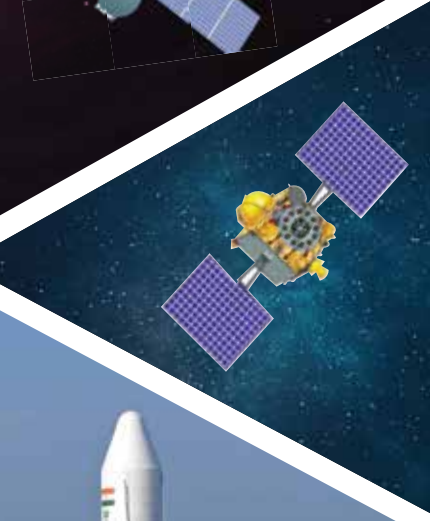
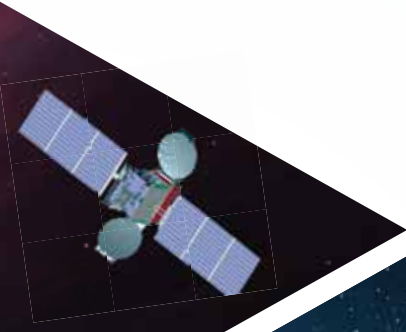


भारत सरकार  
अंतरिक्ष विभाग



GOVERNMENT OF INDIA  
DEPARTMENT OF SPACE



वार्षिक रिपोर्ट  
ANNUAL REPORT  
2020-2021

वार्षिक रिपोर्ट  
ANNUAL REPORT  
2020-2021



## 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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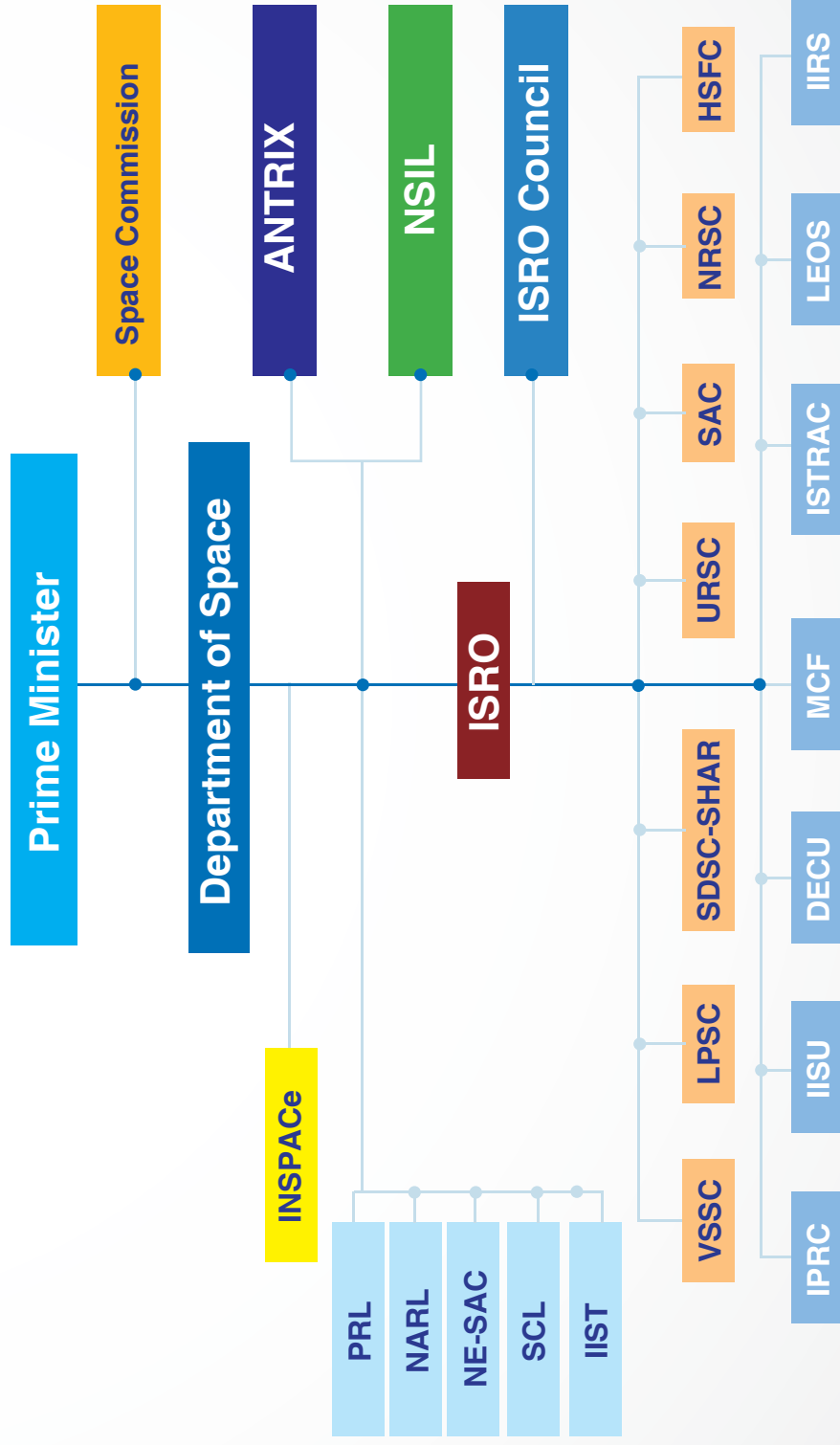
## Space Missions (As per Financial Year)

