

भारत सरकार
अंतरिक्ष विभाग



GOVERNMENT OF INDIA
DEPARTMENT OF SPACE



वार्षिक रिपोर्ट
Annual Report
2019-2020



Citizens' Charter of Department of Space

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

- Indian National Satellite (INSAT) programme for telecommunication, television broadcasting, meteorology, developmental education, societal applications such as telemedicine, tele-education, tele-advisories and similar such services
- Indian Remote Sensing (IRS) satellite programme for the management of natural resources and various developmental projects across the country using space based imagery
- Indigenous capability for the design and development of satellite and associated technologies for communications, navigation, remote sensing and space sciences
- Design and development of launch vehicles for access to space and orbiting INSAT/ GSAT, IRS and IRNSS satellites and space science missions
- Research and development in space sciences and technologies as well as application programmes for national development

The Department Of Space is committed to:

- Carrying out research and development in satellite and launch vehicle technology with a goal to achieve total self reliance
- Provide national space infrastructure for telecommunications and broadcasting needs of the country
- Provide satellite services required for weather forecasting, monitoring, etc.
- Provide satellite imagery required for the natural resources survey, management of natural disasters, public good services and monitoring of environment in the country
- Provide satellite imagery and specific products and services required for the application of space science and technology for developmental purposes through Central Government, State Governments, Quasi Governmental Organisations, Non-Government Organisations (NGOs) and the private sectors
- Undertake proof of concept demonstration of space applications
- Promote research in space sciences and development of applications programmes as per national needs

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

- Provide the required satellite transponders and facilities to meet the communications, television broadcasting and security requirements of our country
- Provide adequate earth observation capability in various spectral, spatial and temporal domains
- Provide launch services to meet national requirements and commercial needs
- Provide its products and services in a prompt and efficient manner to all the users / clients



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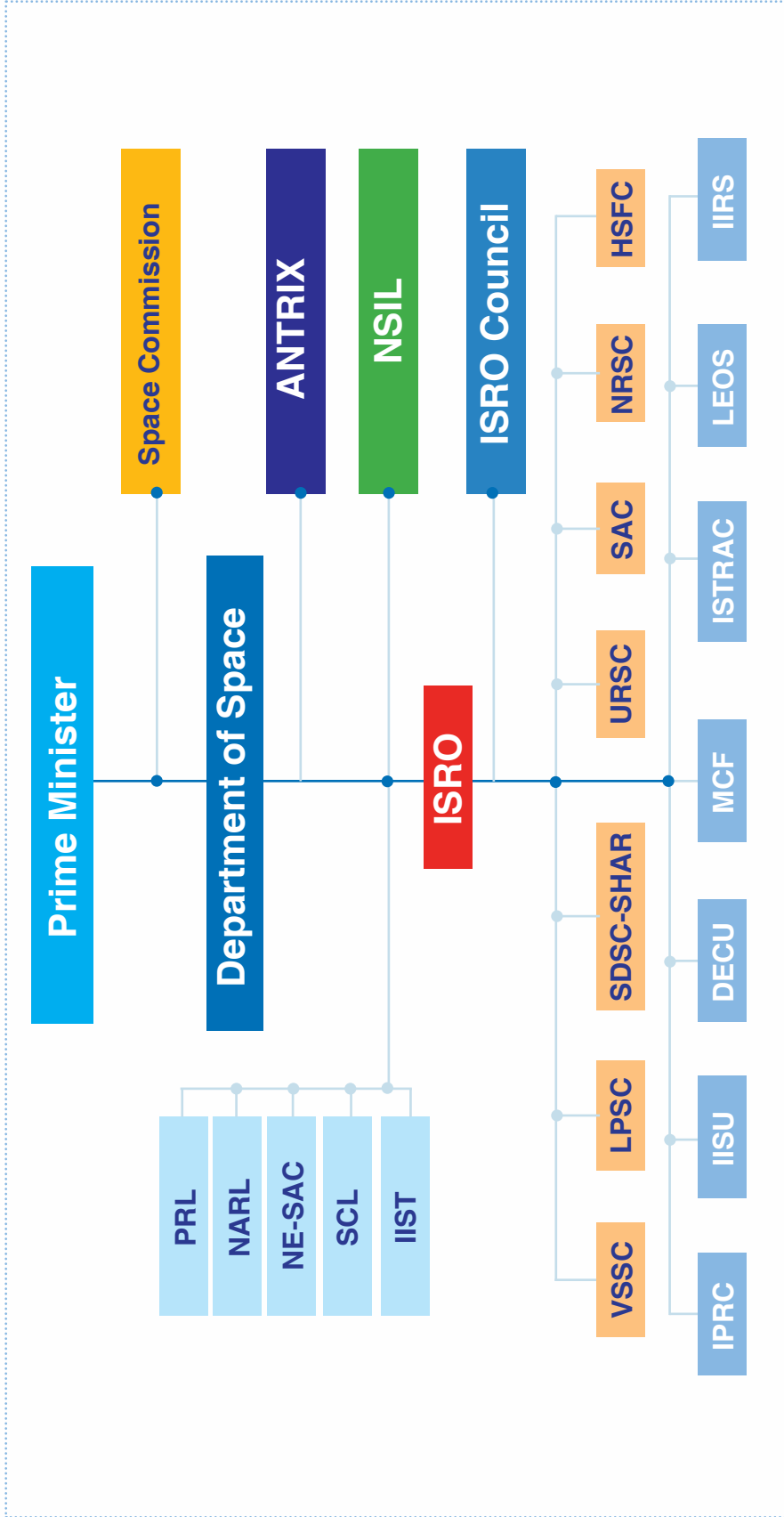
Space Missions (As per Financial Year)

Mission	2018-2019	2019-2020	2020-2021	2021-2022
EARTH OBSERVATION SATELLITES	2	4+2*	10	8
COMMUNICATION SATELLITES	4	1+1*	3	3
NAVIGATION SATELLITES	1	0	2	2
SPACE SCIENCE SATELLITES	0	1	3	0
TECHNOLOGY DEMONSTRATOR	1	0	1	0
PSLV	4	4+2*	10	8
GSLV Mk II	1	0+1*	3	6
GSLV Mk III	1	1	1	0
SMALL SATELLITE LAUNCH VEHICLE	0	0	2	2
GAGANYAAN	0	0	1 (Unmanned)	2
TOTAL	14	11+6*	36	31

* No. of missions expected to be achieved by March 2020



Organisation Chart



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 **NSIL:** NewSpace India 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 Centre
NRSC: National Remote Sensing Centre **HSFC:** Human Space Flight Centre **IPRC:** ISRO Propulsion Complex **IISU:** ISRO Inertial Systems Unit
DECUC: 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



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 Ltd., and NewSpace India Limited, Government owned companies are set up for commercialization of R&D activities of DOS/ISRO.

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).

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, space situational awareness, safety, media & public relations, budget and economic analysis, human resources 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 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 as a tribute to late Prof. U R Rao, who was the 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 the state-of-the-art facilities for fabrication and testing of mechanical and electronic hardware/subsystems and integrated satellite.



URSC Main Building

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 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 thermos 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 Second Vehicle Assembly Building (SVAB) inaugurated on July 14, 2019 is ready for integration of GSLV Mk-II, GSLV-MkIII and future missions. The main objectives of the SVAB are a) to meet increased launch frequency, b) to provide a 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 and cryogenic 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 and cryogenic 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, Valiamala 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.



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.

The communication transponders developed at this Centre for the Indian National Satellite (INSAT) and



Thaltej Campus, Ahmedabad



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 optical and microwave 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 operationalised 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.

Human Space Flight Centre (HSFC)

The Human Space Flight Centre (HSFC) has been established in ISRO in January, 2019 for implementing the vision of human space flight programme. HSFC is entrusted to implement the Gaganyaan programme and to act as the lead centre for the sustained and affordable human spaceflight activities starting with human space flight missions to LEO.



The Gaganyaan project has the objective of demonstrating human space flight capability to Low Earth orbit(LEO) with 3 crew members for 5-7 days in orbit and safely recover them after the mission.

HSFC will focus on the development of engineering systems related to the Orbiter module, development of human centric technologies, act as a hub for bio-astronautics related R&D, establish facilities for crew selection & training, develop state of the art crew life support systems, develop technologies for sustained human space flight activities including space habitat and robotic space exploration. HSFC will also play the role of a technology aggregator to bring together the national expertise in diverse disciplines for multi directional growth and capacity building in the domain of human space flight missions.



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 IMGEOSS for processing, product generation, archival and dissemination.

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.



ISRO Propulsion Complex (IPRC)

ISRO Propulsion Complex (IPRC), Mahendragiri is equipped with the state-of-the-art facilities necessary for realising the cutting edge propulsion technology products for Indian space programme. The centre is responsible for assembly, integration and testing of liquid and cryogenic 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 and cryogenic 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.

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 Byalalu 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 and tele-education.

Master Control Facility (MCF)

Master Control Facility (MCF) at Hassan in Karnataka and Bhopal in Madhya Pradesh monitors and controls all the Geostationary / Geosynchronous satellites of ISRO, namely, INSAT, GSAT 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.



Satellite Control Centre – MCF, Bhopal

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



IISU Main Building

Navigation Systems based on mechanical gyros and optical gyros, Attitude Reference Systems, Rate Gyro Packages, Accelerometer Packages are developed indigenously and used in various missions of ISRO. IISU also designs and develops Actuators and Mechanisms, namely, Reaction Wheel, Momentum Wheel, Solar Array Drive and Scan Mechanisms for spacecraft and allied applications. Presently, IISU is engaged in the process of consolidation and productionisation of the Sensors, Systems, Actuators and Mechanisms for a variety of launch vehicle and spacecraft applications.

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

Laboratory for Electro-Optics Systems (LEOS)

The Laboratory for Electro-Optics Systems (LEOS), Bengaluru is responsible for the 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

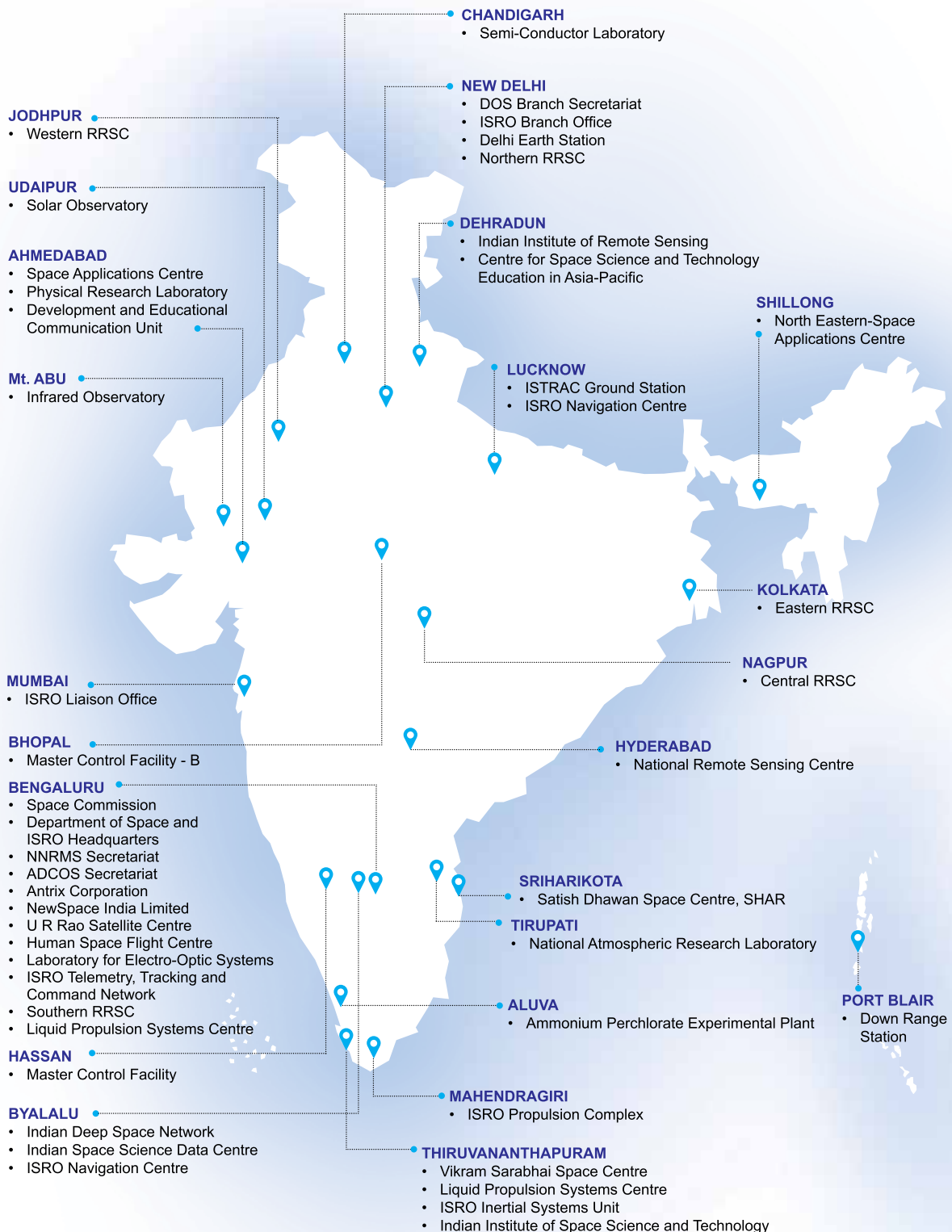


LEOS Main Building

filter, optical masks, optical coatings, Infrared detectors and MEMS based inclinometer. Research & development program by LEOS includes development of miniature sensors, high accuracy Active Pixel Sensor, Miniature star tracker, Vision Sensors, Detectors, MEMS devices, Segmented Mirror Telescope optics and advanced optics for future spacecraft use.



Space Centres in India





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



Indian Institute of Remote Sensing Main Building

in Asia and the Pacific (CSSTE-AP), affiliated to the United Nations. The training and education programmes of the Institute are designed to meet the requirements of various target/user groups, i.e., for professionals at working, middle and supervisory levels, fresh graduates, researchers, academia, and decision makers. The duration of courses ranges from one week to two years.

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.

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 to cater to the scientific needs of the middle atmospheric research community, NARL has now grown into a premier national laboratory carrying out frontline research. It 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)

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



Aerial View of NE-SAC

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 and ISRO Geo-sphere Biosphere Programme.

The Centre has provided more than 17 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-



IIST Campus

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.

Antrix Corporation Limited (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.

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.

NewSpace India Limited (NSIL)

NSIL, the commercial arm of Indian Space Research Organisation, has the primary mandate of enabling Indian Industries to scale up high-technology manufacturing and production base for Indian space programme. NewSpace India Limited, got incorporated on 6th March 2019, as a wholly owned Government of India Undertaking / Central Public Sector Enterprise, under the administrative control of Department of Space.

Major business areas of NSIL involves activities related to (i) Small Satellite technology transfer to industry wherein NSIL will obtain license from DOS/ISRO and sub-license it to industries; (ii) Manufacture of Small Satellite Launch Vehicle in collaboration with Private Sector; (iii) Productionisation of Polar Satellite Launch Vehicle through Indian Industry; (iv) Productionisation and marketing of Space based services, including launch and application; (v) Transfer of technology developed by ISRO Centres and constituent institutions of DOS; and (vi) Marketing of spin-off technologies and products, both in India and abroad.



2. Major Activities

2.1 Earth Observation and Meteorological Satellite System

2.1.1 Program

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. Various instruments onboard IRS 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.

Earth Observation Satellites in Service

Cartosat-2, launched on January 10, 2007 onboard PSLV-C7, carries a single panchromatic camera with the capability to provide better than 1m spatial resolution imagery with 9.6 km swath. It was placed in a Sun synchronous polar orbit at a nominal altitude of 630 km with a re-visit of 4-5 days. The satellite can be steered along and across the track of up to ± 45 degree to facilitate frequent imaging of any specific area. The satellite has served beyond the designed mission life. Presently, this satellite is being de-orbited from existing orbit to 404 km x 638 km orbit.

Cartosat-2A, launched on April 28, 2008 onboard PSLV-C9, carries a single panchromatic camera with the capability to provide better than 1m 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 band Ocean Colour Monitor provides data at 360 m spatial resolution of



1420 km swath with two-day repetivity. The data is used to generate Local Area Coverage (LAC) product of 360m resolution (2-day coverage cycle) and Global Area Coverage (GAC) product of 1 km resolution (8-day coverage cycle). The Ku-band pencil beam Scatterometer 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 degree 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 degree 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. From July 4, 2016 SARAL entered a new phase called SARAL-DP (Drifting Phase).

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, PSLV-C38 & PSLV-C40 respectively. These satellites are similar to the earlier Cartosat-2, 2A and 2B. The Cartosat-2 series satellites are placed in orbit in phased manner. The imageries from Cartosat-2 series satellites are useful for cartographic applications, urban and rural applications, infrastructure planning, coastal land use and regulation, utility management like road network monitoring, water grids for 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 degree 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 was 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. The Scatterometer data is being disseminated to global user community for deriving the global wind velocity (magnitude and direction) over ocean surface, which is used as an input for weather forecasting, monitoring of cyclones & their trajectory and ocean state forecasting.

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-1: 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 can be fabricated and tested independently of payload. This satellite has completed its mission life.

HysIS: Hyper Spectral Imaging Satellite, HysIS weighing 380 kg was successfully launched by 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 a 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.

EMISAT: EMISAT is a user defined satellite jointly developed with the user. The spacecraft is built around the Augmented IMS – II Bus capable of generating 965W and is planned with a mission life of 5 years. EMISAT was successfully launched onboard PSLV-C45 on April 1, 2019.

RISAT-2B: RISAT-2B was successfully realised and launched onboard PSLV-C46 on May 22, 2019. The primary objective of the mission is 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 satellite was realised with new technologies to provide continuity of services to RISAT-2 in a fast track mode. The spacecraft was built around a new Hexagonal structure with separate payload module with a mass of 620 Kg generating 1.3 kw of power for a mission life of 5 years. It carries an X Band SAR with a Payload Radial Rib Reflector 3.6 m mesh antenna for Spot, Strip & Mozaic modes of imaging. The spacecraft was placed at an altitude of 555 km.

CARTOSAT-3: CARTOSAT-3 was successfully launched onboard PSLV-C47 on November 27, 2019. It is a third generation agile advanced satellite, having very high resolution imaging capability, to obtain imageries with spatial resolutions of 0.28 m in Panchromatic, 1m in 4 band multi spectral and intended for advanced Cartographic Applications with an operational life of 5 years. A series of 3 satellites are being planned with similar configuration for cartographic application. The spacecraft is built around hexagonal structure and weighing around @ 1616 Kg generating 1850W of power. The satellite was placed at an altitude of 509 km.

RISAT-2BR1: RISAT-2BR1 is a synthetic-aperture radar (SAR) imaging satellite for reconnaissance built by Indian Space Research Organisation (ISRO). It is part of India's RISAT series of SAR imaging spacecraft and fourth satellite in the series.

RISAT-2BR1, a follow on mission to RISAT-2B, provides continuity in X band SAR services. The configuration of RISAT-2B-R is similar to RISAT-2B. It was launched by PSLV-C48 into an 576 km Low earth orbit on December 11, 2019.



Meteorological Satellites in Service

INSAT-3D, an advanced weather satellite, was launched on July 26, 2013 and positioned at the orbital slot of 82 degree 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 the 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 F05 launch vehicle and positioned at the orbital slot of 74 degree East longitude in the geostationary orbit. It is the 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 payloads.

Future Earth Observation Missions

India's future Earth Observation (EO) programme will ensure 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:

GISAT-1: GISAT-1 is a Geo Imaging Satellite in Geostationary orbit with a high temporal resolution. It has a Multispectral Imager operating in the Visible, Near Infra-Red and Hyper Spectral Imager operating in the 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, multi spectral and hyper spectral imaging - all on a single, agile, jitter free platform.

RISAT-2BR2: RISAT-2BR2 is a third spacecraft in the series of RISAT-2B and RISAT-2BR1 proposed to be launched as a constellation of three spacecraft with 120° phasing to increase the frequency of observation on the areas of interest to provide all weather, day/night imaging services from space. RISAT-2BR2 is a high agility X-Band Synthetic Aperture Radar based satellite. The satellite will offer a multimode of operations with high spatial resolution and is configured with indigenously developed state of the art technologies. RISAT-2BR2 will be placed in the orbit using the PSLV launch vehicle.



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. A Sea Surface Temperature monitor (SSTM-1) with 2 long wave infrared (LWIR) bands with a sensitivity >150 mK and an ARGOS-4 of CNES under international co-operation. Oceansat-3A is planned as a follow on to Oceansat-3

RISAT-1A: RISAT-1A is a repeat Satellite of RISAT-1 and is configured to ensure continuity of Synthetic Aperture Radar in C-Band providing Microwave data to the user community for operational services. The satellite has the capability to operate in day, night and all weather conditions with a Mission life of 5 years and provides imaging data for various applications related to Land, Water and environment which is required for Agriculture, Forestry and Water resource management. RISAT-1B is also planned as a follow on mission to RISAT-1A.

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 3.8 kW. Payload provides imaging capability for strategic applications in spot, strip and mosaic modes. Electronic scanning in both azimuth and elevation direction is employed.

HRSAT: HRSAT is being realised as a constellation of three satellites. All three satellites will be launched together in a single PSLV mission. These three satellites will be suitably placed in the orbit to provide systematic coverage of high resolution panchromatic and multispectral data and with frequent revisit of Area of Interest. They will carry Panchromatic Camera providing images with better than 1.0 m resolution with 15 km swath. Multispectral Camera is providing 4 m resolution with 15 km swath and LWIR sensor is providing 20 m resolution with 6 km swath. The constellation is meant for applications like large scale and cadastral level mapping, urban and rural planning, infrastructure development & monitoring, precision agriculture, irrigation planning and monitoring and to provide spatial information support for disaster management.

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. With this satellite 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.



The spacecraft is built around I-1K Bus (MPL + PPL, modular) capable of generating around 3200 W of power. The spacecraft carries advanced LISS-III providing data continuity for LISS-III in VNIR & SWIR bands.

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

NISAR: This mission is being 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.

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.

Microsat-2A: The satellite is being realised based on Microsat-TD to demonstrate launch on demand capability with SSLV. It is expected to meet the ever-increasing user demands for cartographic applications at cadastral level, urban and rural management, coastal land use and regulation, utilities mapping, development and various other GIS applications. The satellite carries two payloads, MWIR & LWIR, with 6m resolution. The mass of the spacecraft is 142 kg and it will be placed at an altitude of 350 km. The mission life of the satellite is 10 months.

2.1.2 Application

Satellite Data Reception

IMGEOS: The “Integrated Multi-Mission Ground Segment for Earth Observation Satellites (IMGEOS)” established at Shadnagar during 12th FYP delivers emergency products in one hour and standard products in 24 hours. Remote Sensing Data from Indian and foreign missions are acquired through four 7.5 meter S/X band antennae. NRSC Shadnagar ground station acquires data from various 16 Indian Remote-Sensing satellites such as RISAT-2B, Cartosat-2 Series (2C, 2D, 2E & 2F), HySIS, Resourcesat-2A, Resourcesat-2, Cartosat-1, Cartosat-2, Oceansat-2, Cartosat-2A/2B, Resourcesat-1, SCATSAT and SARAL through four 7.5-meter S/X band antenna terminals. Remote Sensing Data from 9 foreign satellites JPSS-1, AQUA, TERRA, LANDSAT-7& 8, S-NPP, NOAA-19 & METOP-A/B satellites is also being received for remote sensing applications including ocean, atmosphere & climate and forestry studies.

AGEOS: “Antarctica Ground Station for Earth Observation Satellites (AGEOS)” facility was established by ISRO during 2012-13 at Bharati (Research base of NCAOR), Antarctica. DRS-1 in S/X band and DRS-2 with S/X/Ka band Antenna systems are being used for data downloading from the ongoing missions. The data received from various Remote Sensing Satellites is transferred through high speed Communication link to NRSC in near real time.

SVALBARD and TROMSO Stations: Payload data dumped for 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.

