International Committee for Global Navigation Satellite Systems
ICT	Information & Communication Technology
IDSN	Indian Deep Space Network
IGS	International Ground Stations
IGS	IRS Ground Stations
IIRS	Indian Institute of Remote Sensing
IISc	Indian Institute of Science
IISL	International Institute of Space Law
IISU	ISRO Inertial Systems Unit
IIT	Indian Institute of Technology
IITs	Indian Institute of Technologies
IMD	India Meteorological Department
IMDPS	INSAT Meteorological Data Processing System
IMPRINT	IMPacting Research Innovation and Technology
IMS	Indian Mini Satellite
INC	and IRNSS Navigation Centre
INCOIS	Indian National Centre for Ocean Information Services
INCOSPAR	Indian National Committee for Space Research
INMCC	Indian Mission Control Centre
INSAT	Indian National Satellite
IPRC	ISRO Propulsion Complex
IRCDR	IRNSS CDMA Ranging Stations
IRDCN	IRNSS Data Communication Network
IRIMS	IRNSS Range and Integrity Monitoring Stations
IRIMS	IRNSS Range & Integrity Monitoring Stations
IRNSS	Indian Regional Navigation Satellite System
IRNWT	IRNSS Network Timing Facility
IRS	Indian Remote Sensing

IRS	Indian Remote Sensing
IRSCF	IRNSS Spacecraft Control Facility
ISECG	International Space Exploration Coordination Group
ISITE	ISRO Satellite Integration and Test Establishment
ISPRS	International Society for Photogrammetry and Remote Sensing
ISRO	Indian Space Research Organisation
ISTRAC	ISRO Telemetry, Tracking and Command Network
ITBP	Indo Tibetan Border Police
IWMP	Integrated Watershed Management Programme
JAXA	Japan Aerospace Exploration Agency
KSDMA	Kerala State Disaster Management Authority
LAC	Local Area Coverage
LEM	Low-altitude Escape Motor
LEO	Low Earth Orbit
LEOS	Laboratory for Electro-Optics Systems
LIN	Liquid Nitrogen
LIS	Land Information System
LISS	Linear Imaging Self-Scanning
IIST	Indian Institute of Space Science and Technology
LPSC	Liquid Propulsion Systems Centre
LST	Land Surface Temperature
LULC	Land Use / Land Cover
LUTs	Local User Terminals
LWIR	Long Wave Infrared
M&C	Monitor & Control
MADRAS	Microwave Analysis and Detection of Rain and Atmospheric Structures
MCF	Master Control Facility
MEMS	Micro-Electro-Mechanical Systems
MHRD	Ministry of Human Resource Development
MIDH	Mission for Integrated Development of Horticulture
MoD	Ministry of Defence
MODIS	Moderate Resolution Imaging Spectroradiometer
MOSDAC	Meteorological and Oceanographic Satellite Data Archival Centre
MoU	Memorandum of Understanding
MRCCs	Maritime Rescue Coordination Centres
MRD	Ministry of Rural Development

MSA	Mechanical Systems Area
MSS	Mobile Satellite Services
NARL	National Atmospheric Research Laboratory
NASA	National Aeronautics and Space Administration
NaVIC	Navigation with Indian Constellation
NDEM	National Database for Emergency Management
NEC	North Eastern Council
NEE	Net Ecosystem Carbon Exchange
NER	North Eastern Region
NESAC	North Eastern Space Applications Centre
NE-SAC	North Eastern- Space Applications Centre
NGOs	Non-Government Organisations
NHP	National Hydrology Project
NICES	National Information System for Climate and Environment Studies
NISAR	NASA-ISRO Synthetic Aperture Radar
NOAA	National Oceanic and Atmospheric Administration
NPLI	National Physical Laboratory India
NRSC	National Remote Sensing Centre
NSSO	National Sample Survey Office
NTU	Nanyang Technical University
NWH	North West Himalaya
OBC	On-Board computer
OCM	Ocean Colour Monitor
ORV	Orbital Re-entry Vehicle
PAT	Pad Abort Test flight
PC-NNRMS	Planning Committee on National Natural Resources Management System
PRL	Physical Research Laboratory
PSLV	Polar Satellite Launch Vehicle
R&D	Research & Development
RAPID	Real Time Analysis Product & Information Dissemination
RCCs	Rescue Coordination Centres
RCS	Reaction Control System
RCT	Reaction Control Thrusters
RDAS	Reconfigurable Data Acquisition System
RESPOND	Research Sponsored

RIS	RLV Interface System
RISAT	Radar of India's Radar Imaging Satellite
RLV-TD	Reusable Launch Vehicle
RN	Radio Networking
ROSA	Radio Occultation Sounder for Atmospheric studies
ROSCOSMOS	Russian Federal Space Agency
ROTs	Receive Only Terminals
RRSCs	Regional Remote Sensing Centres
RS	Restricted Service
SAARC	South Asian Association for Regional Cooperation
SAC	Space Applications Centre
SANSA	South African National Space Agency
SAPHIR	Sounder for Probing Vertical Profiles of Humidity
SAR	Synthetic Aperture Radar
SARAL	Satellite with ARGOS and ALTIKA
SAS & R	Satellite Aided Search and Rescue
SATNAV	Satellite Navigation
SBAS	Satellite Based Augmentation System
SCENC	Semi Cryo Engine Nozzle Closure
SCL	Semi-Conductor Laboratory
SDSC	Satish Dhawan Space Centre
SIS	Signal-In-Space
SITs	Satellite Interactive Terminals
SPADEX	Space Docking Experiment
SPPU	Savitribai Phule Pune University
SPROB	Solid Propellant Space Booster Plant
SPS	Standard Positioning Service
SSC	Swedish Space Centre
SSPA	Solid State Power Amplifier
SST	Sea Surface Temperature
SSTL	Surrey Satellite Technology Limited
SSTM	Sea Surface Temperature Monitor
SSV	Space Service Volume
STC	Space Technology Cells
SVAB	Second Vehicle Assembly Building
SWIR	Short Wave Infrared

TDP	Technology Development Programmes
TDV	Technology Demonstrator Vehicle
TERLS	Thumba Equatorial Rocket Launching Station
TG	Temperature-Greenness
TMA	Trimethyl Aluminum Experiment
TSTO	Two-Stage-to-Orbit
TT&C	Telemetry & Commanding
TTC	Telemetry and Telecommand
TV	Television
TWRIS	Telangana Water Resources Information System
UAE	Ukraine, United Arab Emirates
UAY	Uchchatar Avishkar Yojana
UFA	Unfurlable Antenna
UFS	Urban Frame Survey
UK	United Kingdom
ULBs	Urban Local Bodies
UN	United Nations
UNISPACE	United Nations Conference on the Exploration and Peaceful Uses of Outer Space
UNNATI	Unispace Nanosatellite Assembly &Training
URSC	U R Rao Satellite Centre
USA	United States of America
USGS	United States Geological Survey
VEDAS	Visualization of Earth observation Data and Archival System
VHRS	Very High Resolution Satellite
VLSIs	Very Large Scale Integrated Circuits
VNIR	Very Near Infra Red
VSAT	Very Small Aperture Terminal
VSSC	Vikram Sarabhai Space Centre
VTM	Velocity Trimming Module


Location & Vehicle Tracking
Urban Planning
Weather Forcast
Flood Monitoring
Telemedicine
Tele-education
Potential Fishing Zones
Irrigation and Agriculture
Live Telecast
Telecommunication
Disaster Management