Mission	2019-2020	2020-2021	2021-2022
EARTH OBSERVATION SATELLITES	4	1+2*	2
COMMUNICATION SATELLITES	1	1	0
NAVIGATION SATELLITES	0	0	1
SPACE SCIENCE SATELLITES	1	0	1
TECHNOLOGY DEMONSTRATOR	0	0	0
PSLV	4	2+1*	2
GSLV Mk II	0	0+1*	1
GSLV Mk III	1	0	0
SMALL SATELLITE LAUNCH VEHICLE	0	0+1*	2
GAGANYAAN	0	0	1 (Unmanned)
<b>TOTAL</b>	<b>11</b>	<b>4+5*</b>	<b>10</b>

\* No. of missions expected to be achieved by March 2021



# 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 **INSPACe:** Indian National Space Promotion and Authorization Center **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 **DECU:** Development and Educational Communication Unit **MCF:** Master Control Facility **ISTRAC:** ISRO Telemetry, Tracking and Command Network **LEOS:** Laboratory for Electro-Optics Systems **IIRS:** Indian Institute of Remote Sensing





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 Public Sector Units are set up for commercialization of R&D activities of DOS/ISRO.

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.



*VSSC Main Building at Veli Range Complex*





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.

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)

U R Rao Satellite Centre (URSC), Bengaluru 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. 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 is functioning



*URSC Main Building*

from its 32 acres main campus, adjacent to NAL, HAL Airport Road and 110 acres ISRO Integration & Testing Establishment (ISITE) campus at Marathahalli, 8 km away from the main campus.

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.

The Centre has two launch pads from where the rocket launching operations of PSLV, GSLV and







*Satish Dhawan Space Centre (SDSC) SHAR*

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.

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.



*Thaltej Campus, Ahmedabad*

The communication transponders developed at this Centre for the INSAT and 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)

Human Space Flight Centre (HSFC) was formed on January 30, 2019 and as a lead Centre, HSFC will undertake multi-disciplinary R&D activities in new domains of human science and technology, while conforming to high standards of reliability and human safety. HSFC is currently concentrating on Gaganyaan mission with thrust on areas like end-to-end mission planning, development of Orbital Module (OM), development of life support systems, selection and training of astronauts, development of various training simulators, co-ordination in recovery and rehabilitation of astronauts,





collaboration with National and International agencies/institutions for multi directional growth to act as a technology aggregator.

The Centre is currently operating in a temporary building in ISRO-HQ campus, Bengaluru. Apart from Gaganyaan, HSFC will focus in future on new areas of technology development, significant amongst them includes nurturing and creating new expertise in the domains of bioastronautics, human space sciences and space habitat systems. The Centre will develop necessary expertise to sustain the human space flight activities in the country including capability to build orbiting space station and become active partners in collaborative interplanetary manned missions to Moon/Mars and near-Earth Asteroids.