New Ground Stations Establishment

Four 9.1m Ku Band (for GISAT) Antennas are established at, Shadnagar, Delhi and Ahmedabad. Further a 7.5 m S/X band Data Reception Terminal is installed in Jodhpur and integrated with IMGEOS facility at Shadnagar to support the data reception from all IRS and Non-IRS missions. Establishment of four 7.3m S/Ka Band Data Reception Systems and a Tri-axis 7.5m X/S Antenna are also progressing.

Data Processing, Products, Archival and Web Applications

Data products were generated using standard product and interactive product generation chain as well as from archives based on user demand. Geometric and Radiometric performance for on-going optical remote sensing missions was periodically assessed through Data product quality evaluation of the respective missions. Resolution based GCP is designed for CARTOSAT3 PAN GSD (0.28m) to find out the absolute accuracy without any ambiguities.

CartoDEM: Generation of 5m CartoDEM for Indian region is initiated. Focus is put on using so far unused satellite stereo data. Global CartoDEM(10 m) of Australia is generated using all cloud-free stereo data of Cartosat-1 over Australia.



Satellite Data Dissemination: The major projects/agencies that were supported during the period include IWMP, Natural Resources Census, Crop production estimation, Crop Insurance, SUFALAM, SARITA, Agricultural drought, ADE, NIC, HRSAC, SASE, GEMI, State requirements (Karnataka, Kerala & Uttarakhand, Orissa), ISM, all IITs, etc. National user projects were also supported with the special / value added products viz. NDVI Full India Mosaics, Ortho-rectified Natural Colour Composites, fused products, City mosaics etc., Academic Institutes were provided satellite images for research and outreach. Besides, Foreign high resolution data based on user demand were also disseminated.

Processing and dissemination of SCATSAT-1 data products and forest fire detections (using S-NPP, JPSS-1 & MODIS data sets) are carried out in Near Real Time.

Web Download: Satellite data coarser than 23m resolution was made available as free downloads since September 2011 on 'NRSC Open Earth Observation Data Archive' (NOEDA) portal and Oceansat-2 data was made available to users for download through Oceansat-2 portal from December 2010. In this period, more than 2.75 lakh products were downloaded by users through Oceansat-2 and Bhuvan-NOEDA portals.

Bhuvan

Bhuvan [<http://bhuvan.nrsc.gov.in>] is ISRO's Geoportal providing visualization services and Earth observation data to users in public domain. It is the Gateway to Indian EO Data Products & Services. During the year, Bhuvan provided 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.

Bhuvan Web Services:

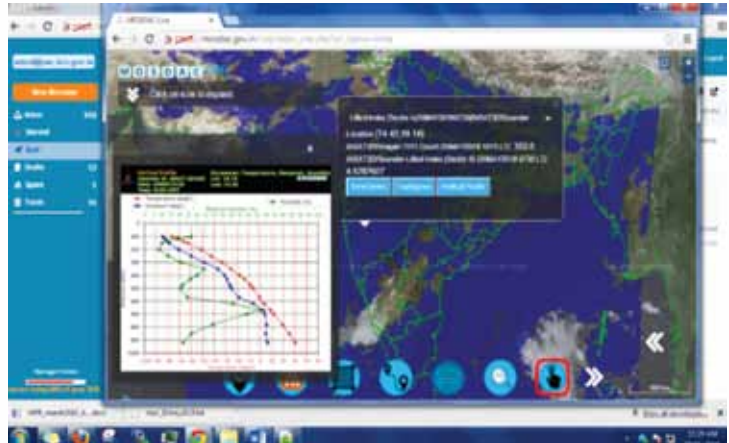
- New Applications: Applications have been developed and implemented for Forest Departments of Telangana, Punjab. Geospatial support for Jal Shakti Abhiyan (JSA), MGNREGA, PMAY, PMKSY, RKVY, IWMP, NABARD, Anganwadi, ASI, NUIS, RGNDWM, NCERT etc. and State Level development & support for APShCL, TWRIS, CDMA, HARPATH, WALAMTARI, State Portals etc. are also implemented



- Vector/Thematic data publication: Nearly 9250 vector products were uploaded onto Bhuvan
- High Resolution data update: Bhuvan Base Satellite layer is updated with High Resolution

satellite image mosaic of Year 2017(HR2017) and 2018, which are being used as base satellite layer for various applications by users

MOSDAC: Location based dissemination (low bandwidth; e-mail based) of Ocean State Forecast has been developed and operationalized. Total 81 ships of Shipping Corporation of India (SCI) have registered and 17 ships have started using this forecast.



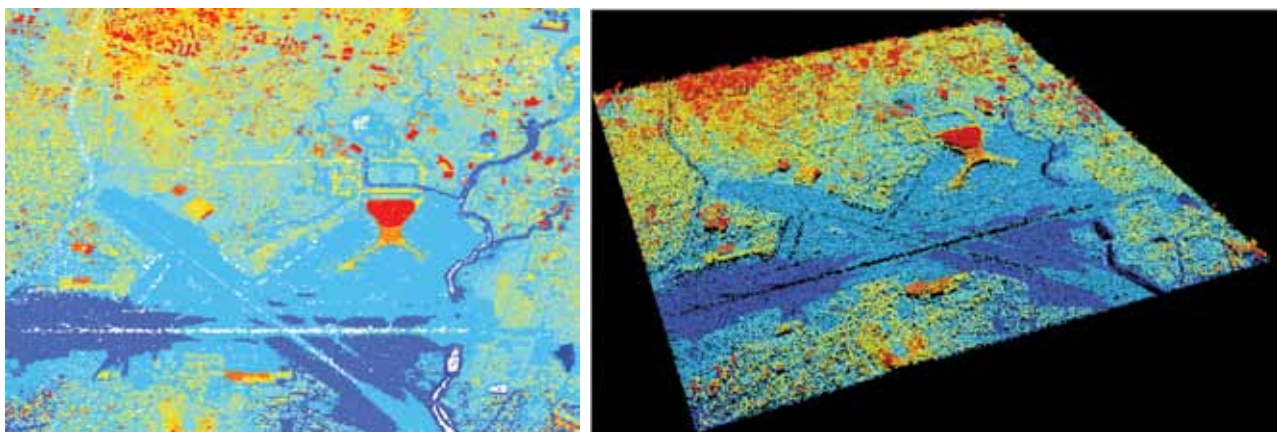
MOSDAC LIVE: Visualisation of vertical profile (Temperature, Dew point, Humidity) of INSAT-3D Sounder operationalized.

Aerial Services and Digital Mapping

The Aerial Services and Digital Mapping area of NRSC is a unique facility with end-to-end capability and state-of-the-art infrastructure for Aerial Remote Sensing that comprises data acquisition of high resolution data (up to 5cm GSD), ground survey, photogrammetric processing, generation of high resolution digital elevation model with vertical accuracy of 20cm, fine contours of 0.4m and large Scale Mapping up to 1:500 scale.

NRSC owns and operates two Beech craft super King Air B200 aircraft, which were procured in the year 1988 and 1997 with call signs VT-EQK and VT-EBB respectively. These aircraft are being operated in line with the regulatory framework of DGCA, Ministry of Defence (MoD) and Airport Authority of India (AAI).

Geodatabase generation using Airborne Laser Scanner & Digital Camera (ALS-DC): Aerial data



Satellite derived snow products for snowmelt runoff estimation

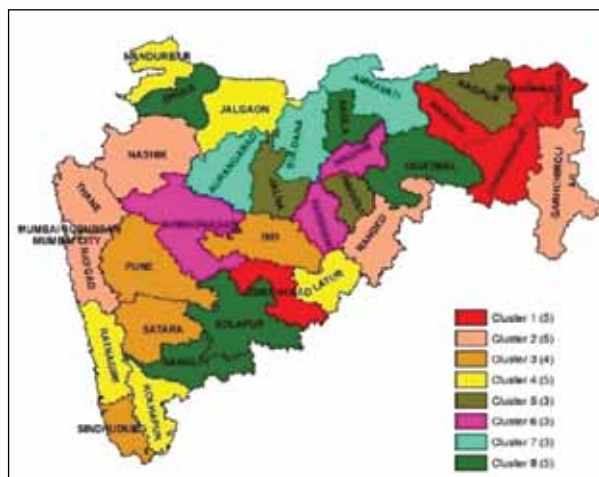


acquisition, geospatial database generation and extraction of building heights are done from for the coastal zone from Sundarbans to Cochin, and is under progress for the coastal zone of Cochin to Gujarat.

Remote Sensing Applications

Risk information product for crop insurance

pricing: For Crop Insurance studies, Agriculture Risk Index (ARI) were developed for different districts of Maharashtra using multiple risks such as drought, weather, crop-management & insurance history. These clusters have been adopted by Maharashtra for insurance rate making in kharif 2019, thus setting a model for technology utilisation in the pricing segment of crop insurance value chain.



Risk based clusters for crop insurance pricing developed by NRSC and adopted by Maharashtra state in kharif 2019

Smart sampling for crop yield estimation

in crop insurance: Smart sampling aims at improving the crop yield estimates by adopting objective methods of plot selection for crop

yield measurement. Under the crop insurance project of Odisha state, Smart sampling technique developed by NRSC/ ISRO was implemented successfully for paddy crop in the kharif season of 2018 and continued in the rabi season during April 2019.

Standard Operating Procedure (SOP) for rolling out of smart sampling and optimization of CCEs for Kharif rice crop 2019-2020 in 10 states has been formalized between MNCFC and SAC/ ISRO.

Crop Intensification (National Food Security Mission): Mapping and monitoring of post-kharif rice fallow lands using satellite remote sensing and GIS technologies for rabi crop area expansion has been completed for six eastern states of India viz., Assam, Bihar, Chhattisgarh, Jharkhand, Odisha and West Bengal. Suitability analysis of these post kharif rice fallows reveals that about 46% of these fallow lands are suitable for growing short duration pulses/oil seeds in the following rabi season.

Crop Acreage Estimation: First cycle of analysis for district and state-level area estimation of four new crops such as Soybean, Castor, Cumin, Rabi-Summer Groundnut covering more than 50 districts spread over 8 states have been completed.

Satellite-based production estimation of crushable sugarcane: carried out in six (6) mill command areas. The satellite-based model estimates were found to show errors within 8% of reported estimates at mill-level for well-organized mill adopting GPS-based field boundary markings.

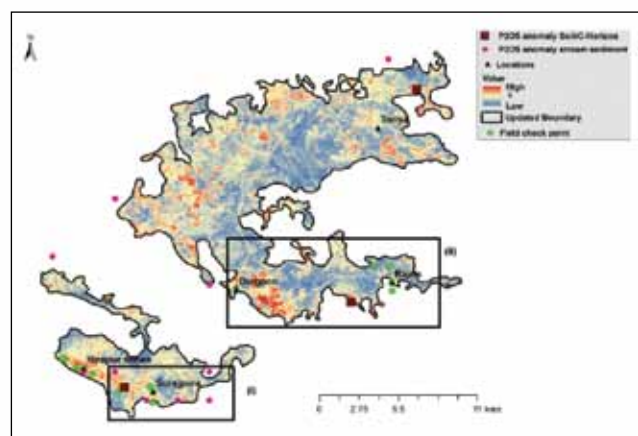
The pilot project report was submitted to Directorate of Sugar, DoFPD, New Delhi who reviewed and suggested for presentation at higher-level for framework of institutionalization and national-scale implementation by sugar mill cooperatives

Sericulture Development: The second phase of the national level project on Applications of RS and GIS for Sericulture Development has been completed and the Project Atlas was released by Member Secretary, Central Silk Board in August, 2019

Automated Detection of Annual Forest Loss Locations: A pixel based method using annual time series data, which is capable of detecting finer changes and not sensitive to phenological changes. Time series of Green Season imagery (OCT - DEC) the years 2011-2018 of IRS - AWiFS satellite data at annual scale was used for change detection. Validation is done for the detected change locations using high resolution corroborative satellite data and Ground validation as well. Android mobile application has been developed by NRSC for collection of field attributes for field verification and feedback mechanism for the improvement of the algorithm.

Biodiversity Characterization at Community level in India using Earth Observation Data: Department of Biotechnology (DBT) - Department of Space (DOS) have jointly initiated a project on “Biodiversity Characterisation at Community level in India using Earth Observation Data” with a multi-institutional participation for (i) Assessment of decadal changes to the regional forest landscape using satellite remote sensing data (ii) Spatial characterization of vegetation communities using multi sensor, multi scale Earth Observation data and field studies (iii) Identifying Earth observation variables that are relevant to monitoring biodiversity and (iv) generation of web based data repository and information system through integration of Bhuvan with IBIN and Biodiversity Information System

Ground Water Quality: Habitation wise groundwater quality database, consisting of seasonal observations of 12 essential geo-genic elements (e.g. Arsenic Fluoride, Nitrate, Sulphate, Chloride, Hardness, Total Dissolve Solids, Alkalinity, Calcium, and Magnesium & Iron) has been prepared for the entire country (except Bihar & Sikkim) with 7.2 lakh observations. Following BIS 2015 ground water quality standard, seamless state mosaic of integrated ground water quality database/maps for the country has also being prepared as a value-added product using geo-statistical approach.



Phosphate anomaly map draped with geochemical anomaly data showing high P₂O₅ values in Chhatarpur area

Village Level Ground Water Potential Mapping: The infrequent monsoonal activity

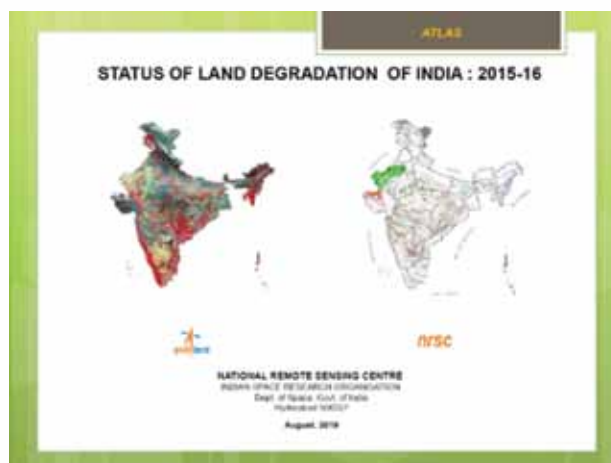


and ever growing demand and uncontrolled exploitation of ground water have led to serious scarcity in many parts of the country. A systematic database on ground water controlling factors on 1:10,000 scale is required to understand recharging of ground water aquifers for sustainability measures. On a pilot scale, NRSC/ ISRO initiated the preparation of village level Ground Water Potential (GWP) maps on 1: 10,000 scale through integration of very high resolution EO data and field based inventory for draught affected villages in various parts of Karnataka, Kerala, Tamil Nadu, Telangana, Andhra Pradesh, Odisha & Madhya Pradesh, Nagaland states.

Rock Phosphate Mapping: A collaborative project for Rock phosphate exploration is being carried out with Geological Survey of India (GSI) and Atomic Mineral Directorate and Exploration and Research for delineating surface exposures of rock phosphate in different parts India. The project is funded by Department of Fertilizer, Government of India.

Planning and monitoring of Geo-MGNREGA activities: A planning portal named GeoPRIME (Geospatial Planning Portal for Ridge to Valley Interventions under MGNREGA) has been implemented for user community of Rural Development functionaries. The portal is under testing by Ministry and aims to develop geospatially explicit plans for taking up future MGNREGA activities, based on the principles of land use and land cover alternatives with respect to accessibility, terrain, hydrology as well as the existing asset spread of completed asset spread for both MGNREGA and Integrated Watershed Management Programme interventions.

Mapping of Land Degradation (1:50,000 SCALE; 2015-16): Nearly 900 LISS-III images were used for generating Land Degradation database, for 4525 effective SOI equivalent map sheets on 1:50,000 scale. The maps were finalized with adequate ground truth and soil analytical results of nearly 2900 soil samples collected exclusively under this project. The land degradation mapping addresses 8 major processes and 36 land degradation classes. An atlas has been brought out with State level compilation of current status of land degradation (2015-16).



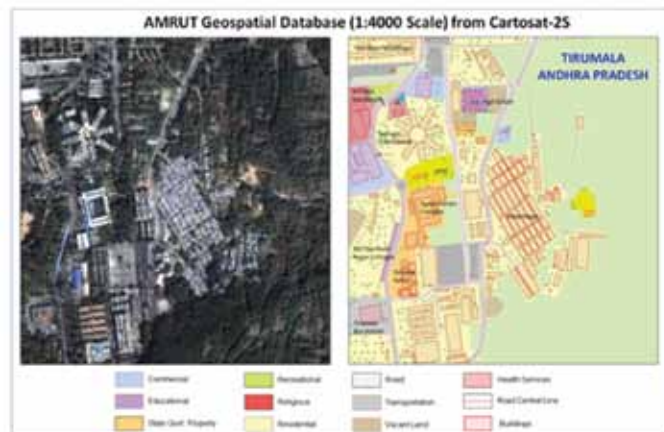
Annual Assessment of National Land Use Land Cover Using Multi-Temporal AWiFS Data: A “snap-shot” of the country’s status of natural resources is realized with the AWiFS National Land Use and Land Cover mapping project. The Land Use and Land Cover maps have a total of 18 classes addressing built-up, kharif, rabi and zaid crops, forest classes, waste lands and water bodies as well as snow. The mapping is done annually using multi-temporal AWiFS data with 56-meter resolution, since 2004. Total 14 cycles of assessment from 2004-05 to 2017-18 have

been completed and are made available through Bhuvan portal of NRSC. 15th cycle (2018-19) LULC assessment is nearing completion.

Use of Geo-informatics in Rural Roads Project (under PMGSY): Pradhan Mantri Gram Sadak Yojana (PMGSY), was launched by Govt. of India to provide connectivity to unconnected habitations as a part of poverty reduction strategy. National Remote Sensing Centre (NRSC) and National Institute of Rural Development (NIRD) are jointly working to produce geospatial datasets, connectivity status and road-lengths (as per the inputs provided by National Rural Road Development Agency) of rural roads for the entire India.

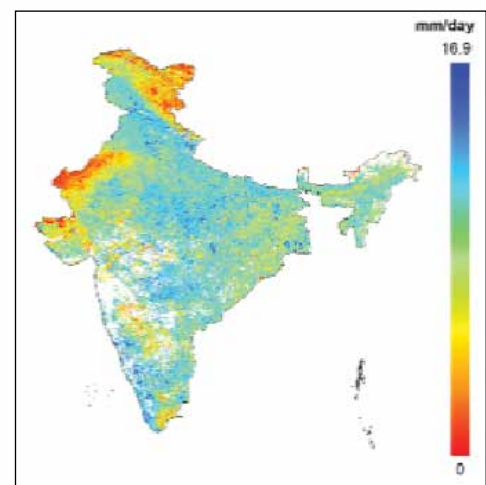
Large Scale Urban GIS Database creation for AMRUT Cities:

NRSC is carrying out Large scale (1:4,000 scale) Urban GIS database creation from Very High Resolution Satellite (VHRS) data for formulation of GIS based Master Plans, for 242 AMRUT cities. GIS base maps of about 105 cities is prepared and provided to the respective Urban Local Bodies (ULBs) for ground verification, attribute data collection and formulation of GIS based Master Plans. NRSC has brought out a document explaining the process of field verification and attribute data collection for the benefit of ULBs. A Training of Trainers (ToT) to the officials of TCPO, Ministry of Housing & Urban Affairs (MoHUA) has also been organised.



Geospatial Components under National Hydrology Project (NHP): (i) Actual Evapotranspiration:

Modified Priestley Taylor algorithm is implemented for estimation of daily actual evapotranspiration (AET) using Net Radiation, soil heat flux and surface condition indicator estimated from satellite data. (ii) Hydrological Drought Assessment: Composite hydrological drought index is derived to characterize the hydrological drought. (iii) Spatial snowmelt runoff: Satellite observations (snow cover extent, snow albedo, AOD, Water vapour, Ozone, LST, cloud cover, etc.) are used for estimation of energy exchange at snow surface and snow melt rates. (iv) Glacial Lake Outburst Flood (GLOF) Risk Assessment: Glacial lakes and water bodies of size >0.25ha are mapped using Resourcesat-2 LISS-IV data (2016-17) for the Himalayan region of Indian



AET product for first fortnight of September 2019



river basins. Lake attributes generation including downstream infrastructure and other associated terrain parameters are extracted for ranking and GLOF risk simulation.

National Health Resources Repository: National Health Resource Repository (NHRR) is a joint project of Central Bureau of Health Intelligence (CBHI) and National Remote Sensing Centre, Indian Space Research Organization (ISRO). Development of android based mobile (tablet) application for collection of healthcare resources assets details (operational phase) with 4000 attributes, Development of web analytics modules and Continuous support for operational phase of data collection are the highlights.

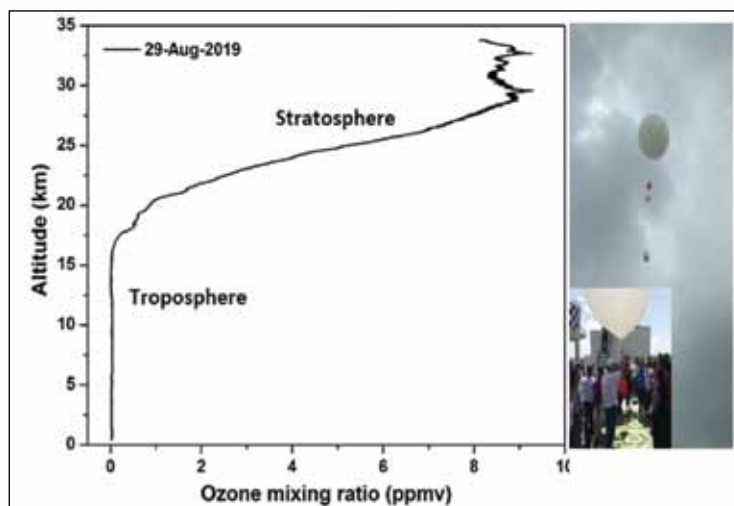
Automation Software for SWAT Model: The automation of the model mainly involves the preparation of these inputs for the SWAT run by aggregating basin-wise parameters from the weather products on a day-to-day basis. The model executions for different river basins covering over 1,00,000 grid points across India are parallelised for efficient processing. The model outputs are finally extracted and processed to generate daily spatial products.

Application of Space Technology in Wind and Solar Energies Forecasting: Methodology is developed for day-ahead forecast of surface reaching solar radiation for cloud-free conditions by incorporating near real time satellite derived aerosol data and AWiFS derived LU/LC data into WRF-Solar model.

Trends of Black Carbon aerosols over India: Long term trends of surface level and columnar loading of Black Carbon (BC) aerosols were estimated over India. Monthly MERRA-2 aerosol reanalysis products, at a latitude \times longitude resolution of $0.5^\circ \times 0.625^\circ$, for a period of 39 years from 1980 to 2018 were used for the analysis.

Fog Optical Depth (FOD) using INSAT-3D: Retrieval & Validation: A methodology was developed for estimation of optical thickness of fog, which is a proxy for visibility. FOD is retrieved, after identifying the fog covered pixels, by means of an inverse method, which makes use of look-up tables for cloud/fog-reflected radiance at visible wavelength that are prepared by radiative transfer calculations as a function of zenith angle.

New initiative on Ozone profile monitoring: The Ozone Balloon launching experiment network is initiated under NICES program and executed from Kerala (Ponmudi), Mojerla (Telangana), Nagpur and Jodhpur, for studying spatio-temporal



distribution of Ozone concentration in atmosphere, and to build Long-term data base for use in validating the satellite derived tropospheric ozone and other meteorological parameters for the Indian region.

Seasonal variability of surface layer atmosphere CO₂ over the Indian region: Seasonal variability of the surface layer atmosphere CO₂ over the Indian region was studied based on Goddard Earth Observation System Chemical transport model solution and the Greenhouse gas satellite and in situ measurements of 2009-2015. Annual and semi-annual harmonics and the climatological mean of CO₂ tendencies were estimated from the model solutions and satellite observations. Both datasets coherently show large positive tendency (> 0.5 ppmv yr⁻¹) for the climatological mean over the Indian peninsula and other nations located on the similar latitudinal belts and small positive or negative tendency (< 0.3ppmv yr⁻¹) over the oceanic regions.

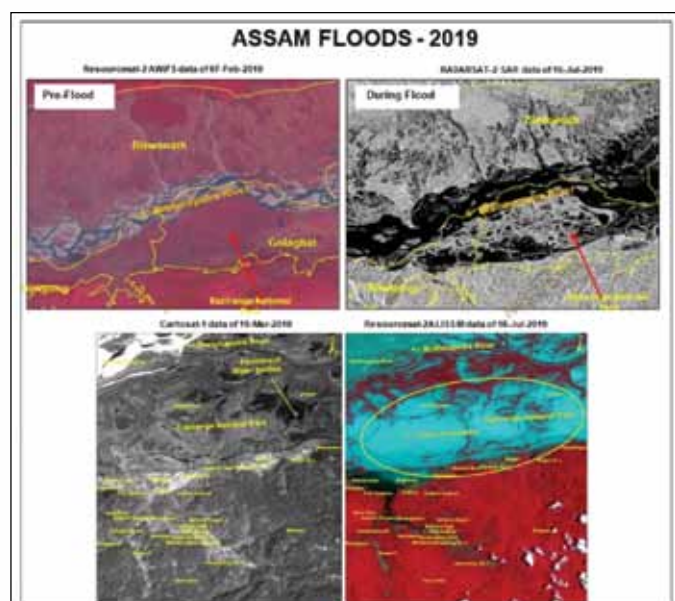
Air Quality Monitoring & Forecast System: Synergistic use of numerical prediction models for the forecasting of dust, particulate matter (PM 2.5 and PM 10) and gaseous pollutants (CO, O₃, SO₂, NO_x), using ground based inputs and remote sensing data sets of aerosol optical depth (AOD) and particulate matter (PM 2.5 and PM 10) towards monitoring air quality of Indian region has been carried out. A Geoportal is developed (<https://airquality.iirs.gov.in/>) and to disseminate model generated forecast fields and satellite based inputs for the monitoring and analysis of air quality over Indian sub-continent.

Mass Induced Sea level variability in the Tropical Indian Ocean: Assessment of Mass Induced Sea Level (MISL) variability in the Tropical Indian Ocean (TIO) is carried out based on the observations from Gravity Recovery and Climate Experiment (GRACE) data and Residual of the steric corrected altimeter measured Sea Level Anomaly (RSLA) data of 2003-2015. The MISL is a significant contributor to the sea level variability at intra-seasonal and seasonal time scales and a minor contributor to the sea level inter-annual variability.

Disaster Management Support Activities

Floods and Cyclones

During 2019, India experienced major floods spread across the states namely Assam, Bihar, Maharashtra, Odisha, Uttar Pradesh, Kerala, Delhi, Karnataka, Punjab, Haryana, Gujarat, Andhra Pradesh, West Bengal, and Madhya Pradesh. The floods were monitored and mapped using IRS Series satellites (Optical), Radarsat-2 SAR and Sentinel Series of satellite datasets on a





regular basis and inundation maps at State and District level were generated and disseminated to State/Central Governments. All the major flood affected states were monitored using satellite based analysis and about 256 flood maps & value added products in 14 states (39 lakh ha) were disseminated to the concerned departments. 350 officers are trained through 14 DMS training programmes.

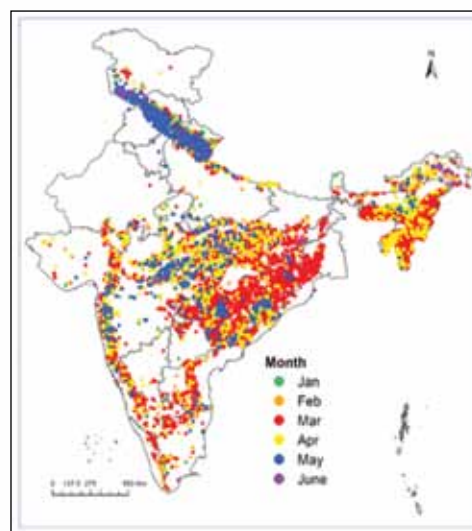
Due to the extent of damage reported in the Assam State due to flooding and also in Odisha due to Cyclone FANI, International Charter and Sentinel Asia were activated and more than 350 satellite datasets were provided. Nearly 60 value added products were generated and disseminated to concerned users.

Data dissemination to International Charter & Sentinel-Asia: Under International Charter, 8 Charter requests were serviced towards Emergency & Disaster Management support for the disaster events occurred during the year. Also, 15 requests were serviced under Sentinel-Asia cooperation for emergencies. During the period, 100% requests were serviced for International Charter and Sentinel Asia.

Flood Hazard Atlas Preparation: Flood Hazard Atlases of Odisha was prepared and released by the Honourable Chief Minister of Odisha in June 2019. Preparation of Flood Hazard Atlases of Andhra Pradesh, West Bengal, Uttar Pradesh and updation of Bihar Atlas are taken up on top priority.

Active forest fire detection using satellite data – 2019

Fire Season: Near real time active Forest Fire monitoring (Feb-Jun every year), Burnt Area assessment, Fire burnt area progression monitoring and Ecological damage assessment due to forest fires are carried out. Forest Survey of India, Dehra Dun (FSI) is the primary user of the fire alert system (dissemination in near real time by email). Additionally, fire alerts are published on Bhuvan and sent as SMS to few State Forest Departments (AP, Telangana, MP, Maharashtra, and HP and the facility is being extended to Punjab and Tamil Nadu). As part of Fire monitoring activity.



National Database for Emergency Management (NDEM) Services

Daily disaster alerts/warnings with products such as daily meteorological data, cloud movement, near real time lightening data, thunder storm warnings, flood warnings, sea state forecast, heat wave / cold wave prediction, city weather forecast, forest fire locations and earthquake events have been disseminated through NDEM disaster dashboard. So far 950 products have been disseminated through NDEM Version 3.0.



2.2. Communication Satellite Systems

2.2.1 Satellite Communication Programme

Communication satellites have been contributing significantly in the socio-economic and strategic activities in the country. At present, there are 18 satellites in operation. Of these, 3 are for strategic users, 1 for international cooperation, 3 are new generation high throughput satellites (HTS) and the remaining 11 are for commercial and societal applications. The details of the operational satellites are briefed in the following sections.

SATELLITES IN SERVICE

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.

GSAT-8

GSAT-8 is a 3000 Kg class (I-3K) communication satellite launched in May 2011. It 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 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 launched in September 2012, Weighing 3400 kg at lift-off, carries payload in normal C-band, Extended C-band and Ku-band as well as a GAGAN payload operating in L1 and L5 bands.

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 bus. 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 on December 06, 2014.

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. It provides communication through S-band payload with five spot beams covering whole India for user links and C-band beam for hub links. It carries a 6 m diameter S-band unfurlable antenna.

GSAT-15

GSAT-15 is a communication satellite configured around I-3K bus and it is designed for a mission life more than 12 years. The payload includes Ku-Band transponders and a two channel GAGAN payload. The satellite was launched in November 11, 2015.

GSAT-18

GSAT-18 is a communication satellite configured around I-3K extended bus and it carries Ku, Normal C and Extended C band transponders. It is designed for a mission life of more than 15 years. The satellite was launched on October 06, 2016.

South Asia Satellite

South Asia Satellite 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. 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 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 a 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 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 a 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 and 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 05, 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-31

GSAT-31 was successfully launched on February 06, 2019 from Kourou with a lift off mass about 2536 Kg. GSAT-31 is configured on ISRO's enhanced I-2K Bus. It is a communication spacecraft carrying 18- Ku-band transponders with 36 MHz and one 225 MHz bandwidth. The satellite provides Indian mainland and island coverage.

GSAT-30

GSAT-30 is configured with 12 Normal C-band and 12 Ku-band transponders. This satellite will provide replacement capacity in Ku-band & Nor-C band from the same orbital location to ensure the continuity of DTH services as well as DSNG, VSATs, etc. The satellite provides Indian mainland and island coverage.

SATELLITES UNDER DEVELOPMENT

GSAT-20

The Configuration of GSAT-20 Spacecraft is 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 realisation.

GSAT-22, 23 & 24

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

2.2.2 Satellite Communication Applications

A fleet of 18 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 299 operational bent-pipe transponders and 25 Gbps high throughput satellite (HTS) capacity. These satellites support the services like television broadcasting, DTH 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-20 is planned to be launched in the near future. GSAT-20 satellite will enhance the HTS capacity by another 48 Gbps.

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 the aim of addressing specific requirements at different strata of the society.

In order to meet additional transponder requirements from various users, about 81 transponders in C & Ku-band and HTS capacity of 1.3GHz are leased from international satellite operators, 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

Satellite Communication has been a major catalyst for the expansion of Television coverage in India. DOS has made available the required transponders through INSAT/GSAT satellites and through leased capacity to cater to the needs of television service.

Doordarshan is presently operating 34 satellite channels and has a vast network of 66 Studios and 635 terrestrial Transmitters of varying power installed throughout length and breadth of the country. Break up of these transmitters is as under:-

Service	HPTs	LPTs	VLPTs	Total
DD-National Transmitters	118	392	19	529
DD News Transmitters	55	22	06	83
Digital Transmitters (DTT)	23	---	---	23

The details of satellite channels operated by Doordarshan are as under:-

All India Channels (6)	DD National	DD News	DD Sports
	DD Bharati	DD Urdu	DD Kisan
Regional Channels (17)	DD Malyalam	DD Chandana	DD Yadagiri
	DD Podhigai	DD Sahyadri	DD Girnar
	DD Odiya	DD Kashir	DD North East
	DD Bangla	DD Punjabi	DD Rajasthan
	DD Bihar	DD UP	DD MP
	DD Saptagiri	DD Arunprabha	
State Networks (10)	Himachal Pradesh	Jharkhand	Chhatisgarh
	Haryana	Uttarakhand	Tripura
	Mizoram	Meghalaya	Manipur
	Nagaland		
International Channel (1)	DD India		



Out of 41 C band earth stations, Doordarshan has upgraded nine C-band earth stations at DDK Delhi, CPC Delhi, Bengaluru, Hyderabad, Patna, Dehradun, Srinagar, Raipur & Ranchi, which are equipped with MPEG-4 compliant SD/HD compression chain and spectrum efficient DVB-S2 compliant RF chain equipment. These earth stations are capable to uplink in HD/SDTV channel. New C band earth station at DDK Gorakhpur was also inducted in DD network in Sep 2019. This earth station is equipped with MPEG-4 compliant SD/HD compression chain and spectrum efficient DVB-S2 compliant RF chain equipment and capable to uplink in HD/SDTV channel.

In addition, Doordarshan launched its free-to-air DTH service “DD Free Dish (Earlier DD Direct+)” with the primary objective of providing TV coverage to the areas hitherto uncovered areas. DTH signals can be received anywhere in the country (except Andaman & Nicobar Islands) with the help of small sized dish receive units. For A&N Islands, DTH service in C-band with a bouquet of 10 channels was started with effect from September, 09. DD has planned to upgrade DD Free Dish DTH platform from 104 SDTV channels to 120 SDTV by the introduction of spectrum efficient equipment and also capable to uplink HDTV channel in HEVC compression format.

Apart from Doordarshan, the public broadcaster, 4 private DTH operators provide service in India. It is estimated that (TRAI Report :Apr - Jun 2019) there are about 54.36 Million active subscribers availing private DTH services. About 908 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 61 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.

Doordarshan alone has 25 C-band and 16 Ku-band Digital Outdoor-Broadcast Digital Satellite News Gathering terminals operating through GSAT satellites.

Radio Networking

The Satellite based Connectivity was started in 1985 with 5 Satellite Radio Channels in S- Band(Analog) and has been expanded to 90 Digital Channels (Through Captive Earth Station - 80 Channels & DSNG – 10 Channels) for National, Regional & Vividh Bharati Networking with GSAT -10 (For Coverage Over Indian Geographic Main Land) & GSAT -18 (For Coverage Over Andaman & Nicobar and Lakshadweep Islands). The following Infrastructure was created by All India Radio for utilising C-band Transponder.

- o Captive Earth Station & DSNG - 44 Nos.
- o Down Link Radio Network Terminals (RNTs) - 504 Nos.



AIR is also Broadcasting 37 Radio Channels (Ku Band) on DTH Platform of Doordarshan 'DD Free Dish'.

Telecommunications

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

1534 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 2,70,000 VSATs are being used in star / mesh connectivity of various size and capabilities.

Satellite based captive networks are operational using VSAT systems for establishments like NTPC, ONGC, IOCL, ICAR, ERNET, Indian Railways, 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

Satellite Communication based Telemedicine is one of the unique applications of space technology that is being utilised for the benefit of the society at large. Telemedicine technology utilises Information and Communications Technology (ICT) based system consisting of customised Telemedicine software integrated with computer hardware and medical diagnostic instruments connected to the commercial Very Small Aperture Terminal (VSAT). Telemedicine enables the doctor to 'see & interact' with the patient through videoconferencing facility.

Under Telemedicine programme, various remote & rural medical colleges & hospitals and mobile units are connected to major specialty hospitals in cities and towns using satellite communication. At present, 210 nodes are operational, which have been upgraded with new Telemedicine and in-house developed "Daksh" Learning Management Software.

Additional 32 TM nodes were installed for Integrated Defence Staff (IDS)-Medical, Indo Tibetan Border Police Force (ITBPF), Indian Coast Guards and ESIC this year. Four more nodes were installed in Siachen. These nodes are providing invaluable service to our soldiers in the remote posts. The TM node at Panchtarani, near the holy Amarnath shrine in J&K was also re-installed in preparation of annual yatra. In September 2019, TM network configuration and features were demonstrated to a Bhutanese delegation. Nine existing Defence TM nodes in J&K region were upgraded with additional diagnostic equipment such as Multi-Parameter device, stethoscope, derma-scope, digital stethoscope, high resolution digital camera, X-ray view box, etc. Operational training was given to the concerned officials of these TM nodes.



Continuing Medical Education (CME) programmes are conducted on monthly basis from DECU studio in which medical experts/doctors share their knowledge & experiences and interact with the connected remote hospitals. Five CME programmes were conducted and further it is planned to conduct seven more programmes this financial year.

Tele-education

Tele-Education programme has manifold objectives such as supplementing the curriculum-based teaching, impart effective teacher training and provide access to quality resource persons and new technologies, thus, taking education to every nook and corner of India. ISRO provides connectivity to schools, colleges and higher levels of education and also supports non-formal education, including, developmental communication. The networks implemented under this programme comprise two types of terminals, namely, Satellite Interactive Terminals (SITs) and Receive Only Terminals (ROT). At present, around 44 networks are operational with 24 Hubs. Around 1438 SITs & 33147 ROTs are operational.

The revived Jammu & Kashmir TE network is operational with 69 SITs. Live lectures are being conducted from Jammu and Srinagar Teaching-ends which are received by all the SITs. The North-East TE network is functional in eight states with 326 SITs. The TE network configuration and features were demonstrated to the Bhutanese delegation. Technical consultancy was provided to the user agencies on need basis.

Satellite Meteorology

The meteorological satellite data of INSAT is processed and disseminated by INSAT Meteorological Data Processing System (IMDPS) of India Meteorological Department (IMD) which was installed by M/s Antrix Corporation through an MOU with India Meteorological Department. At present, INSAT-3D and INSAT-3DR (Imager, Sounder, DRT) satellites carrying meteorological payloads are supporting weather forecasting services. INSAT-3D Meteorological Data Processing System (IMDPS) was dedicated to the nation by the Hon'ble Minister of Science and Technology, Ministry of Earth Sciences on 15 January 2014. The system is capable to receive and process the data of the two-existing geostationary meteorological satellites. The performance of the system during the current year has been maintained to the level of 99% operation efficiency (24x365 bases).

The output generated by the processing systems was used for efficient and successful forecasting of major cyclones such as SAGAR, MEKUNU, DAYE, LUBAN, TITLI, GAJA, PHETHAI & PABUK during 2018-19. Cyclones warnings were disseminated to all stake holders which resulted in minimum loss to human life.

Modified scan strategy of INSAT-3D and INSAT-3DR sounder payload was implemented with effect from 12.08.2017. INDIAN region sector data is now available on hourly basis and Ocean region data is available on one and half hourly basis. IMD in collaboration ISRO has adopted Rapid scan strategy from INSAT-3DR in for faster tracking of severe weather events.



IMD is at advanced stage for establishing Multi-Mission Meteorological Data Receiving and Processing System (MMDRPS) for INSAT-3D, INSAT-3DR and INSAT-3DS in collaboration with M/s Antrix Corporation Ltd, ISRO for which a MOU has been signed between IMD and ISRO on 6th March 2017. The 90% work of the project has been completed.

Scatsat-1 wind data is being disseminated on GTS since April 2018. INSAT-3D derived Winds (IR/WV/Vis) as in BUFR format is also being provided to UKMET Office through GTS.

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. 12 new AWSs were added during the year in the North Eastern Region. 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 way or other 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. This also have capability to generate time series plot of different products derived from satellites along with measuring capability of distance, area of any cloud system and to display the digital value of different parameters over different types of maps.

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

Satellite Aided Search and Rescue (SAS&R)

India is a member of the international COSPAS-SARSAT programme for providing distress alert and position location service through LEOSAR (Low Earth Orbit Search and Rescue) satellite system. Under this programme, India has established two Local User Terminals (LUTs), one at Lucknow and the other at Bangalore. The Indian Mission Control Centre (INMCC) is located at ISTRAC, Bangalore. The system is operational for the past 28 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.

From Sep 2018 to Sep 2019, INMCC provided search and rescue support to 7 distress incidents in Indian service area and contributed in saving 51 human lives. During this period, about 1913 new radio beacons were added in Indian database.

Till date, there are about 955 registered user agencies and total number registered beacons are more than 16415. Beacon exercises were carried out involving ICG, Navy, DGCA, Indian Air Force and DG (shipping)/SCI during 24 Dec 2018 to 26 Dec 2018 and 10 April 2019 to 12 April 2019.

Seminars and workshops on SAR related activities and operations were conducted for AAI, ICG and Defence and other users. GSAT-17, located at 93.5 deg East has been commissioned.

MEOSAR project

The next generation system MEOSAR is under implementation and the MEOSAR ground segment (MEOLUT) is being installed at ISTRAC. It consists of seven 2.4m antenna systems associated with RF base band, Digital receiver, MNC, Communications system and civil infrastructure.

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 for data collections, tracking and reporting applications.



Using one-way position reporting system developed by ISRO pilot projects, were conducted for Real-time Train Information System (RTIS) for Indian Railways and Sub-20m fishing vessel tracking for MHA. Additionally, asset tracking, one-way position reporting systems have been developed and demonstrated to different user groups.

High Throughput Satellites

In order to address the growing needs of broadband applications, ISRO has launched HTS satellites, i.e., GSAT-19, GSAT-11 & GSAT-29.

The HTS satellite requires dedicated gateway facilities at identified locations to link the services to users through compact VSAT terminals. Gateway facilities for GSAT-11 at all main four sites (i.e. Ahmedabad, Delhi, Bangalore & Ranchi) are made Operational. 50 user terminals are installed at Andaman & Nicobar and Lakshadweep islands for enhancing data and voice services. BBNL started rolling out of Bharatnet in NE States through GSAT-11 and GSAT-19.

The gateways for GSAT-29 and GSAT-20 are in various stages of implementation.

South Asia Satellite

Following the announcement made by Honourable Prime Minister of India, the South Asia Satellite was realised 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.

The establishment of SatCom Hub in Thimphu, Bhutan for the utilisation of SAS is completed and made operational. The network is being used for (i) uplinking two TV channels and 4 Radio channels for Bhutan, connecting the Disaster Management Center, backhauling the critical telecom links and Internet connectivity.

Maldives is establishing a network with 35 terminals and the installation is undergoing. Bangladesh has procured 10 terminals to connect to remote islands. Afghanistan is finalising the procurement for establishing their own network. The plan of utilisation by other member countries is in various stages.

The workshop on “South Asia Satellite (SAS) Ground Segment, Applications and Utilisation” was conducted jointly by MEA and ISRO on December 11, 2018, at New Delhi, to deliberate the utilisation plans to address specific application requirements by member countries and to firm up few common applications that are relevant among the member countries. Delegates from member nations (Afghanistan, Bangladesh, Bhutan, Maldives, Nepal and Sri Lanka) attended the workshop.



2.3 Navigation Systems

2.3.1 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 Indian Airspace. 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 geosynchronous orbit. The navigation payload transmits signals in L5 and S band. The ranging payload consists of a C-band transponder which facilitates accurate determination of the range of the satellite.



IRNSS satellites employ the standard I-1K 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 realised 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 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 (20) with respect to UTC. Time traceability service has been signed with National Physical Laboratory, India (NPLI) on 01 June 2018. 16 IRNSS Range and 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 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 realise five navigation satellites as replacement to the satellites in the current constellation, viz., IRNSS-1J/1K/1L/1M/1N. These satellites will be located at the existing orbital slots for ensuring continuity of NavIC (IRNSS) services.

2.3.2 Navigation Systems Applications

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

The major initiatives in this area have been on the following:

1. **NavIC in Mobile:** To enable the use of NavIC in mobile phones, efforts are being channelised in the following three major stakeholders.

a. **Chip Manufacturers:** It is necessary to first develop NavIC enabled processing chipsets which can be introduced in the Smart phones. Towards this, ISRO has coordinated with major Telecom chip manufacturers to release NavIC enabled SoCs. One of them has released a chip series with NavIC support and demonstrated its performance during India Mobile Congress in October 2019.



The same chip manufacturer has also recently introduced NavIC enabled processors for always connected PCs (5G enabled). Another chip manufacturer also has announced NavIC support in its latest chip series SoC.

b. **Mobile Phone Manufacturers (OEM):** With increasing number of mobiles, chips are supporting NavIC, ISRO is also liaising with mobile OEM's to roll-out new NavIC enabled mobile phones into the market. The first NavIC enabled smart phone is expected to be released during the first quarter of 2020.

c. **NavIC in 3GPP:** To encourage more chip manufacturers and mobile OEMs to support NavIC, ISRO has taken up activities to include NavIC based assisted navigation support in Indian telecom standards through Telecommunications Standards Development Society,



India (TSDSI) and international telecom standards through 3rd Generation Partnership Project (3GPP). Inclusion of NavIC assisted navigation support in 4G networks was taken up as a work item in 3GPP and it is expected to be incorporated into standards by end of 2020 which is a significant step towards proliferation of NavIC.

- NavIC multi-GNSS receiver chips:** There are many GNSS applications which require small form factor hardware like tracking tags for animals, vehicle tracking, NavIC messaging receivers, location enabled locks, etc. To support the small form factor, NavIC enabled GNSS receiver chips are a mandatory requirement. Towards this, ISRO has coordinated with several chip manufacturers to commercially release NavIC enabled multi-GNSS receiver chips by providing testing support and addressing their queries related to NavIC receiver implementation.



- NavIC based vehicle tracking:** To improve the safety of passengers and to enable rapid response in case of an emergency, Ministry of Road Transportation has mandated that, with effect from 01 April 2019, all new commercial and public vehicles shall be fitted with vehicle tracking units and panic button in accordance to Automotive Industry Standards (AIS-14). As per AIS-140 standard, all the vehicle tracking units shall be NavIC enabled and the certifying agencies for the compliance are ARAI and ICAT. Towards the speedy implementation and enforcement of this mandate, ISRO has helped ARAI and ICAT with establishing their test methodology towards NavIC performance and helped them calibrate their simulators for NavIC support. As of today there are more than 100 companies have produced and certified NavIC enabled vehicle tracking devices. There are already more than 40,000 vehicles fitted with the NavIC enabled vehicle tracking devices in the country today.



- NavIC in Launch vehicles:** NavIC based trajectory tracking has already become the standard practice for all PSLV and GSLV Mk III missions. It is part of the NAINS system where it is combined with inertial navigation to provide trajectory tracking in the recent PSLV-C45, C46, C47, C48 and Mk III M1 (Chandrayaan-2) missions in the year 2019.