## National Remote Sensing Centre (NRSC)

National Remote Sensing Centre (NRSC), Hyderabad is responsible for Remote Sensing Satellite data acquisition, processing and dissemination, Applications, Aerial Services, Capacity Building and Outreach. NRSC has three campuses at Balanagar, Shadnagar and Jeedimetla in Hyderabad. It is having five Regional Remote Sensing Centres (RRSCs) in Bengaluru, Jodhpur, Kolkata, Nagpur and Delhi to cater to regional needs. Bhuvan is the flagship programme of NRSC for dissemination of Geo-spatial products and services in the country. Apart from satellite based remote sensing, NRSC is also engaged in executing remote sensing application projects in collaboration with the users including end-to-end Aerial Remote Sensing services and value-added solutions for various large scale applications like aerial photography and digital mapping, infrastructure planning, scanner surveys, aeromagnetic surveys, large scale base map, topographic and cadastral level mapping, etc.



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

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 also 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 Bialalu 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





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



*IISU Main Building*

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

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



*LEOS Main Building*

### Indian Institute of Remote Sensing (IIRS)

Indian Institute of Remote Sensing (IIRS), Dehradun is a premier institute with the objective of capacity building in Remote Sensing and Geo-informatics and their applications through education and training programmes at postgraduate level. The capacity building activities of the Institute are primarily grouped into three domains namely, Training & Education, Research and Outreach.





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



Indian Institute of Remote Sensing Main Building

### Physical Research Laboratory (PRL)

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



The primary mandate of the PRL is to carry out research, publish scientific papers and develop appropriate instrumentation to enable their specific science goals.

### National Atmospheric Research Laboratory (NARL)

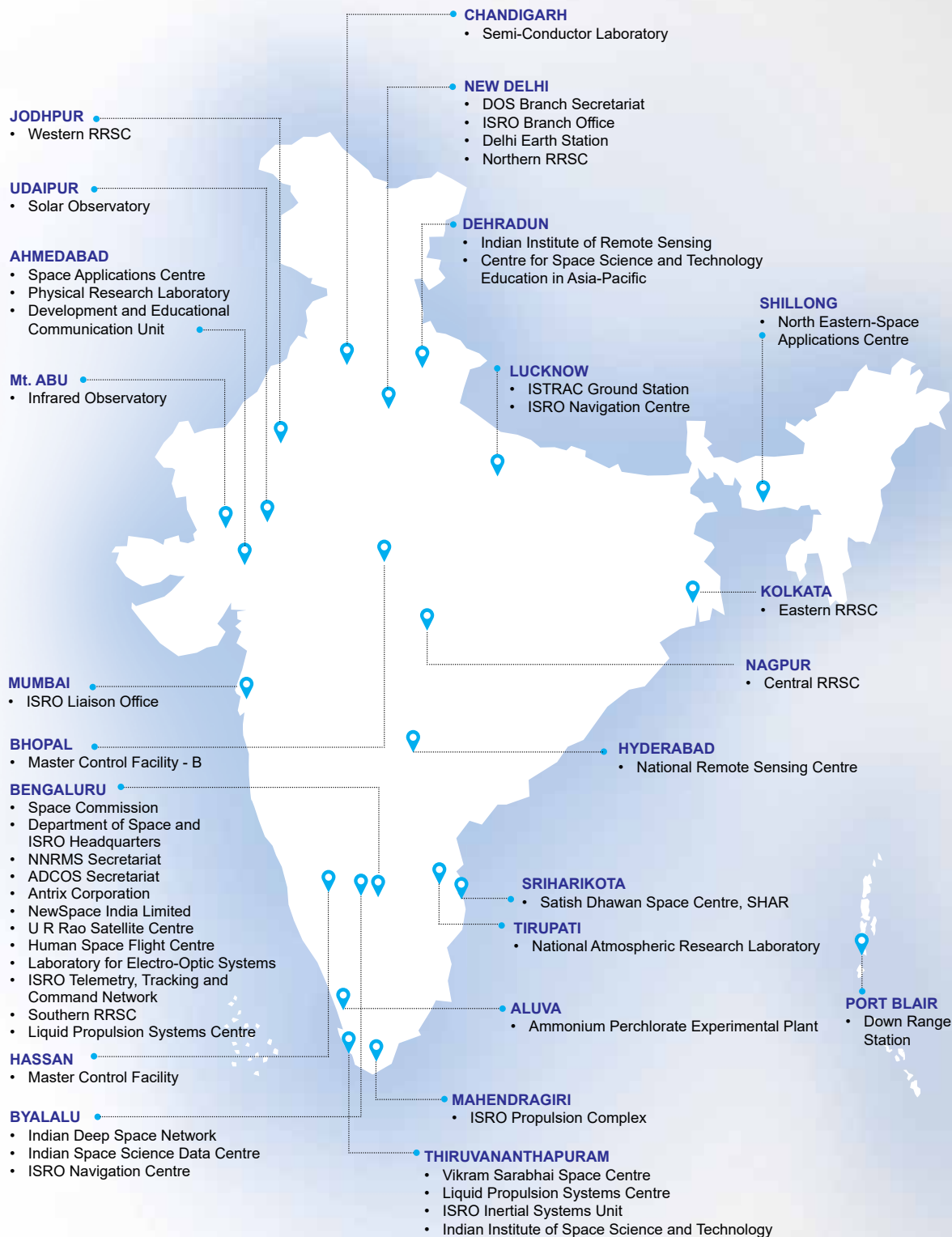
National Atmospheric Research Laboratory (NARL) at Gadanki near Tirupati, an autonomous society supported by DOS, is a centre for atmospheric research in the country. Started as a major national facility with a huge MST radar to cater to the scientific needs of the middle atmospheric research community, 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