5. **NavIC Messaging Service:** Using the NavIC messaging service along with support from Indian National Centre for Ocean Information Services (INCOIS), NavIC messaging receivers (NMR) were developed which transmit alerts messages such as cyclone, high wave, etc., and provide information on Potential Fishing Zone for the fishermen venturing into deep sea. After consolidating the survey results and comments from the fishermen who were provided with NMRs, the integration of existing NMR with Distress Alert Transmitter (DAT) was taken up. With the second generation DAT, the fishermen can send a distress alert through the regular DAT link to the rescue centre and the acknowledgement for the reception of distress signal and impending rescue attempt will be sent through the NavIC messaging service. The hub is established at ISTRAC along with the existing COSPAR SARSAT ground system. Second generation DAT terminal prototype development is completed and the technology was ready for transfer to industry for commercial deployment.



2nd Gen DAT



DAT Link

6. **NavIC based Timing applications:** As part of pilot project, NavIC based timing receivers are installed at Power Transmissions stations at Dadri, Patna, Shillong, Boisar and Tumkur to provide measurement ticks for the Phase Measurement Units. These receivers are used for time stamping which helps in power grid control, measurement and monitoring.
7. **NavIC based Scientific applications:** NavIC enabled GNSS receivers are used in many scientific applications; the following are a few examples.
- Pilot project for air quality monitoring with aid from NavIC receivers was carried out in Ahmedabad and Gandhinagar area. The measurements of air quality and particulate matter were taken at different locations in the two cities with their locations tagged using NavIC. The data was then used for analysis of particulate matter sources, propagation of particulate matter in the air, identification of poor air quality areas, etc.
 - Pilot project is being carried out in Gujarat to generate accurate models for extracting air moisture content using measurements from NavIC receivers.



- c. Pilot project for Satellite based Ground water level monitoring system at various remote locations across India. ISRO has developed a Proof of Concept where NavIC is used for time stamping of ground water level measurements at each location. A report has been submitted to Central Ground Water Board, Ministry of Jal Shakti.
- d. ISRO is also carrying out research into prediction of seismic activity using NavIC receivers. Large scale earthquakes which are over six on the Richter scale cause noticeable build up patterns in the total electron content (TEC) of the ionosphere. This information is being monitored using NavIC and feasibility of predicting earthquakes is being studied.
- e. Studies into using NavIC signals for detecting ocean current and wind speeds, rip current detection, soil moisture detection, etc. are also underway in ISRO.

8. NavIC outreach activities: ISRO has initiated many outreach activities for propagating NavIC in the form of student hackathons, collaborations with academia on NavIC projects through Respond, NavIC-GAGAN Utilization Programme; distributing NavIC receivers and development boards to academia, arranging user-industry meets to encourage start-ups in GNSS and societal outreach through major events like Vibrant Gujarat Summit, SAARC Outreach, etc. ISRO has also shared its performance report of the system on the official website to build confidence in the Industrial community.

9. ISRO activities in International GNSS community: ISRO has hosted this year's International

Committee on GNSS (ICG-14) meeting participated by GNSS service providers (viz., GPS, GLONASS, BEIDOU, GALILEO, QZSS and NavIC), member states and organisations involved in GNSS across the globe. This was a platform wherein, ISRO showcased its



capabilities to the GNSS experts worldwide and contribution towards interoperability of GNSS systems. Collaborations with different GNSS service providers were established on topics like spectrum protection, new services, sharing of monitoring stations, etc.



2.4 Space Science and Planetary Research Systems

2.4.1 Space Science and Planetary Research

India's first interplanetary mission, the Mars Orbiter Mission (MOM), has completed five years in Mars orbit on Sept 2019. India's first multi-wavelength astronomy observatory, AstroSat also completed four years in orbit. Data from AstroSat are being actively utilised for a variety of research on galactic and extra-galactic astronomy sources both by Indian and International scientists. The Chandrayaan-2 mission, India's second mission to the moon, was successfully launched on 22nd July 2019. The mission carried an indigenous orbiter, lander and a rover. The lunar orbit insertion was successfully carried out on 20th Aug 2019. Subsequent to this Vikram (lander) landing was attempted on 7th Sept 2019. Science data from the orbiter are being analysed by various national experts. Also, India's first dedicated solar mission to continuously observe the Sun, Aditya-L1, is being prepared for launch in 2020. The X-ray Polarimeter Satellite (XPoSat), a dedicated mission for polarization studies in medium energy X-rays, is also being prepared for launch in 2020. Both Aditya-L1 and XPoSat are the upcoming space science missions.

Novel research projects in the field of atmospheric science, astronomy and planetary exploration are technically and financially supported at various universities and research institutes. The APEX Science Board (ASB) was constituted to review and recommend steps for the cutting edge research projects on various fields related to space science. Based on the recommendations of ASB, interested scientists/faculties of various research institutes are encouraged to undertake space instrument/payload developmental activities with ISRO funding support. In addition to ongoing approved programs, feasibility studies of experiments for future space missions are also undertaken at several ISRO/DOS centers.

The major activities carried out under space science and planetary research during 2019-20 are summarised below.

Mars Orbiter Mission

Mars Orbiter Mission (MOM), the first interplanetary mission of ISRO, completed five years in its orbit on September 24, 2019 well beyond its design mission life of six months.

Scientific analysis of data being received from the Mars Orbiter spacecraft is in progress. Twenty six scientific papers have been published so far in peer-reviewed journals. The Mars Colour Camera (MCC), one of the payloads onboard MOM, has taken 1061 images so far. In the past year, a large dust storm on Mars and non-optimal solar illumination limited the imagery from MCC. The larger periapsis of the MOM orbit also limited the useful operational time of the mass spectrometer experiment.

Fourth year data release of MOM

On the occasion of five years completion of MOM in its orbit, ISRO released fourth year (24th Sept



2017 to 23rd Sept 2018) data of MOM to public through ISSDC website: <https://mrbrowse.issdc.gov.in/MOMLTA/>. More than 3200 users have registered and downloaded more than 717 GB data so far.

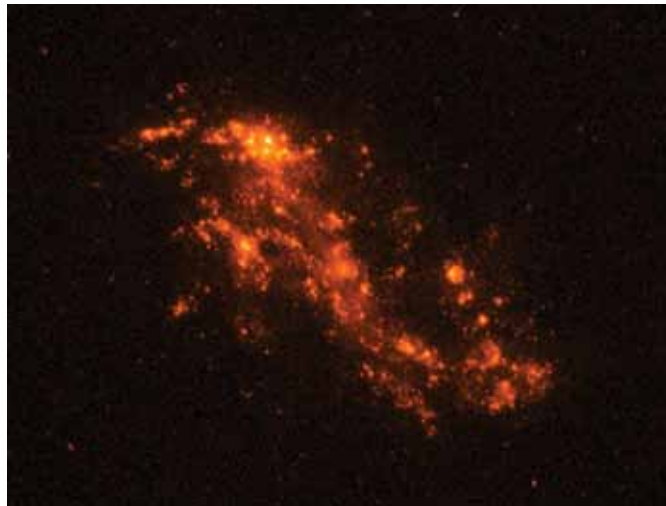
AstroSat Mission

AstroSat is India's first observatory class mission dedicated for astronomy. AstroSat has a unique capability to observe 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 the sky for transients.

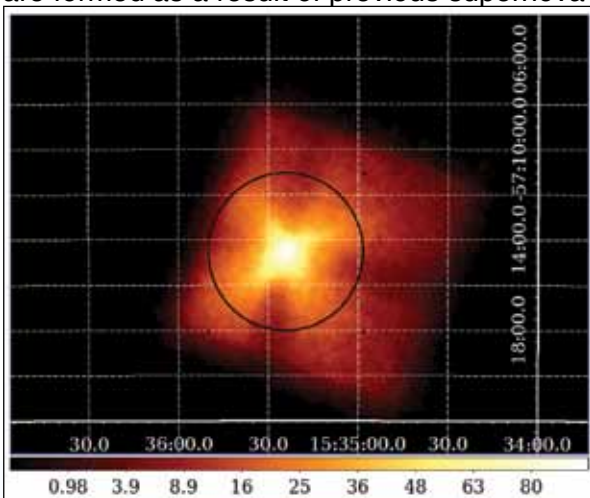
The satellite is operated on proposal basis in which the observation times are allotted to the science proposals made through a specifically developed proposal system. Currently, fifth and sixth cycles are completed and observations under seventh and eighth cycles has started from 1st of October 2019. AstroSat has resulted in a total of 117 publications in refereed journals at the end of October 2019. Including all the conference proceedings, astronomy telegrams and circulars, this number exceeds 350.

AstroSat has more than 1200 users from 43 nations. Some of the main results highlighting AstroSat capabilities are listed below.

Ultra-Violet Imaging Telescope (UVIT) has the highest spatial resolution in space today over a wide field of ~ 0.5 degrees. This high spatial resolution combined with high sensitivity has given many new results. One such result is the study of a Dwarf galaxy IC2574 in which 1/3rd of the massive stars are formed as a result of previous supernova



AstroSat image of dwarf galaxy IC 2574

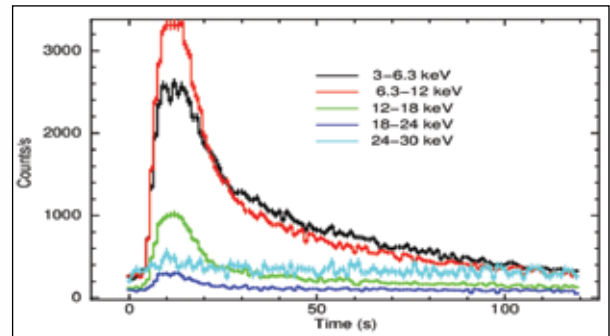


SXT image of galactic black hole binary MAXI J1535-571

explosions. The expanding bubbles from supernova explosions compress the gas between them which initiates the star formation at the rims of the bubble structure. Unlike spiral galaxies like our Milky Way where stars are formed mostly in the spiral arms, in dwarf galaxies stars are formed because of bubble structures.

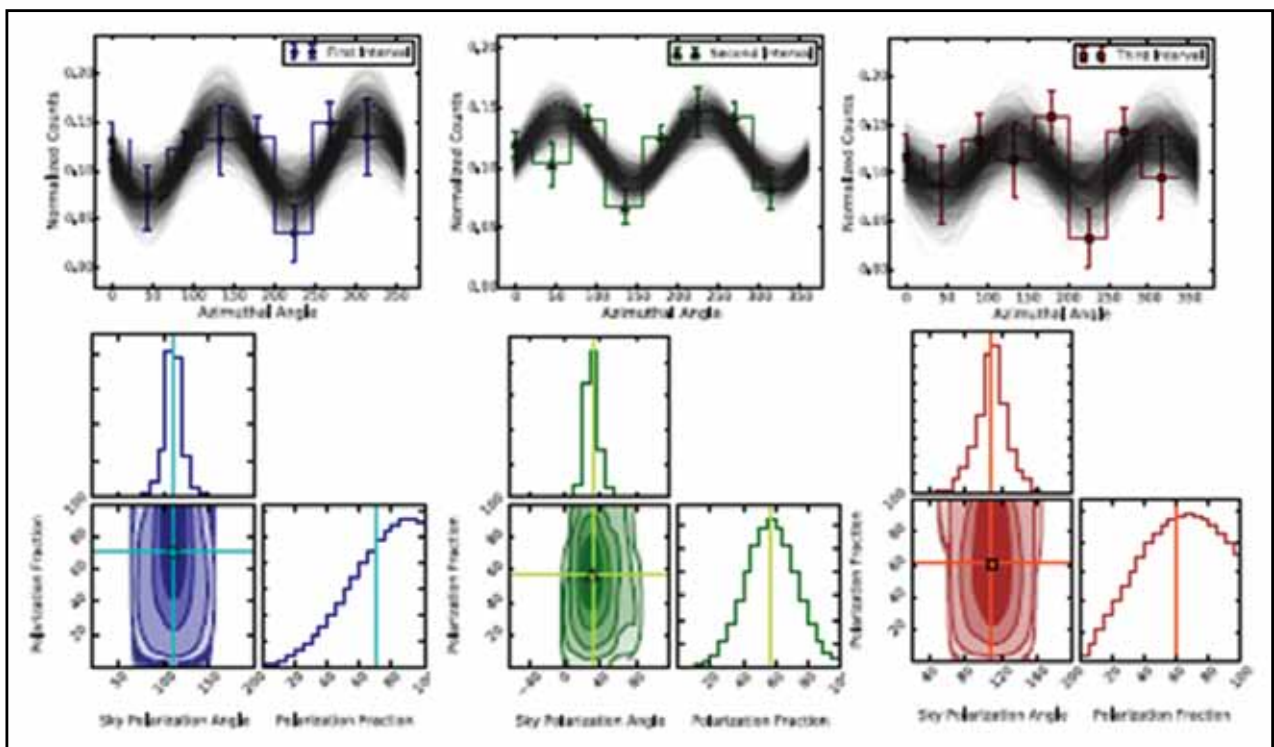
Soft X-ray Telescope (SXT) has measured the spin and mass of Galactic black hole in the binary system MAXI J1535-571. Using the reflection spectrum, the blackhole's mass and distance are estimated to be $10.39 M_{\text{sun}}$ and 5.4 kpc respectively.

Large Area X-ray proportional Counter (LAXPC) detected rapid thermonuclear bursts in a low mass X-ray binary 4U 1636-536. AstroSat has detected seven thermo-nuclear bursts over a period of two days including a rare triple burst. In addition, time varying quasi-periodic oscillations were detected in the light curve of the source.



LAXPC light curve of the X-ray binary source 4U 1636-536 showing the burst

Cadmium Zinc Telluride Imager (CZTi): Though 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. AstroSat CZTi has observed time varying polarized gamma-rays from GRB 160821A and found evidence for ordered magnetic fields.



Modulation of X-ray polarization curve of GRB 160821A.

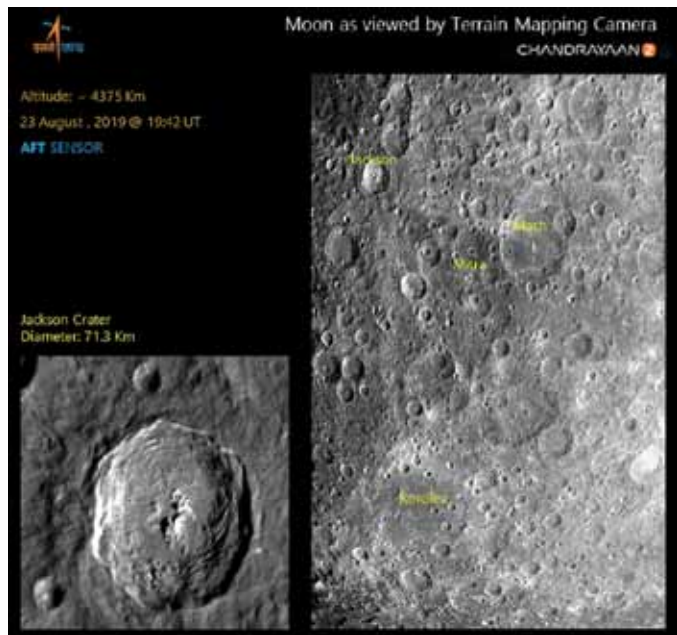
CHANDRAYAAN-2 MISSION

The Chandrayaan-2 mission was successfully launched on July 22, 2019. After a series of Earth



bound maneuvers, the spacecraft entered into Lunar Transfer Trajectory (LTT) on August 14, 2019. Lunar Orbit Insertion (LOI) maneuver was performed on August 20, 2019 thereby Chandrayaan-2 was successfully inserted into an elliptical orbit around the Moon. This was followed by a series of Lunar bound orbit maneuvers for reducing the orbit to a circular polar orbit around the Moon.

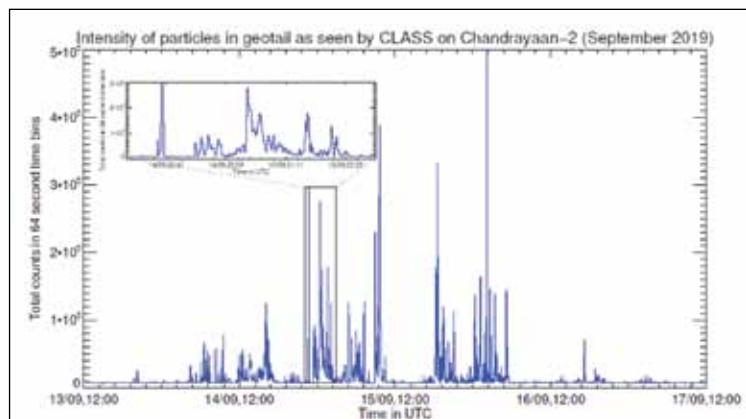
On September 2nd, Vikram lander separated from the Orbiter and de-orbiting maneuver was performed to reduce the orbit to 35 km x 101 km. Vikram landing was attempted on 7th September and it followed the planned descent trajectory from its orbit of 35 km to around 2 km above the surface. Subsequent to this, communication between the lander and ground station was lost. All the systems and sensors of the Lander functioned excellently until this point and proved many new technologies such as variable thrust propulsion technology used in the Lander.



Lunar surface imaged by Terrain Mapping Camera 2 (TMC-2) on 23rd August 2019 at an altitude of ~4375 km showing impact craters such as Jackson, Mitra, Mach and Korolev.

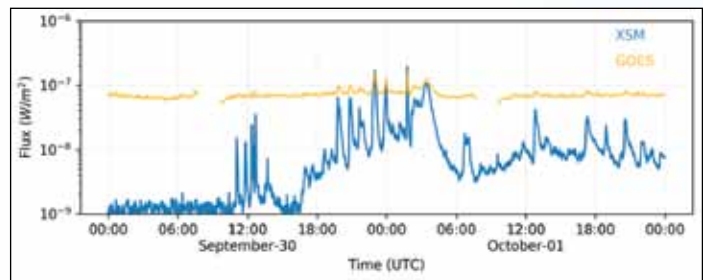
Chandrayaan-2 Orbiter is currently in a 100 km x 100 km orbit around the Moon. It is carrying 8 experiments for studies ranging from surface geology and composition to exospheric measurements. These studies and observations will continue to enhance our understanding about the moon.

Chandrayaan-2 Large Area Soft X-ray Spectrometer (CLASS), an X-ray fluorescence spectrometer is also a continuation of C1XS payload (of Chandrayaan-1) with a larger collection area aiming to map elemental abundances at 12 km spatial resolution at its best. It detected charged particles and its intensity variations during its first passage through the geotail during September. Once every 29 days, Moon traverses the geotail for about 6 days centred around full moon.



Change in intensity of particle events (believed to be mostly electrons), sometimes as much as 10 times the levels outside the geotail, indicating complex interplay with the magnetic field.

Solar X-ray Monitor (XSM), a companion payload to CLASS, measures the simultaneous solar spectrum required for inversion of XRF line flux to elemental abundances. The instrument has observed solar flare with intensity variations much beyond the sensitivity limit of GOES.



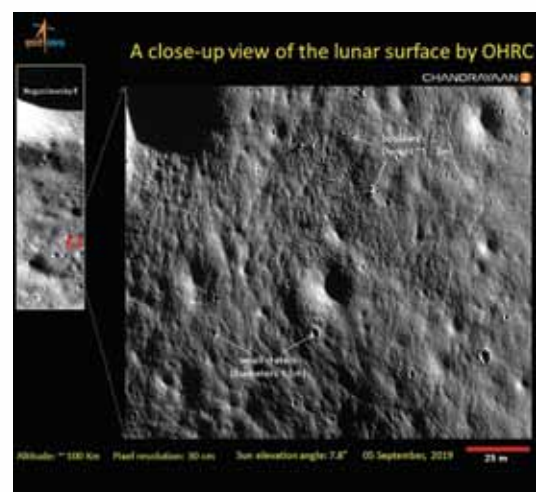
Solar X-ray flux as measured by XSM (in blue) during the episode of solar flare. For comparison, the flux measured by X-ray sensor on the Geostationary Operational Environmental Satellite (GOES-15) is also shown (in orange). For X-ray solar intensity measurement GOES data are considered standard.

The **Imaging Infra-red Spectrometer (IIRS)** measures the surface reflectance in the 0.8-5 micron band uniquely designed to sample in 256 bands at 20 m spatial resolution. This would unambiguously provide clear signatures of water molecule and their temporal and spatial variations. In addition, IIRS will also complete global mapping of lunar surface mineralogy in continuation to M3 on Chandrayaan-1.

The **dual frequency SAR (DFSAR)** in L and S band has both circular polarization mode and full linear polarization mode and can image at 2-75 m spatial resolution. This would again add upon previous SAR instruments in lunar orbit and in addition has the potential for new science given the L band capability for deeper subsurface imaging and full polarimetric modes of operation.

CHandra's Atmospheric Composition Explorer-2 (CHACE-2) is a mass spectrometer which measures neutral species in the tenuous exosphere of the Moon.

An **Orbiter high resolution camera (OHRC)** with a 25 cm spatial resolution from 100km orbit and a swath of 3 km, can provide sharpest images ever from the lunar orbiter platform and generate DEMs of specific target sites of interest. The **Terrain Mapping Camera-2 (TMC-2)** is a continuation to the TMC on Chandrayaan-1 to generate DEMs for the entire Moon.



The initial science results have provided the confidence to pursue lunar science research in detail using orbiter payloads.

Chandrayaan-2 payload data will definitely improve our knowledge about the Moon and attempts are underway to bring in more scientists and researchers from national institutions, academia, universities and colleges in the country for data analysis and interpretation.



ADITYA-L1 MISSION

Aditya-L1 is the first dedicated space-based solar observatory of India. The spacecraft is planned to be placed around the Earth-Sun Lagrangian point L1 in the year 2020. The L1 point is about 1.5 million km from the earth and it would take around 109 earth days for spacecraft to reach L1-orbit. The spacecraft will orbit L1 point with an orbital period of around 178 days.

From the Lagrangian point L1, the phenomena of the sun will be continuously monitored by Aditya L1. The following objective are planned with Aditya L1:

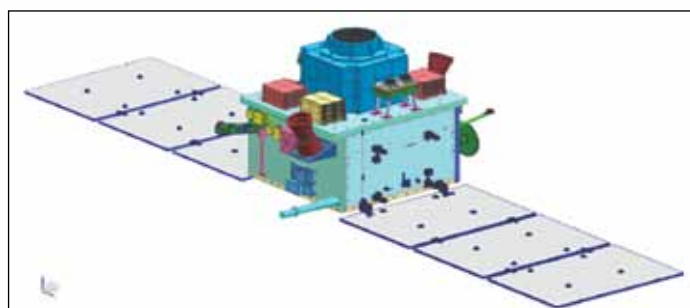
- Study of Solar upper atmospheric dynamics
- Study of chromospheric and coronal heating, physics of the partially ionized plasma, initiation of the coronal mass ejections, and flares
- Observation of the in-situ particle and plasma environment providing data for the study of particle dynamics from the 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. Four payloads will continuously observe the sun and the remaining three will be used for in-situ measurements. Visible Emission Line Coronagraph (**VELC**) will be used for the study of the 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. Aditya Solar 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.

The above payloads are at various stages of development and testing to meet the launch schedule in the year 2020.

X-ray Polarimeter Satellite (XPOSAT) MISSION

XPoSat is an Indian dedicated mission to study X-ray polarization of bright astronomical sources in medium energy band and long duration spectroscopic



observation in soft energy X-ray band. The mission will help to understand the emission mechanism from a variety of X-ray sources. The spacecraft will be carrying two scientific payloads and is planned to be placed in a low inclination orbit. The mission will be launched in the year 2020.

The primary payload POLIX (Polarimeter Instrument in X-rays) will measure the polarimetry parameters (degree and angle of polarization) of astronomical sources in the 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. The payloads and various subsystems hardware of XPoSat satellite are at different stages of development to meet the launch schedule.

Microgravity Experiments

Gaganayaan, the human exploration of space, is a new frontier for the Indian Space Program. Under this program, it is planned to send Indian astronauts and bring them back safely on the ground by the year 2022. Two unmanned flights are also planned to test the end-to-end capacity for a manned space mission. To utilise the unmanned missions for scientific purpose as well, 6 microgravity experiments were selected under Announcement of Opportunity (AO) from different academic institutes of the nation. The budgetary and technical aspects of the experiments have been reviewed. MoUs are planned to be signed with ISRO and the 6 academic institutes towards the development of microgravity experiments.

Future Space Science missions

i Astronomy and Astrophysics

In response to the Announcement of Opportunity (AO) soliciting proposals for future astronomy missions, a total of 20 proposals were received. They were reviewed and four among them were selected for pre-developmental funding support. The four proposals are from Indian Institute of Astrophysics, Raman Research Institute, Pune University and IIT Bombay. Based on progress, these will be presented before a ISRO committee for consideration for a future mission.

ii Planetary missions

The Apex Science Board of ISRO has selected a few scientific proposals to conduct experiments onboard an orbiter mission around Venus and Mars. All these proposals were received based on an Announcement of Opportunity (AO) soliciting proposals from interested scientists. These experiments will address relevant scientific problems and topics of Venus and Mars. Shortlisting and final selection of the payloads for Venus mission have been completed. The payloads are under various stages of development. The feasibility study of these missions are under progress

iii Aeronomy Mission

There are proposals for two small satellites with high and low inclination named 'Disturbed and quiet time Ionosphere-thermosphere System at High Altitudes (DISHA)' which aims to study the effects in the Ionosphere-Thermosphere system during space weather events and normal condition of the



Sun. The proposed DISHA mission will yield critical information on the structures in plasma and neutrals that adversely affect communication and navigation during space weather events. This will eventually help in a better description of influence of space weather on space based technological systems and sub-systems.

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.

Projects under Announcement of Opportunity (AO) Programme:

ISRO/DOS has been supporting 56 proposals which are selected under specific AOs by extending funding support for duration of three years. The 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.

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 was held at Hungary in August 2019. One of the five Indian students bagged a Gold medal, three students received Silver medals while one student received a Bronze medal.



2.5 Gaganyaan – Human Space Flight Programme

The Human Space Flight Centre (HSFC) was constituted in ISRO in January, 2019 for implementing the vision on human space flight programme. HSFC is entrusted to implement the Gaganyaan programme and to act as the lead centre for the sustained and affordable human spaceflight activities to extend the human presence across the solar system starting with human space flight missions to LEO. The Gaganyaan project has the objective of demonstrating human space flight capability to Low Earth orbit (LEO) with 3 crew members for 5-7 days in orbit and safely recovers them after the mission.



Human Space Flight Centre – Inauguration of new Campus at HQ

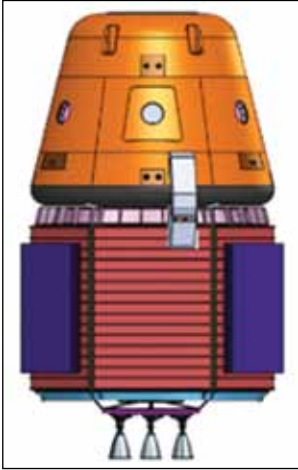
HSFC will focus on the development of engineering systems related to the Orbiter module, development of human centric technologies, act as a hub for bio-astronautics related R&D, establish facilities for crew selection & training, develop state of the art crew-life support systems, develop technologies for sustained human space flight activities including space habitat and robotic space exploration.

HSFC is currently operating from a temporary campus situated in ISRO Headquarters premises at Bengaluru. All the S&T, Administration, Accounts and Finance Departments have been accommodated in two newly built buildings. In order to achieve the targeted schedule of Human Space Flight Programme as set by Government of India, it is required to process the procurement on a fast track basis. In view of this, a Special Purchase Procedure and Guidelines to meet the launch target of Gaganyaan Programme was approved by Space Commission. The special purchase procedure is in place and procurement activities from all Centres related to Gaganyaan have been initiated through HSFC purchase.

Full-fledged Infrastructure and facilities of HSFC are proposed in the land allotted to ISRO in the Science City area of Challakere, Chitradurga District of Karnataka state. State-of-the-art facilities like Astronaut Training Centre, Assembly Integration and Testing facility, Environment Control and Life Support System (ECLSS) and Space-suit Development & Testing facilities, Avionics Production & Development facility, Mission Control Centre, Bioastronautics, Mechanical Systems Production & Development facility and auxiliary support facilities, are planned at the new campus.



The Gaganyaan Project



Artistic view of Orbital Module which will carry Crew into LEO

As per the mandate of Gaganyaan, two unmanned missions will be undertaken prior to the manned mission. The unmanned missions are slated for launch in December 2020 and July 2021 respectively and the first manned mission is scheduled in December 2021.

The Gaganyaan project is being executed through all ISRO Centres with HSFC in the lead role. Various technological and infrastructure developments pertaining to crew, human rated launch vehicle, orbital module, crew safety, reliability and crew escape system are in the process of realisation through ISRO centres, various institutions and Industries. Gaganyaan integrated system concept review with the participation of eminent national experts has been completed. Overall

concept, configuration and interfaces have been firmed up and Preliminary design reviews have been completed.



Human Rated Launch vehicle and Crew Escape System

For effective inter-agency coordination of activities and addressing the criticality, a national level Gaganyaan Advisory Council (GAC) comprising of experts from various Government departments, national institutions and Industries was set up. The first meeting of GAC was held on 8th June 2019.

Considering the importance of safety and human rating certification, a National level expert committee was constituted and the proposal of the committee was discussed in ISRO Council and approved for implementation. Accordingly a human rating certification board has been set up with a secretariat in ISRO HQ for the effective implementation for human rating certification mechanism.



Gaganyaan Advisory Committee with Chairman, ISRO

An inter-centre committee has been constituted to have interaction with industries at various levels to appraise the industries on the requirements of Gaganyaan. A one day Gaganyaan-Industry meet was organised in ISRO HQ, where more than 150 chief executives/heads of units from more than 100 industries from all over the country participated.

Mission strategies for ascent, orbital phase and descent phase including abort scenarios have been worked out. Orbital mission plan has been detailed out and interaction with all the agencies involved in the Crew recovery operation initiated.

Overall configurations of GSLV MK III, crew escape system, crew module and service module have been finalised. The facilities required for carrying out the preparation and check-out of orbital module have been identified and actions taken for the realisation of various systems and equipment. A full scale integration mock-up of Crew module has been realised through industry for integration trials of subsystems.



Crew Module Integration Mock up model

For crew selection and training, HSFC/ISRO has executed an MoU with Indian Air Force and Institute of Aerospace Medicine (IAM) is identified for crew selection and screening criteria. The first phase of Crew Selection has been completed. The training of the selected crew will be carried out at Russian crew training facilities. A contract also signed with Glavkosmos (Russian launch service provider), a subsidiary of Roscosmos State Space Corporation for, crew selection support, medical examination and space training of Indian astronauts.



Signing of MoU with Indian Air Force, Institute of Aerospace Medicine (IAM)



Signing of MoU with Russian Glavkosmos

For some of the critical technologies such as space food, space crew health monitoring and emergency survival kit, radiation measurement and protection and parachutes for safe recovery of crew module, ISRO/HSFC signed MoUs with various DRDO labs. These MoUs were signed with Aerial Delivery Research & Development Establishment (ADRDE), Defence Food Research Laboratory (DFRL), Defence Bio-Engineering & Electro Medical Laboratory (DEBEL), Defence Laboratory (DL) Jodhpur, Centre for Fire, Explosives & Environment Safety (CFEES), Defence Institute of Physiology & Allied Sciences (DIPAS), Centre for Military Airworthiness & Certification (CEMILAC) and Institute of Nuclear Medicine & Allied Sciences (INMAS).



2.6 Space Transportation System

Space Transportation System

The Indian Space Programme has made a 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 has 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 the establishment of facilities and forging partnership with industries. ISRO is now moving forward with the development of heavy lift launchers, reusable launch vehicles and semi-cryogenic engines to cater to different payloads and an array of new missions including Gaganyaan, India's Human Space Flight.

During the reporting year, all the launch complex facilities were activated and utilised to ensure the 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

- **Polar Satellite Launch Vehicle (PSLV):** Polar Satellite Launch Vehicle (PSLV), the Indian operational launcher, completed its fiftieth launch during the reporting period further proving the reliability and versatility. 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.

During the year, PSLV successfully accomplished four missions-

- **PSLV-C45/EMISAT Mission:** PSLV-QL configuration was successfully launched on April 01, 2019 carrying EMISAT along with 28 co-passenger satellites. PS4 stage as an orbital platform was established at ~485km
- **PSLV-C46/RISAT-2B Mission:** PSLV-CA configuration mission was successfully accomplished on May 22, 2019. SCL-Vikram Processor based NGC System was flight-tested by carrying it in piggy-back mode
- **PSLV-C47/Cartosat-3 Mission:** Cartosat-3 and 13 co-passenger satellites were successfully launched using PSLV-XL configuration on November 27, 2019
- **PSLV-C48/RISAT-2BR1 Mission:** The Polar Satellite Launch Vehicle (QL configuration) in its fiftieth mission successfully launched RISAT-2BR1 and 9 customer satellites on December 11, 2019



- **Geo Synchronous Satellite Launch Vehicle MkIII (GSLV MkIII):** GSLV MkIII is the next generation launch vehicle of ISRO capable of launching 4 Ton class of satellites to Geosynchronous Transfer Orbit (GTO). GSLV Mk III 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).
- **GSLV Mk III M1/ CHANDRAYAAN-2 Mission:** The maiden operational flight of GSLV MkIII (M1) successfully launched India's 3854kg Chandrayaan 2 spacecraft on July 22, 2019. It was a text book launch, which met all the mission requirements and delivered the spacecraft into a super synchronous orbit of 170 x 45000 km. With this, India has achieved self-reliance in launching 4 Ton class satellite to Geosynchronous Transfer Orbit (GTO). The major changes in GSLV Mk III M1 include C25 stage burn to depletion, induction of High Thrust Vikas Engine for L110 and tuning of vehicle aerodynamic drag
- **Human Rated GSLV MkIII (Gaganyaan Programme):** The design aspects are being reviewed including human rating requirements, safety margins, additional test and qualification requirements, redundancy aspects, fault detection and isolation schemes and Launch Vehicle Health Management (LVHM) system. Modifications in L110 and C25 stages were finalised
- **Small Satellite Launch Vehicle (SSLV):** The objective of SSLV is the development of a vehicle capable of launching mini, micro or nano satellites (10 to 500 kg class) into 500 km orbit. Configuration is 2m in diameter and 34m in length with a lift-off weight of ~120 Ton with three solid propulsion stages and a liquid propulsion based Velocity Trimming Module (VTM).
- **SSLV-D1:** Design of all vehicle systems is completed and hardware realisation is progressing in fast track mode. The activities towards static test of first stage solid motor (SS1) are progressing. Acceptance testing of second stage (SS2) flight motor case completed. Third stage (SS3) motor is under propellant processing

Design & realisation of new Mission Management Computer (MMC) and Sequencing Execution Module (SEM) has been completed. A new miniaturized telemetry system has been developed for SSLV achieving 70 % mass reduction in the telemetry package. Characterization of vehicle configuration through wind tunnel tests and CFD are nearing completion.



Fig.2 SS1 NES



Fig.3 SS2 motorcase

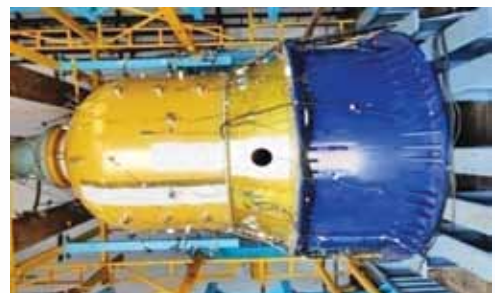


Fig.4 SS2 structural testing



Vibration test of propellant tank for Velocity Trimming Module were completed. 50N thrusters & valves were realised. Assembly and integration scheme and flight measurement plans were finalised.

- **Reusable Launch Vehicle (RLV):** The objective of RLV is to demonstrate technologies for developing a wing body vehicle similar to that of an aircraft. RLV will ascent to orbit, stay there, re-enter and land on a runway like an aeroplane. The technology has the challenges of meeting the complexities of both the launch vehicle and aircraft.
- **RLV Landing Experiment:** It is planned for the last quarter of 2019. RLV wing body will be carried using a helicopter and released at a distance of ~4-5 km ahead of the runway with a horizontal velocity. The RLV will glide, navigate towards the runway and land autonomously with a landing gear in an air field near Chitradurga in Karnataka. Control and Guidance design and all structural designs were completed. RLV flight hardware has been realised. Structural test of RLV Engineering Model has been completed. RLV Interface System (RIS) for interfacing with helicopter and Qualification Model of landing gear were realised



Fig.5 Structural Testing of RLV EM

- **Advanced Technology Vehicles & Sounding Rockets Project (ATVP):** ATVP is the nodal agency in VSSC for conducting sounding rocket launches for the scientific exploration of middle and upper atmosphere and for the realisation of new vehicles to support demonstration of advanced technologies.

- **Rohini Sounding Rocket flights:** Six numbers RH-200 sounding rockets were launched from TERLS including the 167th consecutively successful launch. 10 more launches were planned, including the special launches during the World Space Week from VSSC and SDSC

- **RH560 MkIII Sounding Rockets Experiment(SOUREX) Programme:** 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. Preparations were in progress for flight



Fig.6 RH 200 launch



- **RH300 MkII/IAD Technology Demonstration:** Realisation of IAD system in Polychloroprene coated Kevlar fabric is in progress. Inflation system configuration has been carried out. The flight was targeted by the end of 2019
- **ATV-EX: Sounding Rocket for Microgravity Experiments:** ATV-D series sounding rocket has been reconfigured to meet mission requirements. Activities are in progress towards static test of the motors
- **Air Breathing Propulsion Project (ABPP)**

Hypersonic Air Breathing Vehicle with Air frame integrated system (HAVA): It is a lifting body hypersonic vehicle integrated with scramjet engine, boosted by ADMIRE booster to an altitude of 44 km and glide down to 25 km altitude with a Mach number of 6. The objective is to demonstrate accelerating flight of a hypersonic vehicle with scramjet engine power from Mach 6 to Mach 7 in 250 seconds at constant dynamic pressure. The data base generated can be used for the design and development of a Two-Stage-to-Orbit (TSTO) vehicle, powered by air breathing combined cycle engine. Isrosene is considered as fuel for HAVA. System engineering and design has been completed. Fabrication of heat sink version of Scramjet test combustor, configuration of air intake cowl opening mechanism and effervescent Isrosene injector were completed. Hot test of GH2-GO2 based dump igniter was carried out.
- **Test Vehicle Project (TVP):** Test Vehicle is a single stage liquid propelled launch vehicle being developed to validate the Crew Escape System (CES) performance at different critical Mach numbers, viz, transonic, Qmax, Mach 2.0 and Mach 2.5. Test Vehicle mimics the Human Rated Launch Vehicle trajectory during its atmospheric regime, carries CES as payload and places it at the predefined “M-q’ pill box. This vehicle uses the already proven L-40 earth storable propulsive system with reduced Area Ratio nozzle, new structural elements and full-fledged autonomous avionics & NGC systems. Dual plane Engine Gimbal and Fin Tip Control (4 fins) using electro-hydraulic actuators are planned.
- **Development of Technologies for Gaganyaan:** Configuration of Crew Escape System (CES) for Gaganyaan has been finalised. The configuration has five quick acting solid motors which use newly developed high burn rate propellant system. Four nos. of gridded deployable fins are provided in CES for aerodynamic stability. Preliminary design of all metallic structures in CES has been completed and fabrication drawings were released. Material procurement is progressing in fast track mode. Separation of Crew Module (CM) to CES is effected by firing explosive nuts in the linkage system. Design of grid fin deployment mechanism and

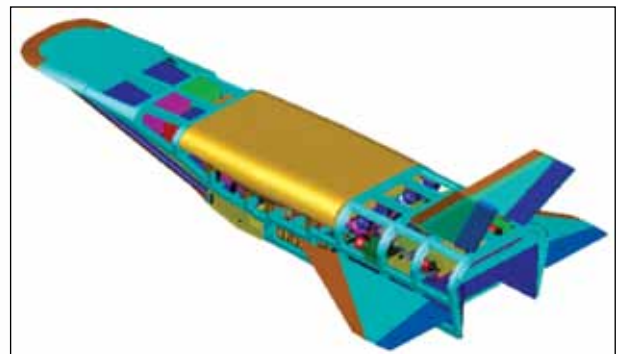


Fig.7 Configuration of HAVA with sub-systems



CES separation system are in advanced stage. Crew Module for Gaganyaan with a height of 3 m & 3.5 m diameter is configured for accommodating a crew of 3. It has a double walled configuration, with inner pressurised shell made of Aluminium alloy having welded construction and external structure configured with CFRP honey comb panels bonded with TPS tiles. The design of structure is in advanced stage and material procurement is in progress.

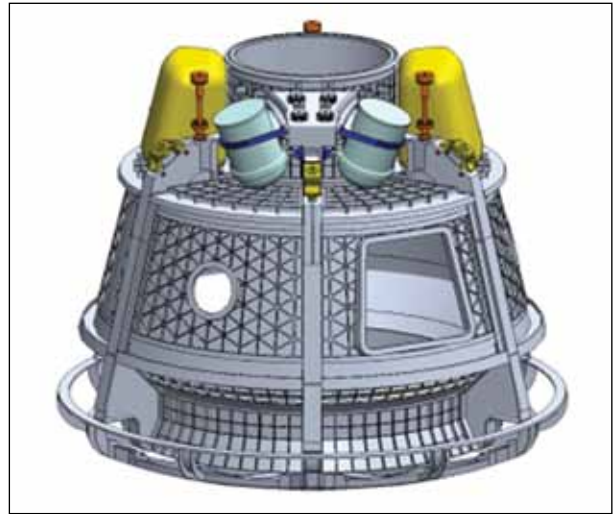


Fig.8 Configuration of Crew Module

The parachute systems are configured with redundancy. An MoU has been signed with Aerial Delivery Research and Development Establishment [ADRDE], DRDO, Agra for design and realisation of parachute systems.

The designs of Crew Module to Service Module separation system, Umbilical Retention and Separation System (URSS), Orbital Module to LV separation system and the separation systems required for parachute release are in advanced stage. Development tests have been commenced.

CES avionics is configured as an independent system including instrumentation system and sequencing system. Instrumentation and telemetry requirements have been finalised. For the Crew Module, configuration of Health Management System (IVHM) and Data Acquisition System (IDAQ) and its electrical interfaces were finalised.



2.7 Space Situational Awareness and Management

Directorate of Space Situational Awareness and Management (DSSAM)

DSSAM manages all Space Situational Awareness (SSA) related activities within ISRO and serves as a focal point for interactions/collaborations between all agencies foreign and domestic in this domain.

The main objectives of the directorate are, to setup infrastructure to detect, track, identify and catalogue space objects and, to provide accurate and timely information to safeguard ISRO's space assets. Towards this goal, the directorate has initiated.

Project NETRA

Network for space object Tracking and Analysis (NETRA) is the first ISRO project with the primary objective as Space Situational Awareness (SSA). The prime goal of the project is to establish a network of observational facilities and a control centre, to identify, track and catalogue space objects that threaten the safety of Indian space assets. The control centre will process the tracking information from the observational network and provide accurate & timely proximity alerts to mission operations centres. The land for the control centre was identified in the Peenya campus of ISTRAC. Chairman, ISRO laid the foundation stone on 2nd August, 2019.

In the initial phase of the project, it is envisaged to established one radar at Shillong, Meghalaya, one telescope at Hanle, Ladakh and a control centre at Peenya, Bengaluru.

The project will also use the space objects tracking data from the existing facilities, Multi Object Tracking Radar (MOTR) at SDSC-SHAR, Sriharikota, Optical telescopes at Ponmudi and Mount Abu.

SSA is very important in the context of Gaganyaan due to the safety of life component involved in the mission. The directorate coordinates efforts towards safety of astronaut life including studies related to the probability of space debris impact in the selected orbit and selection of orbit with low probability of space debris impact.



International Collaborations

1. ISRO being an active member of the Inter-Agency Space Debris Coordination Committee (IADC), ISRO delegation (5 member team) attended the 37th IADC meeting at ASI, Roma, Italy and engaged in various technical discussions.
2. ISRO is currently in the process of signing an MoU with USSPACECOM for "Cooperation in Safety of Spaceflight and Provision of SSA Services and Information".



2.8 Infrastructure

Creation of new infrastructure across ISRO centres, in line with programmatic requirements and long term goals of organisation, is a major capacity building exercise. Discussions on 17 proposals through the institutionalised mechanisms of Programme Coordination Board [PCB] and Programme Management Council [PMC] were held during the period.

Infrastructure at different centres

IISU

- Inauguration of Integration Test Complex (ITC) - ITC was conceived to meet the enhanced production requirements of inertial sensors, inertial systems, actuators and mechanisms for launch vehicle and spacecraft programmes of ISRO
- Inauguration of Second Assembly Production Line of CSA and Ion-Beam Coating System
- Inauguration of Confocal Raman Microscopy
- Inauguration of Ultra Nano Indenter
- Accelerometer Test Station

ISTRAC

Realisation of NavIC Ground segment - ISTRAC has made significant progress in realising the ground segment for Navigation with Indian Constellation (NavIC). Out of the planned network of 17 One-way ranging stations, 16 have been realised and are supporting the NavIC ground segment operations on a 24/7 basis. Establishment of new IRIMS station at Biak is in progress and will be completed during 2020-21.

NavIC based timing receivers have been realised with the help of Indian industry. These receivers have been installed at ISTRAC TTC stations at Bangalore, SHAR, Lucknow and at MOX. They are being installed in other TTC stations and control facilities. NavIC based timing signals are being provided to all ISRO centres via spacenet. NavIC based Common view receivers are being deployed in place of GPS receivers at Hassan, Bhopal, Jodhpur and Shillong IRCDR stations.

LPSC

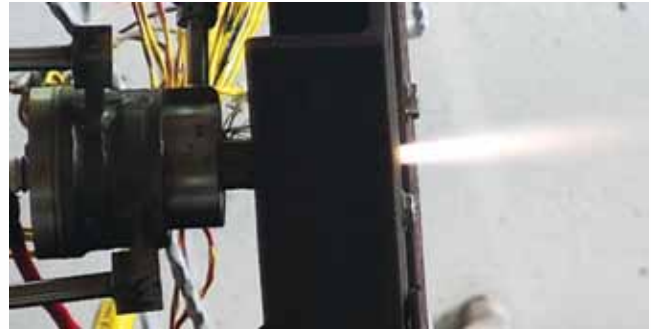
Integrated Cryogenic Engines Manufacturing Facility (ICMF) - This is an integrated facility for the realisation of the subsystems for Cryogenic and semi-cryogenic engines, viz., Thrust chamber, Gas Generator, Steering Engine, Turbo pump, Pre-burner and Heat exchanger for CUS, CE-20 and Semi cryo engines. This facility is established at M/s. HAL-



View from ICMF Main Entrance

ASD, Bengaluru. The civil works for the facility was completed by 2018. The procurement and installation of the equipment are also in progress with a target to commission the facility in 2019-20.

Combustion Research Lab (CRL) - A centralised data acquisition and control facility was commissioned in Combustion Research Lab with a capacity of 560 channels. Test and evaluation committee has given clearance for conducting hot tests in this facility.



Hot test of GOX-Methane igniter

Establishment of GOCO model Calibration Facility

- GOCO model calibration facility was established at LPSC-B for acceptance testing of pressure transducer and assembly and testing of level sensors. Validation for the assembly, calibration and testing lab to be operated on work package basis has been completed. Training has been imparted and operation has commenced from August, 2019.