X-band radar building at NARL



# Space Centres in India







and improve various atmospheric probing techniques, innovative ideas and algorithms, besides capacity building in lower, middle and upper atmospheric research and technology.

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

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

North Eastern-Space Applications Centre (NE-SAC), Shillong is a joint initiative of DOS and North Eastern Council (NEC) to provide developmental support to the North Eastern Region (NER) using space science and technology. The centre has the mandate to develop high technology infrastructure support to play the catalytic role in holistic development of NER of India by providing space science



*Aerial View of NE-SAC*

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 19 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



*IIST Campus*

undergraduate, postgraduate, doctoral and post-doctoral programmes in broad areas of space science, technology and applications. The institute is committed to excellence in teaching, learning and research. IIST fosters state-of-the-art research and development in space studies and provides a think-tank to explore new directions for the Indian Space Programme.

## 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 got incorporate on March 06, 2019, as a wholly owned Government of India Undertaking/ Central Public Sector Enterprise (CPSE), under the administrative control of Department of Space (DOS). NSIL has been categorized as Schedule 'A' CPSE by Department of Public Enterprises (DPE) on February 06, 2020.

Government of India enhanced the role and scope of NSIL to encompass more responsibilities in the primary business areas and widen the scope in June 2020. The revised mandate broadly covers (i) Owning satellites for Earth Observation and Communication applications; (ii) Providing space-based Earth Observation and Communication services; (iii) Building satellites and launching





them as per demand; (iv) Building launch vehicles through Indian Industry and launch as per requirements; (v) Providing lunch services and (iv) Technology Transfer to Indian Industry.

### Indian National Space Promotion and Authorization Center (INSPACe)

Recently, the space sector was opened up to promote, handhold, regulate and authorise private enterprises and start-ups to undertake space activities by creation of an independent nodal agency under Department of Space - the Indian National Space Promotion and Authorization Center (INSPACe). This will enhance the diffusion of space technology and boost space economy within the country.

IN-SPACe will permit and oversee the following activities of private enterprises and start-ups:

- Space activities including building of launch vehicles and satellites and providing space based services as per the definition of space activities
- Sharing of space infrastructure and premises under the control of ISRO with due considerations to on-going activities
- Establishment of temporary facilities within premises under ISRO control based on safety norms and feasibility assessment
- Establishment of new space infrastructure and facilities, by Non Government Private Entities (NGPE), in pursuance of space activities based on safety norms and other statutory guidelines and necessary clearances
- Drawing up integrated launch manifest based on priorities and readiness level for ISRO, NSIL & NGPE
- Initiation of launch campaign and launch, based on readiness of launch vehicle and spacecraft systems, ground and user segment
- Registration and maintenance of Space Objects in National registry
- Usage of spacecraft data and rolling out of space based services and all the associated infrastructure for the same





## 2. Major Activities

### 2.1 Earth Observation, Meteorological Satellite System and Applications

#### 2.1.1 Programme

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.