Integrated Assembly & Test Facility for Spacecraft Thrusters (IATF-ST)

- This integrated facility being established for assembly, testing and delivery of 10N/22N Thrusters at a production rate of 200 thrusters per annum through GOCO mode. Clean room & Flow calibration facilities, Inspection lab, Vacuum furnace and EBW are established and ready for commissioning. Pre-delivery inspection had been completed for both CMM & Vibration Shaker, which are being imported.



IATF-ST Hot test facility

For HAT, all four Vacuum chambers along with Pumping system have been installed. Currently, the instrumentation activities are going ON and expected to be completed by October end. For sea level test facility, both mechanical and instrumentation side activities have been completed. The facility is awaiting T & D committee's clearance for a short duration hot firing.

Vacuum Brazing and Heat Treatment facility - This facility also has five of vacuum furnaces and two of Box type muffle furnaces. It contributed for production of pressure transducers and Sensors, 1N/11N thrusters, ageing of spacecraft propellant tanks, heat treatment of CUS thrust frame, Permendur core for magnetic torquers, PS4-PAS and other launch vehicle hardware.



NRSC

- **Construction of Outreach facility building at NRSC Campus Jeedimetla:** The facility is for the outreach activities of NRSC/ISRO including Training and Skill Development
- **Antenna Facility at CAZRI campus Jodhpur** - RCC framed antenna terminal building in two floors with antenna supporting structure
- **Construction of canteen building at RC-C, Nagpur** - Facility accommodating with general dining for 40 seater capacity and VIP dining area with 32 capacity
- Establishment of Ku band ground station GSAT Mission at Shadnagar
- Construction of S/Ka-band antenna terminal building (one) at Shadnagar campus
- Extension of Data Centre facility (IMGEOS Block B&C) at NRSC campus, Shadnagar is under progress

SHAR

Second vehicle Assembly Building

(SVAB):The Second Vehicle Assembly Building (SVAB) is realised and is ready for integration of GSLV Mk-II, GSLV-MkIII and future missions of the Indian Space Programme. It has been dedicated to the nation by the Honourable President of India, Shri Ram Nath Kovind on 14th of July 2019.



Honourable President of India Shri. Ram Nath Kovind inaugurated the SVAB

Visitors Complex - In tune with the Govt. of India policies and impetus on outreach programme, and to provide the opportunity to more public for witnessing the launch, a Visitor Complex – The Space Theme Park is planned at SDSC SHAR, Sriharikota. The major systems are 10,000 persons seating capacity Launch View Gallery, Space Museum, Space Theatre, Rocket garden and the Entrance plaza with necessary Security arrangements.



Inauguration of Launch View Gallery



Audience visit at Launch View Gallery to see Launch



Present Status:

- One of the major attractions of the Space Theme park, the Launch View Gallery, structural works are completed
- Around 8500 people from all age groups and walks of life, coming from all over the country witnessed the Chandrayaan-II Launch from the Launch view gallery on 22nd July, 2019
- The finishing works of the Launch View Gallery are under progress. All work packages are identified and are in various stages of tendering

VSSC - More than 30 major facilities were commissioned.

Trisonic Wind Tunnel Project: The Trisonic Wind Tunnel is being built for the generation of aerodynamic data for control, structural, thermal, flight dynamic design of launch vehicle/reentry spacecraft in the Mach number range 0.2 to 4.0. The turn-key project contract is being executed. Critical design of major systems has been completed and fabrication of systems requiring long lead time such as settling chamber, model cart and pressure vessels are in progress. Site activities for civil construction have progressed substantially. Readiness of all systems has been streamlined for the first blow down by May 2021.

Two PetaFLOPS Supercomputing Facility: Two PetaFLOPS Supercomputing facilities with computing nodes based on latest CPUs having sustained computing power of 2000×10^{12} floating point operations per second and high speed fully non-blocking interconnect (~ 100 Gbps) is being established for CFD analysis, structural analysis, weather prediction, big-data analysis, image processing etc. Technical evaluation of tenders has been completed and commissioning of the facility expected to be complete by April 2020.



2.9 Technology Management

Technology Transfer

The current year saw some notable technologies being licensed to Indian industries for commercialisation and regular production.

- Silver Plating with a Private Sector Industry
- Distress Alert Transmitter with a Private Sector Industry
- INRNSS(RS) receiver with three Public Sector Industry
- NavIC Messaging receiver with a Public Sector Industry
- Thermal Sensors with a Private Sector Industry
- BMT Ceramics with a Private Sector Industry
- ATN & GZT with a Private Sector Industry
- Waveguide bending with a Private Sector Industry

IRNSS (Restricted Services) receiver – a vital service for strategic users was licensed to Defence PSU. IRNSS–RS provides location navigation service with anti-spoofing technology for authorised users.

The year also saw the transfer of technologies related to societal applications, such as **Distress Alert Transmitter [DAT] and NavIC Messaging Receiver**. The INSAT based DAT can transmit emergency conditions and position location to a central HUB station via UHF transponder for rescue operations. Originally made available for transfer in 2010, the product has seen a rise in demand once again. **NavIC Messaging Receiver** is a relatively recent product, originally made available for transfer last year and mainly for fishermen community. The product is being offered free of cost, so as to ensure maximum permeation for societal benefits.

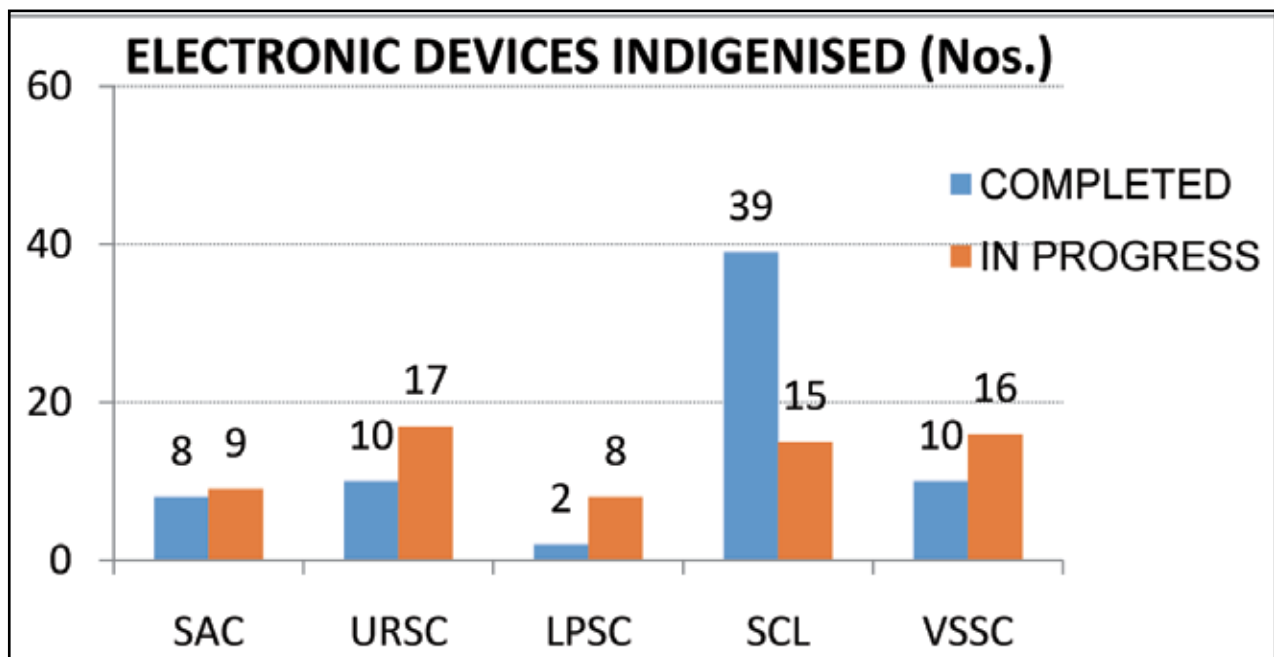
Besides, products such as **BMT Ceramics, Thermal sensors, explosives** such as **ATN & GZT**, were transferred to Indian industries for production. **BMT Ceramics** find applications in oscillators, multiplexers, filters, etc., above 10 GHz in satellite and terrestrial microwave communication systems. **Thermal Sensors** are used for heat flux measurement in laboratories. **GZT** is a nitrogen rich fuel, which has potential applications in airbag inflation systems for automotive industry, as an environment friendly alternative to Sodium Azide. **ATN** is a nitrogen rich oxidizer, an ideal ingredient for green propellant.

Know-how transfer of processing techniques such as **silver plating** and **waveguide bending** to private players was also done. **Silver plating** on Aluminium alloy components such as RF filters improves surface conductivity, thereby reducing the insertion losses. **Silver plating** on Invar is used for manifold, cavities, iris and adaptors. The know-how transfer for **waveguide bending** involved transferring an innovative process technology to fabricate waveguide run from thin-walled rectangular tubes, having various cross sectional dimensions.

Indigenisation

Launch vehicles and satellites use various critical materials and components which are space qualified. Even though Indian industries are supplying a majority of the materials, few critical materials and electronics components & packages are still being imported, as the volumes are very less for industry to produce and owing to non-availability of certain critical technologies. The import component is around 10% for launch vehicle and around 50 – 55% for satellites. A majority of materials are indigenised and inducted into the programmes. Development of materials is a continuous activity to reduce the structural weight of the hardware. In case of electronic items, a manifest is being prepared to cataloguing the items and prioritising the components and packages for indigenisation. Efforts are initiated with the Indian industry encouraging them to form consortium to invest and produce the components and packages. ISRO is also taking initiation to set-up facilities which run on GOCO basis, where the activities are not viable through industry.

Indigenisation of Electronic Items by various ISRO centres:



Productionisation and Industry Interface at various ISRO Centres

IISU - With the objective of enabling Indian Industries in inertial sensor technology area, IISU has initiated licensed production of major inertial sensors such as DTG, CSA and ILG. During last year, the phase 0 activities (Transfer of inertial sensor processing technology, training and handholding activities) were completed. IISU has provided Knock Down Kits (KDKs) for selected industries and they have completed few sensor subassemblies. The next phase activities for end to end realisation of sensor subassemblies have commenced.



IISU has also initiated vendor development activities in the area of mechanical fabrication of Inertial Sensor components and electronic package realisation. New vendors have identified in mechanical fabrication considering increased throughput due to programmatic requirements.

LPSC - Industry interface is given utmost importance to ensure production of quality products for both ongoing and development programme. Manufacturing of parts and sub-assemblies for launch vehicle and spacecraft engines, thrusters, propellant tanks, structures, flow control components, modules, umbilical systems, stage subsystem and interface elements, transducers, etc. are regularly being carried out.

Launch Vehicle related - 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. Integrated Production of Control System Modules and Components (IPCS) completed. Production of PS2/GS2 Propellant tank through second work centre initiated and first tank delivered.



First PS2 tank realized through BATL

Integration and testing of PS1–RCS packages, Integrated L40 stage production, Integrated production of components and modules, electrical actuators and DC Geared motor production, continued through Public & Private Sector Industries. Commissioning of ICMF at HAL at a public sector industry is in progress. Augmentation of tank production facility in the industrial partner.

Spacecraft related - Through the production contract with a Public Sector Industry, seven sets of Cassini end dome tank parts were delivered. A state-of-art fixture for realisation of 390 mm height central ring of Dia 1150 mm was developed and demonstrated meeting stringent tolerance requirements. Further, a Public Sector Industrial Partner deliver six more sets of pressure vessel parts before December 2019.



Realisation of pressure vessel parts at M/s. BHEL

Transducers & Sensor related - Orders are placed for production of transducers for propulsion systems through industries. Temperature sensors, MEMS & IDLV Pressure transducers, 21NA and DPT production through industries were continued. A total of 847 various types of transducers were successfully delivered to launch vehicle program to meet requirements up to PSLV-C48, GSLV F11, LVM3 M2 missions, Semi-cryogenic engine, GEOSAT & IRS projects. During the period of reporting.



New production contracts - Towards improving the throughput of propulsion systems, assembly and integration of matured systems were transferred to Industry. The major contracts signed in this direction are given below;

SAC - There is a significant involvement of Indian industry for the subsystem development of various projects. SAC pursues the indigenisation programme for critical components and material with industry participation. During the period, Two MoUs and Three Technology Transfer Agreements were signed.



2.10 Quality Management

The Directorate of Systems Reliability and Quality (DSRQ) is an apex body at ISRO Headquarters closely interacting with Centres/Units developing the quality and reliability policy aspects of space and launch systems. The major role of DSRQ is to empower Systems Reliability and Quality teams across ISRO to achieve high reliability by ensuring implementation of excellent quality systems and procedures in all ISRO Centres and Units as well as at all external work centres. The major thrust areas of the Directorate include implementation of the Absolute Quality Program pooling the wisdom of all ISRO employees as a participative venture, review of quality practices at various ISRO Centres/Units and implementation of uniform practices wherever applicable, contributions towards ISRO projects in ensuring the proper closure of non-conformances, generation of ISRO Technical Standards (ITecS) in all areas of activities, sharing of best practices among ISRO Centres, quality outreach, etc.

Review of Quality practices at ISRO Centres/Units/External work centres

The Directorate reviewed the quality practices at most of the ISRO Centres/Units towards the identification of systemic quality issues in the functioning. Action taken reports were obtained from many of the Centres, and specific areas for improvement were identified. Review of external workcentres supplying various deliverables to ISRO Projects is also envisaged. Quality system at Aerospace Division of M/s HAL was also reviewed by DSRQ and salient points with respect to operational missions of PSLV, GSLV, GSLV Mk III as well as Gaganyaan mission were addressed.

Integrated Product Assurance Board (IPAB)

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. Meetings of the Integrated Product Assurance Board (IPAB) focusing on the on-ground and in-orbit observations in Payload systems, power/electrical distribution systems, TTC RF / DH-RF, composites, pyros, EO Payload data and ground segment related observations in communication, navigation & ranging, meteorology and earth observation spacecraft of ISRO were organized. Follow up was carried out for the actions identified in the previous meetings of IPAB and more meetings are periodically planned.

ISRO Projects

For the prestigious Gaganyaan mission, DSRQ prepared the document, "Safety and Mission Assurance guidelines for Gaganyaan" jointly with Directorate of Occupational Health and Safety (DOHS). Presentations on Human Rating aspects of space missions, human rating certification mechanism and risk management were made to the Gaganyaan review committees. DSRQ is working out Probabilistic Risk Analysis (PRA) methodology for safety analysis as well as calculation of the risk metrics Probability of Loss of Crew, P(LoC) and Probability of Loss of Mission, P(LoM) in Gaganyaan.

DSRQ has been closely involved in the follow up of the Non-conformances, changes and pending actions identified by major review towards ensuring the quality and reliability of launch vehicles. A report on the observations in PSLV C45, C46, C47 and C48 missions specifically identifying the OPEN issues for future missions was prepared. This report also includes issues identified as 'OPEN for future missions' from the previous PSLV campaigns for necessary follow up and closure. This exercise is being taken up for all future launch vehicle missions of PSLV, GSLV and GSLV Mk III as well. A report on systemic quality improvements in launch vehicle area in general in the light of the observation in GSLV Mk III M1 during its first aborted launch attempt was made based on the active participation in the recovery activities during launch hold, assessment and cause identification, correction, verification and successful re-launch. The lessons learned from previous missions were also included in the report. In the spacecraft area, DSRQ prepared a brief compilation of observations seen in RISAT-2B post-launch. Further, it prepared a report on observations in GSAT-11 Propulsion system in consultation with the relevant experts. Similar exercise is planned for future spacecraft missions as well.

Based on the continuous follow-up of closure reports for on-orbit anomalies, task teams have been setup to review the same observed in inertial systems developed by IISU as well as sensors & FOGs developed by LEOS.

ISRO Technical Standards (ITecS)

DSRQ has been playing an anchor role in the generation of ISRO Technical Standards towards documenting the best practices in the various disciplines of engineering for standardizing the practices as well as for preserving this knowledge base for the benefit of future generations. 39 Task Teams are working towards generating these standards

in all areas of Space Systems. Six

ITecS documents have been printed and released by Chairman, ISRO during the 118th meeting of ISRO Council on October 16, 2019.



Another nine standards have also been approved by the two tier review mechanism of Expert Review Committee and Executive Committee for printing. Another set of about 15 documents have also been reviewed and approved by the first level Expert Review Committee. Further reviews and downstream activities are planned for generation of the remaining standards. The picture below shows one of the completed standards.



Absolute Quality Program

Chairman, ISRO announced the Absolute Quality Programme (AQP) for operational missions of ISRO on 19th November, 2018. Focus on operational missions and involvement of not just QA teams, but each and every individual of ISRO sets AQP apart as an innovative initiative. AQP is a participative venture involving all stakeholders and focuses on lessons from the past and improvements for the future. AQP also seeks to sustain the culture of openness, integrity and trust and also serves as a motivator for the entire workforce of ISRO. AQP aims at empowering all - from the top management to the shop floor personnel – to imbibe the quality awareness and follow quality protocols in every step of realising the mission. It encompasses all areas of component realisation from design stage to final acceptance and application. The focus will shift from detection to prevention of non-conformances. AQP sessions were conducted at VSSC, LPSC, URSC, SAC, NRSC, PRL, SDSC, NESAC and IPRC including a few sessions at the sub-contractors' sites.

ISRO Quality Awards

This new awards scheme is specifically aimed at encouraging and motivating all personnel contributing towards the quality and reliability of space systems of ISRO. This scheme has been approved by the Space Commission with a total of 16 annual awards for engineers, scientists, technicians, technical assistants, junior engineers, etc.

The Committee for finalizing guidelines and selection modalities for ISRO Quality Awards was constituted and different categories of awards as given below were identified.

1. Dr. Vikram Sarabhai Quality Award for Outstanding Achievement, one award for Scientist / Engineers- G and Above
2. Dr. Satish Dhawan Quality Award for Excellent Performance , two awards for Scientist / Engineers- SF & SG
3. Dr. Brahm Prakash Quality Award for Significant Achievement, three awards for Scientist / Engineers- SC, SD & SE
4. Dr. S Srinivasan Quality Award for Significant Contributions, ten awards, for Technical/Scientific Assistants, Technicians, Draughtsmen, Junior Engineers, Assistant Engineers, Scientific Officers and Technical Officers, etc.

The Selection committee constituted has scrutinised the nominations received from various ISRO Centres/Units and finalised the names of ISRO Quality awardees which were submitted to Chairman, ISRO for approval. The list of awardees has been declared through ISRO HQ portal on December 06, 2019.



Participation in ISO Technical Committee meetings

DSRQ represented India through ISRO & Bureau of Indian Standards (BIS) and participated in the International Plenary meetings of ISO TC20/SC14 at British Standards Institution (BSI) Office, Chiswick, London during June 10 – 14, 2019.





2.11 Occupational Health and Safety

Space programme necessitates critical operations which are hazardous in nature and requires extreme precautions to prevent an unintended incident or an accident. A minor safety lapse is enough to jeopardise the programme or delay a vital schedule of the programme. ISRO has well defined Occupational Health and Safety management system in place. The primary objective of Occupational Health and Safety management system is to control the hazards at the system level by eliminating failure modes. Occupational Health and Safety management is a planned, disciplined and systematic approach to identify, analyze, and control / eliminate hazards to protect men, machine and material.

In order to achieve highest occupational health and safety standards for every operation in ISRO Centres/Units and to take care of statutory obligations with external agencies, Directorate of Occupational health and Safety (DOHS), at ISRO HQ and Centre Safety committees at ISRO Centres/Units are keenly monitoring each and every activity through a systematic review mechanism.

DOHS Programme Highlights

- Completed safety audit and inspection of various Centres/Units, namely IPRC, SAC, NRSC, ISRO HQ and NARL as part of the Inter-Centre Safety audit programme
- Organized two sessions of the life saving training program on 'Basic Life Support' for the employees of ISRO HQ to empower them with first aid practices on Cardiopulmonary Resuscitation for reviving the heart beats and breathing in the event of a cardiac arrest/ stroke



"Basic Life Support" session in progress

- Prepared and provided emergency evacuation guidelines to all ISRO Centres/Units to conduct Fire Emergency Mock drill
- Submitted the required safety amendment clauses, applicable to ISRO activities, to DOS for getting the same included in the forthcoming amendment of Explosive Rules 2008 by DIPP

2.12 Academia Interface & Sponsorship Research

RESPOND

Introduction

RESPOND (Research Sponsored) programme started in the 1970s, aims at establishing strong links with the 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 the wide range of topics in space technology, space science and space application areas to universities/ institutions. 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.

Also, under the new initiatives of Capacity Building Programme, ISRO has established three new Space Technology Cells at IIT Roorkee, IIT Guwahati and IIT Delhi to carry out advanced research in the areas of relevance to the future technological and programmatic needs of ISRO. Further, ISRO has already established three Regional Academic Centres for Space (RACs), at MNIT Jaipur, Gauhati University, Guwahati and NIT Kurukshetra, Kurukshetra and is also in the process of setting up a few more (RAC-S) and hence covering all six regions of the country (such as North, West, Central, South, East and North-East). RAC-S aims to pursue advanced research in the areas of relevance to the future technological and programmatic needs of the Indian Space Programme and act as a facilitator for the promotion of space technology activities among students in the region. This will also inculcate scientific research temper in the student community and will give them an opportunity to work in the advanced field of research. RAC-S will also facilitate and engage other institutes of excellence in the region to take part in the capacity building, awareness creation and research & development activities.

As per the MoU with the Centre for Nano Science and Engineering (CeNSE), IISc, Bengaluru, R & D activities, utilisation of nanofabrication and characterisation facilities have been taken up by various centres of ISRO, in addition to training/capacity building with the centre.

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 materials, especially non classical continuum mechanics and Geometric and data driven models for space applications.

In addition to this, in order to enhance infrastructure requirement for Space Science activities in the Jammu & Kashmir region, an MoU has been entered into with Central university of Jammu to establish a centre for Space Science. The centre will also take care of the emerging Geospatial and Space technology requirements for the development of the region.



Also, 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) and Smart India Hackathon (SIH).

Activities

During the year, RESPOND supported 56 New Projects and 63 Ongoing Projects and five Space Technology Cells and Joint Research Programme with SavitribaiPhule Pune University. In addition, 5 ISRO Chairs, 72 conferences/symposia/ publication and other scientific/promotional activities have been supported. During the year, 25 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 53 Universities/Colleges, 22 IITs /NITs and 5 Research Institutes/ Laboratories with sponsored projects (Figure-1). Further, during the year, a large number of projects have been supported in the area of Space Technology (74) followed by Space Applications (32) and Space Science (13) (Figure-2).

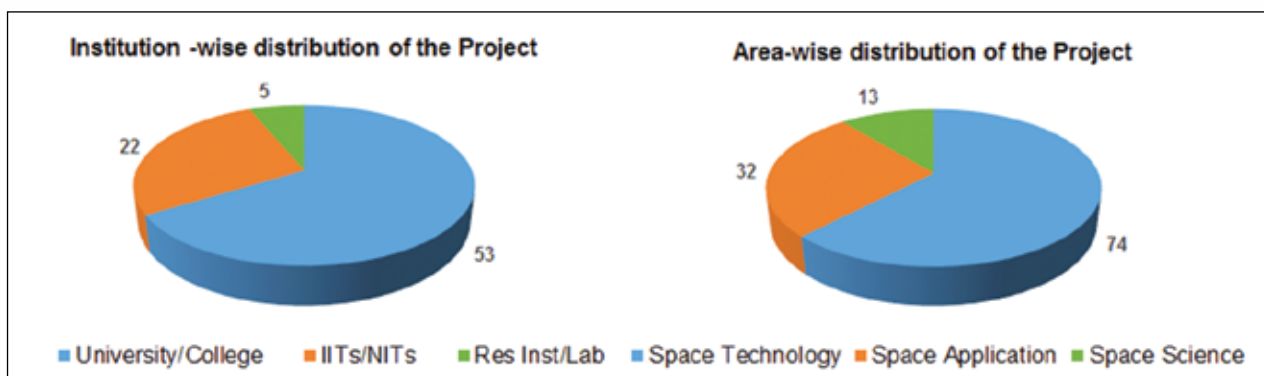


Fig (1)

Fig (2)

Projects at Space Technology Cells (STC): During the year 2018-2019, RESPOND has supported 76 new projects, 125 ongoing projects of five Space Technology Cells and Joint Research Programme at Pune University. Under STCs, 69 projects have been successfully completed during the year. Details are given in the table below:

Sl. No	Name of the STC/JRP	No. of Projects (2018-19)		
		New	Ongoing	Completed
1.	IISc Bengaluru	18	20	19
2.	IIT Madras	7	16	9
3.	IIT Bombay	9	13	12
4.	IIT Kanpur	20	27	9
5.	IIT Kharagpur	11	28	9
6.	SP Pune Univ.	11	21	11
	Total	76	125	69



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 completed RESPOND Projects

- *Simulation of interaction of rocket engine exhaust with lunar dust using DSMC*- Under this project, a 2-D axi-symmetric code was developed to simulate expansion of nozzle exhaust from the lunar lander. The flux was tabulated for different particle sizes. The code has been parallelised and transferred to LPSC. This code will be used to estimate lunar dust profile generated at various altitudes when central engine alone would be firing in Chandryaan-2 mission
- *Effect of Terrain Relief and vegetation cover on interferometric SAR derived digital elevation models* - The project has successfully developed an Algorithm and code for the fusion of the ascending and descending pass DEMs. The technique will be useful in the NISAR based DSM generation on hilly terrain
- *Study of shock turbulent boundary layer interaction in high speed air intakes* - Under this project, the intake configuration of interest to VSSC was taken for study. The three dimensional flow was simulated using CFD code and the solution was analysed. The developed software was delivered to VSSC. The project deliverable will be useful in the development of advanced Air Breathing Propulsion Project
- *GPU based Multi-Temporal Implementation of Image Change Detection Algorithms and their Verification (TIT)* - Under this project, the developed algorithms (both multispectral image and SAR image based algorithms) were installed and demonstrated at SAC and will be used in related future projects
- *Experimental studies on ISROsene/Kerosene Gel Propellant spray loaded with Nano – Alumina Particles* -The project studied the atomisation of gelled ISROsene loaded with micro and nano particles of alumina in the like-on-like impinging jet atomiser. Under this project, facility for the gelling of ISROsene with or without the simulat alumina has been successfully built, tested and employed. It has the capacity of producing 1.5 kg gelled propellant per hour
- *HEMT modeling for broad temperature and frequency ranges* - Under this project, a physical surface potential based model for AlGaIn/GaN HEMT framework has been developed. The model is validated rigorously with DC and RF experimental data for a wide bias and temperature range which makes it suitable for the space applications. The model accuracy and robustness have been tested by performing the standard benchmarking tests. The model code is written in Verilog-A language. Device characterisation and TCAD simulations were also performed to understand various physical mechanisms related to GaN HEMTs which helped to enhance the compact model by including real device effects
- *A local short term model for forecasting Ionospheric Scintillations for GNSS applications over Indian region* - The project has successfully developed an efficient algorithm for short term forecasting of scintillations on local basis for Indian Conditions. Reports have been generated



on a the usefulness of the forecasting of ionospheric scintillations for the ongoing ISRO research and on the applicability of the results to improve the integrity aspects of GNSS based navigation systems in India to reduce the system development costs

- *Erosion Behaviour of ZrB₂-SiC Composites* - Under this project, the understanding on the effect of SiC particle reinforcement on the erosion wear behaviour of ZrB₂ –SiC composites were obtained. Superior erosion resistance of ZrB₂-SiC composites with large amount (30 vol%) of SiC suggests suitability of the composites for wear resistant applications in Space Vehicle Assembly
- *Design and development of a Proof-of-Concept Model of an adaptive Membrane* - The project aimed to understand dynamic behavior of membrane structures and its control at on-orbit conditions. Under this project, Adaptive Shape Controller is developed to make membrane – based Space Structures adaptive. This work invention provides the surface flat of the planar membrane structures which improves the efficiency of Space based membrane reflector, mirror etc. This can be directly used on the development of Inflatable antenna membranes for future missions
- *Solar wind turbulence, viscosity and implications for the propagation of coronal mass ejections* - Under this project, the PI has studied the solar wind turbulence and used the results to get implications for the aerodynamic drag operating on coronal mass ejections as they propagate from the Sun to the Earth. The proposal is relevant to current national and international research activities in solar heliospheric physics. The outcome of this project is expected to help interpret the data from the Aditya Mission.
- *Non-linear structure (evolution and effects) of Oscillating plasma bubbles in various experimental conditions* - Under this project, PI has successfully developed a laboratory experiment to create plasma bubbles of different geometries under different physical conditions

ISRO ACADEMIA DAY-2018

ISRO has always looked for greater participation and contributions from academia in a focused manner, for timely accomplishment of its objectives. Considering the ongoing involvement of academia in ISRO activities and to enhance the collaboration to newer areas, ISRO Academia Day-2018 was organized at Indian Institute of Remote Sensing (IIRS), Dehradun on November 13, 2018.

ISRO Academia Day-2018 aimed at providing a common platform to Academia as well as the scientific

community of ISRO to share their knowledge, experience and create awareness about the



opportunities available in ISRO for the promotion of Space Science & Technology, Education and Research.

Around 150 participants, mainly from IITs, NITs, selected Private and Scientific Institutes attended the programme. There were invited talks on the topics like Capacity Building Programme and Initiatives, IIST activities and interface with academia, Gaganyaan, Opportunities in Space Science Programme, Student Satellites; Training and R & D opportunities at IIRS; Opportunities under Sponsored Research; Emerging Research Areas of ISRO; Space Technology Cell-Activities and Highlights of Research Findings to name a few.

Two documents were released during the “Academia Day-2018”-“Research Areas in Space” and “RESPOND Basket”

The “Research Areas in Space” document was prepared to enable the faculty of Universities/ Institutes to prepare suitable proposals of relevance to Space programme. In the document, a detailed list of R&D areas/sub areas/topics/problems and a brief write up is provided about major programmes of ISRO. The faculty/researcher can select a suitable topic/problem and prepare the proposal and submit it to the concerned centre/unit for consideration. “RESPOND Basket” comprises around 150 urgent and most important research areas with a brief write up about the topic for the participants to select and prepare detailed proposals on a priority basis.

Young Scientist Programme (YUva Vigyani KARYakram YUVIKA)- 2019

During the year 2019, ISRO has successfully conducted a special programme for School Children called “Young Scientist Programme” “YUva Vigyani KARYakram”. The programme was in tune with the Government’s vision “Jai Vigyan, Jai Anusandhan”. The Program aimed at imparting basic knowledge on Space Technology, Space Science and Space Applications to the younger ones with the intent of arousing their interest in the emerging areas of Space activities. The program thus aimed at creating awareness amongst the youngsters who are the future building blocks of our Nation. The programme was chalked out to “Catch them young”.

The programme was of two weeks duration and the schedule of the programme included invited talks, experience sharing by the eminent scientists, facility and lab visits, exclusive sessions for discussions with experts, practical and feedback sessions and a few local excursions. Three (3) students from each State/ Union Territories were eligible to participate in the programme based on their 8th standard result. Weightage was also given for the membership of the Science Club/





Space Club, Prizes in school based individual extra-curricular activity and Winners of District/ State/National/International Level sports activities, Scout and Guides/NCC/NSS Member. Special weightage was also given to the schools located in the rural areas. A total of 111 school students attended the programme.

Under this programme, the students were given an opportunity to visit the major centers of ISRO to understand the technology and science. All the students were given an opportunity to visit SDSC, Sriharikota during the programme and SAMWAD with Chairman, ISRO.

ISRO-STC Confluence

The First ISRO Space Technology Cell Confluence was held at IIT Madras, Chennai during September 16-17, 2019. The conference was organised with an objective of sharing information about the research underway in various institutions, the salient findings and to understand the utilisation of STC outputs in ISRO.



The confluence was attended by the Conveners and JPC Members of the Existing STCs (IISc, Bangalore; IIT Kanpur; IIT Bombay; IIT Kharagpur; IIT Madras; UoP Pune) and by the conveners of the newly established STC (IIT Guwahati, IIT Roorkee). Apart from this, RESPOND Committee Chairmen and RESPOND Coordinators also actively participated in the Confluence. Around 100 participants enthusiastically participated in the two days Confluence.

Space – Technology Incubation Centres (S-TICs)

To attract and nurture the young academia with innovative ideas / research aptitude for carrying out research and developing the Academia–Industry ecosystem for Space Technology, ISRO is in



the process of setting-up of one Space Technology Incubation Centre in six regions of our Country, viz., Central, East, North, North-East, South and West. This will enable the young academia to realize their innovative ideas / research aptitude into space grade components/elements which can be utilised for space applications, and guide them towards setting-up the future start-ups.

In this regard, S-TICs at NIT-Agartala, Trichy and Jalandhar have been inaugurated and interaction meetings with ISRO centres for sharing of projects are ongoing.



2.13 International Cooperation

Indian Space Research Organisation (ISRO) is pursuing bilateral and multilateral relations with space agencies of other nations and multilateral organisations through carrying out joint activities of mutual interest; sharing expertise in the applications of space technology, organising international events in India and participating 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.

In order to intensify the existing space relations and also to establish new relations with other nations in the peaceful uses of outer space, the following eight cooperative documents with Space agencies of eight countries were signed during this period:

- i. Memorandum of Understanding (MoU) between India and Tunisia for cooperation in the exploration and use of outer space for peaceful purposes
- ii. Implementing Arrangement (IA) between ISRO and Korea Aerospace Research Institute for cooperation in space exploration
- iii. IA between ISRO and DLR of Germany for exchange of personnel
- iv. Statement of Intent between ISRO and Bahrain's National Space Science Agency on collaboration in the area of space technology
- v. IA between ISRO and CNES of France for the establishment of a framework for the realisation of joint maritime domain awareness mission
- vi. Agreement between India and Mongolia on cooperation in the exploration and uses of outer space for peaceful and civilian purposes
- vii. IA between ISRO and NASA of USA for cooperation on the airborne synthetic aperture radar (ASAR) campaign
- viii. IA between ISRO and Japan Aerospace Exploration Agency (JAXA) concerning collaborative activities on APRSAF/SAFE Agromet project.

India and USA intensified their space cooperation and carried out many activities during this reporting period. Significant progress has been made in the joint realisation of microwave remote sensing satellite mission 'NASA-ISRO Synthetic Aperture Radar (NISAR)' by conducting various technical review meetings both at NASA's Jet Propulsion Laboratory (JPL) and ISRO's U R Rao Satellite Centre (URSC) and also the Joint Steering Group (JSG) meeting. The Balloon measurement campaigns of the Asian Tropopause Aerosol Layer (BATALL) was conducted in July-August 2019. Chandrayaan-2 lander carried NASA's Laser Reflectometer Array (LRA). Both agencies have also formed a Working Group on Human Spaceflight Programme (HSP) by signing a Charter in June 2019. Also, ISRO and NOAA officials finalised the interface control document for SCATSAT-1 data reception and commanding setting at NOAA. Overall cooperation among the space entities of both nations were reviewed during the seventh meeting of India-USA Civil Space Joint Working Group (CSJWG), organised at ISRO Headquarters, Bangalore during November 20-21, 2019.

India-Russia space cooperation made significant progress in this period mainly in the field of Human Spaceflight Programme. In follow up to the MoU signed in October 2018 for cooperation in HSP, both agencies have formed “ISRO - ROSCOSMOS Joint Working Group” and concluded a few contracts for specific activities in India’s GAGANYAAN programme. The astronaut candidates were selected and deputed to Russia for medical examination. In addition to HSP cooperation, 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 completed the feasibility study to realise an earth observation satellite mission with thermal infrared imager ‘TRISHNA’ and are working towards finalising an implementing arrangement. Both agencies have also finalised all interface control documents for accommodating CNES’s ARGOS instrument in ISRO’s OCEANSAT-3 satellite. India and French institutes took review in April 2019 on the on-going Ka-band propagation experiment using signals from GSAT-14 satellite. The discussions on establishing a NavIC reference station in France and CNES Scintillation receivers in India are also progressing well. Joint working groups were formed in many themes including Earth observation, Planetary exploration, Launch vehicle development, Communication and Navigation and HSP to further explore cooperation opportunities. HSP Working Group had a number of discussions on medical aspects of human spaceflight, As part of this, a Flight Surgeon from CNES space medicine facility visited India in July-August 2019 and interacted with medical experts of ISRO and Indian Air Force.

India-Japan space cooperation is currently focusing on earth observation, lunar exploration, satellite navigation and human spaceflight programme. ISRO and JAXA are specifically working on sharing earth observation data and to carry out calibration/ validation experiments; establishing ISRO’s NavIC reference station in Japan; and exploring the possibilities of utilising JAXA’s HSP elements engineering models for ground tests at ISRO for validating the software and interfaces.

As part of India-Germany space cooperation, the fourth ISRO-DLR technical workshop was organised in March 2019 at Oberpfaffenhofen, Germany. As a follow-up to this, ISRO and DLR officials are currently exploring cooperation in Earth observation data processing; Calibration and Validation of remote sensing optical and microwave payloads; Disaster management support; Ground station support; Flight dynamics of inter planetary missions; X-ray spectroscopy and robotic exploration.

India and Bhutan have formed a Joint Working Group to explore the possibility of jointly realizing a small satellite. A team of 10 Bhutanese Students’ accompanied by three Bhutan officials visited ISRO in September 2019 to witness the final operations of Chandrayaan-2 landing on the moon.

ISRO delegation visited the Ukraine’s National Space Facilities Control and Test Center (NSFCTC) and other space situational awareness and monitoring facilities in July 2019 and discussed on cooperation opportunities in the field of space situational awareness. An NSFCTC delegation visited ISRO in December 2019 to further discuss on this.



Officials of ISRO and the newly formed Australian Space Agency (ASA) had interactions to explore cooperation in earth observation and satellite navigation. Australia has communicated that ASA will be the implementing agency for the space cooperation MoU signed in October 2012.

During this period, ISRO has interacted with officials of Bangladesh, Canada, Chile, Mongolia, Morocco, Panama, Peru, South Korea, Sweden, Tajikistan and Uzbekistan on various areas of cooperation.

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 2885 beneficiaries from 109 countries.

A Course on “Space Debris and Space Situational Awareness” was organised at ISRO HQ in June 2019 with experts from European Space Agency (ESA). IIRS conducted specialised one-week training in August 2019, on ‘Forest fire monitoring through space technologies’ to Mexican officials. A one week course for five Sri Lankan officials was organised at NRSC on ‘Geospatial technologies for drought and water management’ in August 2019.

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), ISRO has completed two batches of 8-week capacity building training programme on nano satellite development, named as UNNATI (UNISpace Nanosatellite Assembly and Training by ISRO). 29 officials from 17 countries successfully completed the training during January – March 2019 (Batch 1) and 30 participants from 16 countries successfully completed the training during October – December 2019 (Batch 2).

ISRO hosted the 14th meeting of International Committee on Global Navigation Satellite Systems (ICG) at Bengaluru, during December 8-13, 2019. ISRO is also organising a symposium on human space flight in January 22-24, 2020 in association with International Academy of Astronautics and Aeronautical Society of India at Bengaluru, India. The theme of the symposium is ‘human spaceflight – present challenges and future opportunities.

During this period, ISRO has hosted a number of dignitaries including Hon’ble President of Mongolia, the US Secretary of Commerce, Ambassadors of Tunisia, France, Luxembourg, Argentina and Thailand and High Commissioner of Australia to India.

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 for a 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).

Space Act

The department is in the process of enacting a legislation to support overall growth of the space activities in India with a higher order of participation of various agencies including public/ non-governmental/private sector stake holders, in compliance with the obligations under international 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 and start-up companies in aerospace sector, under due authorisation by the Central Government.



2.14 Space Commerce

NewSpace India Limited (NSIL) was incorporated during March 2019 as a wholly owned Government of India company, under the administrative control of Department of Space. NSIL acts as a Commercial arm of India Space Research Organisation (ISRO).

The vision of NSIL is to provide space related products and services emanating from Indian Space Programme to global customers and to spur the growth of Indian Industry in undertaking technologically challenging space related activities. NSIL was incorporated with the primary mandate of production/ manufacturing of Polar Satellite Launch Vehicle (PSLV) and Small Satellite Launch Vehicle (SSLV) through Indian industry, production and marketing of space-based services including launch and space-based applications, Transfer of Technology developed by ISRO to Industries and to market the spin-off technologies and products/ services emanating out of ISRO's activities. NSIL since inception has actively taken up various business-related activities.

Towards productionising PSLV and SSLV through Indian Industry, NSIL held an Industry Meet during June 2019 and has subsequently charted out plans for the same. NSIL is presently working on a proposal for realising five PSLV's through Indian Industry.

In the area of Launch services, NSIL has signed several Launch Service Agreements for launching customer satellites, which includes two dedicated PSLV Mission and one dedicated SSLV Mission. During NSIL as part of the commercial arrangement with customers, has launched 13 customer satellites onboard PSLV- C47 during November 2019 and 9 Customer satellites onboard PSLV-C48 during December 2019.

Recently, NSIL has also commenced its satellite-based services activities. In the area of Remote sensing data services, NSIL has signed a contract to carry out End Line Impact Evaluation Study (Sujala-III Project). As part of Mission Support services, NSIL has signed Contract with a customer for providing LEOP services.

Under technology transfer, NSIL signed an MoU with SCL/DOS for the production of Application Specific Integrated Circuits (ASICs) for Control Electronics for supply to the end user. NSIL has also worked out a Generic MoU with SCL/DOS to utilise the services of SCL for the Development and Supply of ASICs and Systems/ Sub-systems as per user requirements on a Commercial Basis.

NSIL is in discussion with various international space agencies/ organisations to provide end-to-end solutions to build, launch and operate Communication and Earth Observation Satellites, provide Mission Support Services and establish Ground Systems to meet their requirements.

As part of outreach and promotion of company's commercial activities, NSIL participated in the International Astronautical Congress-2019 held at Washington DC, USA during October 2019.

2.15 Outreach Activities

Vikram Sarabhai Centenary Programme

100th birth day of Vikram Sarabhai was on August 12, 2019. To commemorate this, ISRO and Department of Atomic Energy (DAE) initiated various programmes at national level during the centenary year, starting with Inauguration function on August 12, 2019 at Ahmedabad and extending till valedictory function on August 12, 2020 at Trivandrum.

Inaugural function at Ahmedabad

The function was conducted in Gujarat University Convention Centre, Ahmedabad on August 12, 2019 and was attended by 2500 dignitaries (DOS, DAE, Sarabhai family, Dr Sarabhai Affiliated Institutes and industries)



The following events are being conducted across centres and broad guidelines have been given for conducting the events.

VIKRAM SARABHAI LECTURE SERIES:

Lectures related to space programmes and contributions of Vikram Sarabhai by eminent speakers are planned at major cities / educational centres of various states covering the entire country.



CENTENARY EXHIBITION:

Exhibitions displaying the space related activities and contributions of Sarabhai are being conducted at around 100 locations across India by all ISRO/ DAE centres. The display material includes panel boards narrating the information and models for the demonstration to students and public. The publicity materials like caps, T-shirts, key chains, posters, brochures, stickers, cards, etc., being are distributed at each location.





COMPETITIONS:

Various competitions are being planned at colleges and schools and the winners of the competitions will be given mementos and certificates.



SPACE CLUBS:

A special module was developed in collaboration with Vikram Sarabhai community Science Centre, Ahmedabad to create space clubs at various schools across the country where students are being exposed to activities like water rockets, do-your-own kits and teaching instruments.





MURALS:

Hoardings displaying space activities, achievements and societal applications are being organised at prominent places of major cities.

AWARDS / RECOGNITIONS

Vikram Sarabhai journalism awards were announced in two categories. These awards may contain mementos / citations in commemoration of Sarabhai.

ARCHIVAL

Compilation of various articles, papers, journal reports, books and media matters related to Sarabhai are being carried out by ISRO centres based on the feasibility.

MOBILE EXHIBITIONS:

Space on wheels – ‘Space on wheels’- which is a mobile exhibition having ultra-modern interactive systems, dioramas and static models to carry out outreach activities in remote location across India was conceived and realised Six such mobile exhibition buses were handed over to ISRO centres region wise and are being utilised for outreach activities.





COLLABORATIVE EVENTS:

Collaborative events with Industry / academia / institutions/ professional bodies like arranging pep-talks, workshops, shows and seminars on space related topics are planned at convenient locations.

World Space Week was Celebrated from October 4-10, 2019 in all ISRO centres.

Two Space related movies were screened at LPSC seminar hall on 4th October for Employees (Apollo 13) and 9th October for Girl students of GHSS, Nedumangadu (October Sky) at LPSC Seminar Hall.



LPSC organised the all Kerala Painting Competition for Upper Primary and high school students on 5th October 2019, simultaneously at four venues across Kerala, jointly with VSSC and IISU. The competitions were organised at St. Joseph's HSS, Trivandrum. The program attracted huge public interest and was noted for the participation of more than 1300 students across the 4 venues. A team of eminent judges evaluated the paintings and prizes were distributed at the respective venues.



LPSC conducted essay writing, poster, cartoon and photography for Arts and Science college students and video making for Journalism students. Public were also allowed to participate

in Cartoon competition. All these competitions were in online mode. Respective prize winners of competitions were awarded on the valedictory function.



One-day workshop conducted by NARL at IIT, Bhubaneswar

LPSC organized a quiz cum awareness program with a mini exhibition at National Institute of Speech and Hearing, Trivandrum. Huge response was there for the program around 104 Hearing Impaired students participated in Quiz Competitions. Three winners were invited to valedictory function.

A one-day workshop on “Research opportunities at National Atmospheric Research Laboratory” was conducted in IIT, Bhubaneswar to introduce the world-class experimental facilities available at NARL to students, faculty and early career researchers in universities/institutes/ colleges in and around Bhubaneswar and attract them to utilize the facilities for their research. A



team of senior scientists of NARL and distinguished scientists delivered lectures and interacted with participants.

Outreach Talent Day – March 2019 was celebrated at NRSC on 29th March, 2019 which included technical presentations, cultural programme and prize distribution for the technical competition and sports activities held during previous week.

UNISpace Nanosatellite Assembly & Training by ISRO (UNNATI)

As one of the leading space faring nations, India has been actively associated through ISRO with United Nations Office for Outer Space Affairs (UNOOSA) as a member of the Committee on the Peaceful Uses of Outer Space (COPUOS) since its inception.

During the 54th session of Scientific & Technical Subcommittee of COPUOS at Vienna in February 2017, UNOOSA requested Member States to propose new initiatives for the benefit of member countries. In June 2018, the international community gathered in Vienna to celebrate the 50th anniversary of the first United Nations Conference on the Exploration and Peaceful uses of Outer Space (UNISPACE+50). During this meet, India announced a capacity building training programme UNNATI (UNISpace Nanosatellite Assembly & Training by ISRO) on Nanosatellites development through a combination of theoretical coursework and hands-on training on Assembly, Integration and Testing (AIT).

Being the lead centre of ISRO for satellite building, U R Rao Satellite Centre (URSC) has designed the basic structure of this programme with equal emphasis on theoretical and practical exposure.

The programme is planned in three batches.

Programme consists of two theoretical modules where the participants are taken through basics of satellite technology (module 1) and nanosatellites (module 2). The participants are introduced to the design aspects of satellites, the various subsystems of a satellite and their functionality, configuration evolution and post-launch mission operations. Hands-on training (module 3) on a nanosatellite assembly, integration and testing is also provided.

The first batch of the above programme was organised during 15th January – 15th March 2019. 30 participants from 17 countries were screened in for the first batch of the above programme. The theoretical sessions of the programme were held in ISRO Guest House, Devanahalli and the practical sessions in URSC campus.

The programme was inaugurated on 17th January 2019 by the esteemed Chief Guest, Minister of State (Space), Dr. Jitendra Singh.

The programme turned out to be highly useful for the participants which gave them an exposure to the in-depth knowledge on Nano satellite technology. With this kind of international programmes, India is extending its knowledge base and sharing the vast experience of satellite technology with other countries, there by contributing towards the Peace and harmony in space fraternity.