#### 2.1.2 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. The satellite can be steered along and across the track of up to  $\pm 45$  degree to facilitate frequent imaging of any specific area. The satellite has served beyond the designed mission life.

**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  $\pm 45$  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). 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  $\pm 26$  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.

**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  $\pm 45$  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. 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-2B-R1:** RISAT-2B-R1 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.

**EOS-01:** EOS-01 was successfully realized and launched onboard PSLV-C49 on Nov 07, 2020. The primary objective of the mission is to provide X band SAR imaging services with improved frequency of observation over area of interest. The satellite has the capability to operate in day, night and all-weather conditions and provides imaging data for various applications related to land, water & environment which is required for agriculture, forestry, water resource, flood inundation estimation and disaster management. This is the third satellite in the constellation of three satellites to meet the user requirement. All three satellites in the constellation viz RISAT-2B, RISAT-2BR1 and EOS-01 are performing to specification and providing satisfactory services to the users.

### 2.1.3 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.



## 2.1.4 Future Earth Observation and Meteorological 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:

**EOS-03:** EOS-03 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. EOS-03 is aimed at providing fast revisit capability, real time monitoring, multi spectral and hyper spectral imaging - all on a single, agile, jitter free platform.

**EOS-02:** EOS-02 is configured around MicroSat-TD bus platform to demonstrate launch on demand capability with SSLV. It is expected to meet the ever-increasing user demands for cartographic applications, urban and rural management, coastal land use and regulation, utilities mapping, development and various other GIS application. The mission life of the satellite is 9 months. The satellite is slated for launch in the first quarter of 2021.

**INS-2 TD:** The prime objective of the mission is to demonstrate the in-orbit performance of new technologies identified for second generation Nanosatellite. It also incorporates the redundancy for critical systems and hence enhance the overall satellite reliability. The main bus capabilities are also enhanced to cater to variety of payloads in the subsequent Nano satellite missions. INS-2 TD carries a Thermal Imaging Camera (TIC) and is expected to improve the applications using the land surface temperature, surface temperature of large wetlands / lakes etc. The TIC payload has a ground sampling distance of 166m and a swath of 64x48 km.

**INS-2B:** INS-2B carries a nano Multispectral (Nano-MX) Imaging Camera as prime payload. Nano-MX has a ground sampling distance of 29m and with a swath width of 116 km. This payload has potential applications in the area of agriculture, forestry & environment, water resources, snow and glaciers and geology.

The prime objective of the mission is to build a nanosatellite using INS-2 bus to cater to the applications specific to Bhutan territory. It incorporates the redundancy for critical systems like onboard computer, telecommand and telemetry systems. The enhanced capability of main bus accommodates a secondary payload being developed by Department of Information Technology and Telecom/Bhutan along with primary payload from ISRO.

**EOS-04:** EOS-04 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 find useful inputs for Agriculture, Forestry and Water resource management.

**EOS-06:** The prime objective of EOS-06 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. EOS-06 satellite is envisaged to carry Scatterometer, 13 band Ocean Color Monitor (OCM-3) with spectral bandwidth of 10-20 nm and better SNR as well as sea surface temperature monitor (SSTM-1) for Sea Surface Temperature measurement. An ARGOS-4 payload of CNES will also fly on-board the satellite under international co-operation.

**EOS-07:** The primary objective of the mission is to provide imaging capability with systematic coverage over the area of interest in the Indian Ocean region and also generate spot images over land region as and when needed.

**EOS-08:** EOS-08 is an advanced agile satellite to obtain imageries for advanced cartographic applications with an operational life of 5 years. The satellite is built around hexagonal structure.

**RESOURCESAT-3/3A:** The mission is envisaged to provide continuity of data services on an operational basis in the area of land and water resources management with improved spatial resolution, spectral resolution and better revisit frequency. It is planned to enhance remote sensing applications in the areas of agriculture, forestry, water resources monitoring, developmental planning at regional and state level, environmental impact assessment, wasteland and wetland monitoring, land degradation, drought assessment, flood inundation, landslide inventory etc. The satellite is built around I-1K bus capable of generating around 3200W of power. The satellite carries advanced LISS-III providing data continuity for LISS-III in VNIR & SWIR bands.