The second batch of UNNATI programme was inaugurated by Chairman, ISRO/Secretary, DOS,



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Dr K Sivan and Senior programme officer, UNOOSA Mr Luc St-Pierre on Tuesday, October 15, 2019 at U R Rao Satellite Centre (URSC), Bengaluru. In the second batch, 30 participants from 16 countries (Bahrain, Bangladesh, Belarus, Bolivia, Brunei Darussalam, Colombia, Kenya, Mauritius, Nepal, Nigeria, Peru, Republic of Korea, Srilanka, Thailand, Tunisia, and Vietnam) are participating and second batch concluded on December 15, 2019.



3. Resource Management

3.1 Budget

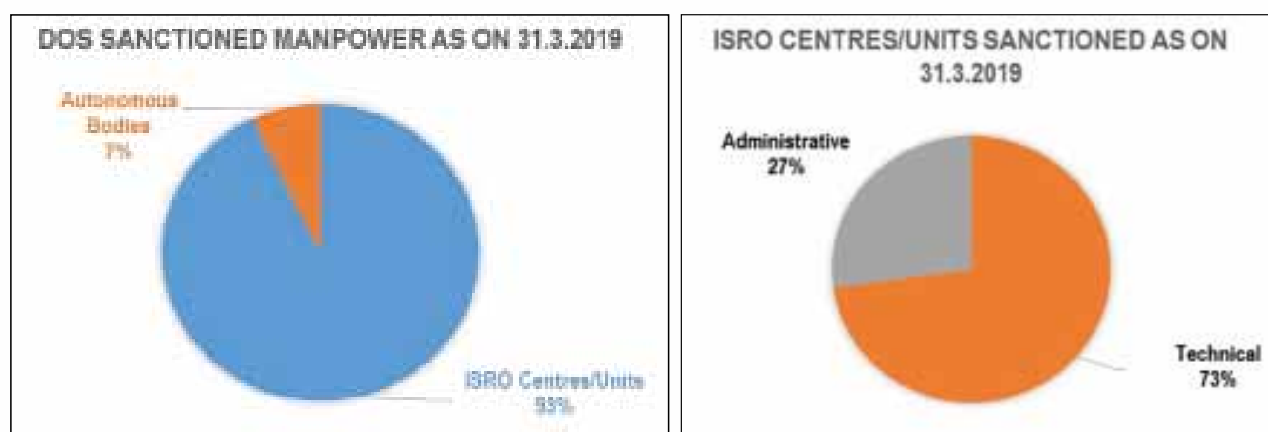
Budget at a Glance

(₹. in Crores)

Sl. No	AREA	BE 2019-2020	RE 2019-20	BE 2020-21
1	Establishment Expenditure	367.00	273.48	230.17
2	Space Technology	8,407.59	8,991.13	9,761.50
3	Space Applications	1,885.45	1,862.77	1,810.00
4	Space Sciences	285.80	281.88	265.00
5	INSAT Satellite Systems	884.42	1,008.56	750.50
6	Other Central Expenditure	643.00	721.44	662.30
	Grand Total	12,473.26	13,139.26	13,479.47

3.2 Human Resource

The total approved sanctioned strength of the Department as on 01.03.2019 is 20,039, out of which 18,619 is sanctioned strength of ISRO Centres/Units and 1,420 is sanctioned strength of autonomous units of DOS. The ratio of the manpower with respect to ISRO Centres V/s Autonomous bodies and breakup of technical v/s administrative posts of ISRO Centres/Units is as depicted below:



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

Key importance is laid to the competency requirements of the individuals, required for contributing effectively and efficiently towards 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 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 reputed institutes are conducted.

ISRO/DOS has been absorbing bright graduates from the Indian Institute of Space Science and Technology (IIST) on successful completion of the B.Tech/Dual degree programme, meeting the benchmark set. The ninth batch of students, who were admitted to B. Tech/dual degree during September 2015 at IIST have graduated during June 2019 and a total of 104 eligible students are inducted in DOS/ISRO.

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 265 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.

Annually an average of about 13000 employees are extended training opportunity in different areas.

Awards & Recognition:

ISRO has instituted various schemes for recognising the contributions of consistent performers in various categories, viz. Life time achievement award, outstanding achievement awards, performance excellence awards, merit awards, young scientist awards, service excellence awards and quality awards.

EMPLOYEE DETAILS (INFORMATION AS ON 31.10.2019)

Sl. No	Details	Group-A		Group-B		Group-C	
		Sci/Tech Staff	Admn Staff	Sci/Tech Staff	Admn Staff	Sci/Tech Staff	Admn Staff
A.	GENERAL: Total Number of Employees						
	(i) Male Employees	7920	303	2286	844	1257	1253
	(ii) Female Employees	1820	156	218	821	69	275
B.	B. SCHEDULED CASTES/ SCHEDULED TRIBES:						
	(i) Number of Scheduled Caste Employees	699	49	407	248	211	317
	(ii) Number of Scheduled Tribe Employees	182	21	111	124	94	83
C.	PERSONS WITH DISABILITIES (PWD):						
	(i) Number of persons with disabilities existing						
	1. Deaf & Dumb	11	1	18	6	15	5
	2. Blind	3	0	1	1	0	7
	3. Partially Blind	1	0	1	4	1	8
	4. Orthopaedically handicapped	109	10	75	34	37	15
	(ii) Number of Persons with disabilities appointed during the year 2019						
	1. Deaf & Dumb	0	0	1	0	3	1



	2. Blind	0	0	0	0	0	3	
	3. Partially Blind	0	0	0	0	1	1	
	4. Orthopaedically handicapped	2	1	1	1	4	4	
D.	<u>EX-SERVICEMEN:</u>							
	(i) Number of Ex-servicemen existing	13	6	43	33	25	214	
	(ii) Number of Ex-servicemen appointed during the year 2019	0	0	0	0	7	47	
E.	<u>OTHER BACKWARD CLASSES:</u>							
	(i) Number of OBCs existing	1869	64	1101	377	678	509	
	(ii) Number of OBCs appointed during the year 2019	39	0	45	7	98	124	
F.	<u>APPRENTICES TRAINING:</u>							
	(i) Number of Apprentices trained during the year 2019 - 2020	2182						
	(ii) Number of successful apprentices out of (i) above	1017						
	(iii) Number of apprentices appointed as regular employees during the year 2019 - 2020 (as on 30.10.2019)	3						

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

TABLE - I

SI No	Centre/Unit	Total Strength of Employees 2019-20	Strength of SC Employees 2019-20	Strength of ST Employees 2019-20
1	DOS/ISRO HQ	447	55	24
2	VSSC	4691	366	57
3	URSC	2723	311	110
4	SDSC-SHAR	2258	343	134
5	SAC & DECU	2070	187	135
6	LPSC	1295	145	29
7	NRSC	867	113	40
8	ISTRAC	445	65	14
9	MCF	308	33	17
10	ADRIN	157	16	5



11	IIRS	120	10	6
12	PRL	268	12	4
13	SCL	587	111	6
14	NARL	70	10	1
15	NESAC	42	2	4
16	IIST	100	3	0
17	HSFC	77	7	0
18	IPRC	697	142	29
	TOTAL	17222	1931	615

STATUS OF PERSONS WITH DISABILITIES IN DOS/ISRO

TABLE - II

SI No	Centre/Unit	Total Strength of Employees 2019-20	Strength of Persons with Disabilities	Classification of Employees with Disabilities			
				Deaf & Dumb	Blind	Partially Blind	Orthopedically Handicapped
1	DOS/ISRO HQ	447	5	0	0	1	4
2	VSSC	4691	111	23	7	13	68
3	URSC	2723	70	15	4	1	50
4	SDSC-SHAR	2258	46	2	1	1	42
5	SAC & DECU	2070	45	5	2	0	38
6	LPSC	1295	33	8	0	1	24
7	NRSC	867	22	4	0	0	18
8	ISTRAC	445	15	2	0	0	13
9	MCF	308	5	1	0	0	4
10	ADRIN	157	3	0	0	0	3
11	IIRS	120	6	0	1	0	5
12	PRL	268	5	1	0	0	4
13	SCL	587	5	0	0	0	5
14	NARL	70	1	0	0	0	1
15	NESAC	42	1	0	0	0	1
16	HSFC	77	0	0	0	0	0
17	IIST	100	1	0	0	0	1
18	IPRC	697	12	0	0	0	12
	TOTAL	17222	386	61	15	17	293

STATUS OF REPRESENTATION OF EX-SERVICEMEN IN DOS/ISRO

TABLE - III

SI No	Centre/Unit	Total Number of Employees in Group - C 2019-2020	Total Number of Ex-Servicemen in Group - C 2019-2020
1	DOS/ISRO HQ	86	7
2	VSSC	725	159
3	URSC	412	11
4	SDSC-SHAR	641	32
5	SAC & DECU	324	7
6	LPSC	218	42
7	NRSC	122	12
8	ISTRAC	48	1
9	MCF	43	2
10	ADRIN	15	0
11	IIRS	15	0
12	PRL	16	0
13	SCL	61	2
14	NARL	8	0
15	NESAC	2	0
16	HSFC	0	0
17	IIST	0	0
18	IPRC	118	18
	TOTAL	2854	293

WOMEN EMPLOYEES IN DOS/ISRO

TABLE - IV

SI No	Centre/Unit	Total Number of Employees 2019-2020	Number of Women Employees 2019 - 2020	
			Scientific & Technical Staff	Administrative Staff
1	DOS/ISRO HQ	447	26	118
2	VSSC	4691	542	452
3	URSC	2723	584	151
4	SDSC-SHAR	2258	131	124
5	SAC & DECU	2070	271	78
6	LPSC	1295	95	106
7	NRSC	867	147	57



8	ISTRAC	445	75	37
9	MCF	308	36	9
10	ADRIN	157	32	10
11	IIRS	120	19	8
12	PRL	268	30	19
13	SCL	587	39	19
14	NARL	70	5	6
15	NESAC	42	8	3
16	HSFC	77	3	7
17	IIST	100	20	6
18	IPRC	697	44	42
	TOTAL	17222	2107	1252

4. Others

4.1 SPACE IN PARLIAMENT

Indian Space Programme continued to attract the attention of both the Houses of Parliament. Question were answered in Parliament during March 2019 - December 2019 as shown below.

Questions	Budget Session 2019		Winter Session 2019		Total	
	18 th Session of Lok Sabha	249 th Session of Rajya Sabha	19 th Session of Lok Sabha	250 th Session of Rajya Sabha	Lok Sabha	Rajya Sabha
Starred Questions	0	1	0	1	0	2
Unstarred Questions	18	11	15	11	33	22
Total	18	12	15	12	33	24

The Questions were with respect to Asia Pacific Regional Space Agency, Space Policy, Communication Gadgets to Fishing Vessels, Space Research and Technology, Space Tourism, Search for life on other planets, Space Missions, Space Technology, Private participation in Space sector, Help of ISRO in oil exploration, Indian Satellites in Space, Location of oil and gas reserves, Progress of Chandrayaan-2 Mission, New Company for commercial exploitation of research and development, Status of Gaganyaan Project, Space Station to conduct microgravity experiments, Earth Observation Satellite RISAT-2B, Launching of Space Station, Creation of Gaganyaan National Advisory Council, Launching of student satellites, Achievements in Research and Space expeditions, Startups processing technical capabilities, Launch of satellite made by students, Progress of IRNSS, Constellation of Remote Sensing Satellites, Satellites to Assess Pollution Status, PSLV Mission, First Manned Mission, Study by Chandrayaan, Space Research Projects, Preparations for Chandrayaan-3, Technology Transfer of Li-ion Cell Developed by ISRO, Unsuccessful Chandrayaan Mission, Establishment of Incubation Centres by ISRO, PSLV Missions to Carry Small Foreign Satellites, Setting up of New Lunar Trophy Hunt, Setting up of Rocket Launching Pad in Tamil Nadu, Designing and Development of Application for Earth Observation, Training of Students under New Young Scientist Programme, BRICS Remote Sensing Satellite Constellation, Setting-up Dedicated Cells in IITs in Collaboration with ISRO, Satellites Launched by India.

4.2 Space Sports-Recreation Promotion Board (SSRPB)

DOS/ISRO Inter-Centre Sports Meet 2019 (Outdoor Games) was held in two phases at IPRC, Mahendragiri as detailed below:

- Phase-I : for 5 days from 04.11.2019 to 08.11.2019 and
- Phase-II : for 4 days from 11.11.2019 to 14.11.2019



4.3 Vigilance

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

Category of employees	Type of cases	Cases pending as on 01.10.2018	Cases received during the period 01.10.2018 to 30.09.2019	Total (Col. 3+4)	Disposed during 01.10.2018 to 30.09.2019	Pending (Col. 5-6)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Group-A & Group-B (Gazetted)	Disciplinary (Non-Vigilance)	10	-	10	1	9
	Vigilance	7	-	7	-	7
Group-B (Non-Gazetted) Groups C & D	Disciplinary (Non-Vigilance)	9	13	22	14	8
	Vigilance	-	1	1	-	1
	Total	26	14	40	15	25



4.4 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.
- Due to general elections of Lok Sabha during 2019, the tenure of JHSS was extended for one year upto 30.06.2019 with the approval of the Honorable MOS, PMO, the Chairman of the Committee. At present, process for re-constitution of the said Committee is under process in the Department.
- 41st meeting of Central Official Language Implementation Committee was held on 11.10.2019 under the Chairmanship of Secretary, DOL, where Joint Secretary, DOS and Joint Director (OL), DOS participated.
- 161st meeting of Departmental Official Language Implementation Committee across the table was held on 29.07.2019 under the Chairmanship of Joint Secretary, DOS.
- Responsibilities of holding TOLIC Secretariat is undertaken by URSC, Bangalore, MCF, Hassan and SCL, Chandigarh of the Department.
- 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, Department and its centre/units purchased Hindi books for Library, which is in accordance with the target set up by DOL.
- During the year, Department has incurred expenditure in accordance with the target set by DOL for the publication of advertisements in Hindi in newspapers.
- 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 Sections of DOS/ISRO and also other Centres/Units were carried out to increase use of Hindi in day to day work. Sections for their best implementation of Official Language were awarded in DOS/ISRO HQ during Vishwa Hindi Divas Celebrations organized on 10th January, 2020.
- Training programmes in Hindi through Hindi Teaching Scheme, under Correspondence courses were continued 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 18,534 in the Department, 16,279 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**, family members of the employees were also included during Hindi Fortnight celebrations in all Centers/Units of the Department and there was an overwhelming response.
- Children of the employees who secured highest marks in Hindi in class X & XII were awarded cash prizes and certificates.
- With a view to refresh and update the knowledge of Official Language personnel, an 'Official Language Orientation Programme' was organized by DOS, Branch Secretariat, New Delhi on 08.11.2019. In this programme, a special training session was organised on the "Kanthastha" translation on tool, as directed by DOL. "Kanthastha" is a memory based translation on tool. The training sessions were conducted by the officials of DOL. This training is considered to be very useful in the field of translation.
- World Hindi Day was celebrated on 10th January, 2020 in all Centers/Units of the Department by conducting various programmes. In DOS/ISRO HQ, 'Rajbhasha Written Quiz' Competition was organized for Hindi and Non-Hindi speaking category on this occasion.
- Department plays always an active role in the activities of Town OLIC. It conducts various programmes under the auspices of Town OLIC. This year, Hindi Essay Writing competition was organized by the department for the member offices of Town OLIC on 22.10.2019.
- DOS/ISRO HQ in-house magazine "Disha" and compendium of technical articles "Antariksh Gyan Sarita" were published during the year.
- Several Pamphlets, Panels and Stickers/Posters on Chandrayaan-2, Indian Space Programme, HySIS Mission, Glimpses of Indian Space Programme, Gaganyaan brochures were brought out 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.
- 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.



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- 'Hindi Month Incentive Scheme' continued during the year, under which the Officers/Employees doing maximum work in Hindi during the Hindi month were awarded. 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.
- 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, a book titled "Antariksh – Ek Khoj" written by Dr. Rajshree Bothle Sci./Eng. of NRSC was published. Also, an Atlas in Hindi titled "Antariksh Se Bharat Ke Sanskritik Dharohar" was prepared by Dr. Prakash Chauhan, Director IIRS, Dehradun and Smt. Vandita Shrivastava, Sci./Eng., IIRS. Both the books were released by Dr. K. Sivan, Secretary, DOS / Chairman, ISRO on 30.10.2019 on the occasion of Hindi Month Valedictory function. During this event, the authors of these books were awarded and presented Certificates. Also, Shri Shantanu Bhatawdekar, Associate Director, EDPO, ISRO HQ, Chairman, Dr. Alok Shrivastava, Deputy Director (Mechanical), URSC, Deputy Chairman and other members like Dr. Dinesh Agarawal, SAC, Dr. Shankar Kumar, DOS, BS, New Delhi of the committee constituted for this purpose were awarded shields and certificates. During this event, many other officials were also honoured with shield and certificates for giving their valuable contribution for the effective O.L. implementation in Antariksh Bhavan.
- During the year, various Centres/Units of the Department have 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.
- 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.
- 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.

AWARDS:

National Level -

- For Best implementation of Official Language, Department of Space was awarded the "*Rajbhasha Kirti Puraskar*" (1st Prize) by the Honorable Home Minister of India in a function organized at Rashtrapati Bhawan, New Delhi on 14.09.2019 and it was received by Joint Secretary, DOS.



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:-

S.No.	Centre/Units	Award	Position
1	SAC, Ahmedabad	Under TOLIC for best O.L. Implementation	Third
2	VSSC	Under TOLIC for best O.L. Implementation	First
		In-house Magazine-GAGAN	First
		Rolling Shield (Chal Vijanti Puraskar)	
		Joint Hindi Fortnight for securing highest marks	Second
3	LPSC	Under TOLIC for best O.L. Implementation	Second
		In-house Magazines – 'Nodan Mukur' and 'Propulsion Today'	First
4	URSC	Under TOLIC for best O.L. Implementation	First

4.5 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 of Space/ISRO had decentralized 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.
- Milestones of the Department of Space/Indian Space Research Organisation
- Annual Report – 2018 – 2019 (English / Hindi)
- Human Resources
- Citizen Charter
- Public Grievances
- Suo-Moto disclosure of official tours of Joint Secretary level officials and above
- Suo-Moto 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 use 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 of the Department of Space & 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) Transfers & 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 of Department of Space for 2019 -2020
 - (f) Output-Outcome Framework

During the period November 2018 to November 2019, 2709 applications were received and information were disseminated under the provisions of the RTI Act. 222 Appeals were received by the First Appellate Authority and 21 appellants approached the Second Appellate Authority, i.e., Central Information Commission.



4.6 Audit Observation

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	<u>Report No.30 of 2015 (Para No. 5.1)</u> Implementation incentive scheme	One	Nil	Nil	Nil	Nil
2	<u>Report No.30 of 2015 (Para No. 5.2)</u> Irregular payment of service tax	One	Nil	Nil	Nil	Nil
3	<u>Report No.30 of 2015 (Para No. 5.3)</u> Avoidable payment of electricity charges	One	Nil	Nil	Nil	Nil



4	<u>Report No.12 of 2016 (Para No.5.1)</u> Computerisation in administration, finance and related areas	One	Nil	Nil	Nil	Nil
5	<u>Report No.12 of 2016 (Para No.5.2)</u> Implementation of Telemedicine Programme	One	Nil	Nil	Nil	Nil
6	<u>Report No.12 of 2016 (Para No.5.3)</u> Wasteful expenditure on material for propellant tanks	One	Nil	Nil	Nil	Nil
7	<u>Report No.12 of 2016 (Para No.5.4)</u> Loss due to delayed commissioning of equipment	One	Nil	Nil	Nil	Nil
8	<u>Report No.12 of 2016 (Para No.5.5)</u> Unfruitful expenditure on consultancy services	One	Nil	Nil	Nil	Nil
9	<u>Report No.12 of 2016 (Para No.5.6)</u> Non-levy of labour welfare cess on construction work payment	One	Nil	Nil	Nil	Nil



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10	<u>Report No.33 of 2016</u> Management of Launch Services	One	Nil	Nil	Nil	Nil
11	<u>Report No.17 of 2017 (Para no.6.1)</u> Management of VSAT Services	One	Nil	Nil	Nil	Nil
12	<u>Report No.17 of 2017 (Para No.6.2)</u> Irregular Expenditure on Pre-Project Activities	One	Nil	Nil	Nil	Nil
13	<u>Report No.17 of 2017 (Para No.6.3)</u> Lack of Financial Prudence and improper contract Management in the Delivery of Commercial Spacecraft	One	Nil	Nil	Nil	Nil
14	<u>Report No.17 of 2017 (Para No.6.4)</u> Infructuous Expenditure in purchase of ecologically fragile land	One	Nil	Nil	Nil	Nil



15	<u>Report No.02 of 2018 (Para No.7.1)</u> Operationalisation of Satellite navigational system	One	Nil	Nil	Nil	Nil
16	<u>Report No.02 of 2018 (Para No.7.2)</u> Infructuous expenditure on Software Development	One	Nil	Nil	Nil	Nil



4.7 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)



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- Successful launch of INSAT-4B by Ariane launch vehicle from Korou, French Guyana on March 12, 2007
- PSLV-C8 successfully launches an Italian satellite AGILE on April 23, 2007 under a commercial contract with Antrix Corporation
- Launch of GSLV-F04 with INSAT-4CR onboard from SDSC SHAR on September 2, 2007

2008

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

2009

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

2010

- Successful static testing of GSLV Mk III Launch Vehicle's S200 Solid Propellant Booster Rocket Stage (January 24, 2010)
- GSLV-D3, the first launch of GSLV with indigenous Cryogenic Upper Stage and GSAT-4 satellite onboard. GSAT-4 could not be placed in orbit (April 15, 2010)
- PSLV-C15, the seventeenth flight of PSLV, successfully launches India's Cartosat-2B and STUDSAT, Algeria's ALSAT-2A, Canada's NLS-1 and NLS-2 on (July 12, 2010).
- Successful Static Testing of GSLV Mk III 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-French Satellite SARAL along with six smaller satellites from abroad from Sriharikota on February 25, 2013
- PSLV, in its twenty fourth flight (PSLV-C22), successfully launches India's first dedicated 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-C40 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, satellite lost communication with ground station.
- 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.
- On November 14, 2018 GSLV MK III-D2 successfully launched communication satellite, GSAT-29 into the orbit weighing about 3423 kg from SDSC SHAR, Sriharikota.
- PSLV-C43 on November 29, 2018 successfully launched India's Hyperspectral 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.
- 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 forerunner 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.

2019

- PSLV-C44 successfully launched Microsat-R and Kalamsat-V2 on January 24, 2019 from Sriharikota.
- On February 06, 2019, GSAT 31 was successfully launched from Kourou, French Guiana onboard Arianespace rocket.
- EMISAT and 28 customer satellites were successfully launched onboard PSLV-C45 on April 01, 2019 from Sriharikota. The launch viewing gallery was inaugurated and opened to the public for viewing launches live from Sriharikota.



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- On May 22, 2019 RISAT-2B satellite was successfully launched onboard PSLV-C46 from Sriharikota.
- Chandrayaan-2 satellite was successfully launched into an earth orbit by GSLV-MKIII-M1 on July 22, 2019.
- On November 27, 2019 Cartosat-3 and 13 customer satellites were successfully launched by PSLV-C47 from Sriharikota.
- On December 11, 2019, PSLV-C48 successfully launched RISAT-2BR1 satellite and 9 customer satellites from Sriharikota.



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
CHAMAN	Coordinated programme on Horticulture Assessment & Management using Geoinformatics
CME	Continuing Medical Education



CMOS	Complementary Metal Oxide Semiconductor
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 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 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
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 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
ICG	International Committee for Global Navigation Satellite Systems



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ICT	Information & Communication Technology
IDSN	Indian Deep Space Network
IGS	International 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 & Integrity Monitoring Stations
IRNSS	Indian Regional Navigation Satellite System
IRNWT	IRNSS Network Timing Facility
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
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
NSIL	NewSpace India Limited
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	Uchcharat 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