**RESOURCESAT-3S/3SA:** The satellite is 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 satellite is built around I-1K bus capable of generating around 3200 W of power. The satellite carries two panchromatic payloads providing a spatial resolution of approximately 1.25m and a multispectral payload with spatial resolution of approximately 2.5m.

**NISAR:** This mission is jointly being developed by NASA & ISRO. The primary mission goals are 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, Interferometry with precision orbit & pointing control.

The mission is built around I-3K bus and carries two payloads namely L-band SAR and S-band SAR. The L-band SAR payload will be delivered by NASA and S-band SAR payload is developed by SAC, ISRO.





**HRSAT:** A constellation of small satellites with sub meter resolution in PAN and a daily revisit capability has a great potential for civilian and commercial applications in large scale mapping, agriculture, urban planning, rural development, infrastructure development, disaster management, etc. HRSAT carries advanced cameras such as Panchromatic Camera providing images with better than 1m resolution, Multispectral Camera providing around 4m resolution and LWIR camera with around 17m resolution. HRSAT Mission is aimed at design, development and realization of four integrated identical satellites.

**INSAT-3DS:** INSAT-3DS is a follow-on mission of INSAT-3D/3DR and will be used as a 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 Search and Rescue services. Considering, the ground and on-orbit observations of INSAT-3D/3DR satellites, appropriate improvements/modifications have been incorporated into the INSAT-3DS configuration to optimize its performance. The satellite is built around I-2K bus platform with a planned mission life of around 10 years. 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.

**EOS-05:** EOS-05 is an agile geo imaging satellite envisaged to provide near real time images of large area of interest at frequent intervals from geostationary orbit. The satellite is primarily meant for near real time imaging (under cloud free conditions) of natural resources and disaster events.

### 2.1.5 Applications

#### Satellite Data Reception

**IMGEOS:** Integrated Multi-Mission Ground Segment for Earth Observation Satellites (IMGEOS) established at Shadnagar delivers emergency products in one hour and standard products in 24 hours. IMGEOS acquires data from various Indian Remote Sensing satellites and also from foreign satellites.

**AGEOS:** “Antarctica Ground Station for Earth Observation Satellites (AGEOS)” facility was established by ISRO during 2012-13 at Bharati (Research base of NCAOR), Antarctica. 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 at these stations is being transferred through Network to IMGEOS, Shadnagar and Ancillary Data Processing is being carried out to generate Level-0 Products.

#### 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.





Cartosat-3 PAN and multi spectral (MX) data products were analysed for geometric quality, radiometric response for various quality parameters.

**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 sets 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.

### Bhuvan

Bhuvan (<https://bhuvan.nrsc.gov.in>) is a Geoportal platform of Indian Space Research Organisation (ISRO), with a host of wide ranging services that cover visualization of multi-date, multi-platform, multi-sensor satellite data, thematic map display, query and analysis, free data downloads and products, near real-time disaster services, apps for crowd sourcing and diverse geospatial applications. Bhuvan with its rich visualization, data services diversified its major applications and services catering to disaster support, crowd sourcing and mash up applications in collaboration with State, Central Government agencies and supporting ministries with *G-Governance* applications.

High Resolution Data of 1m spatial resolution of 2018 year, 2.5m color using Cartosat data (20 lakh sq. Km) has been added in Bhuvan portal for visualization. 96325 satellite data products were downloaded by users.

There were about 430 Crore hits to Bhuvan geoportal including 10 lakhs IPs in this year. 8000 geophysical products were uploaded in the portal for use of researchers on earth and climate sciences as part of National Information System for Climate & Environmental Studies (NICES) programme and there were about 23600 downloads.

### Bhoonidhi – ISRO Open Data Access Portal

Bhoonidhi web portal ([bhoonidhi.nrsc.gov.in](http://bhoonidhi.nrsc.gov.in)) enables free satellite data dissemination of Landsat 8, Sentinel 1A,1B and 2A, 2B, OCM-2 Global Area Coverage (GAC) Product, Scatsat-1, OSCAT and GHRC Mission data acquired and archived for online users. It serves as a single window for downloading IRS and non IRS free datasets and acts as regional data hub for the Sentinel satellite series data products enabling

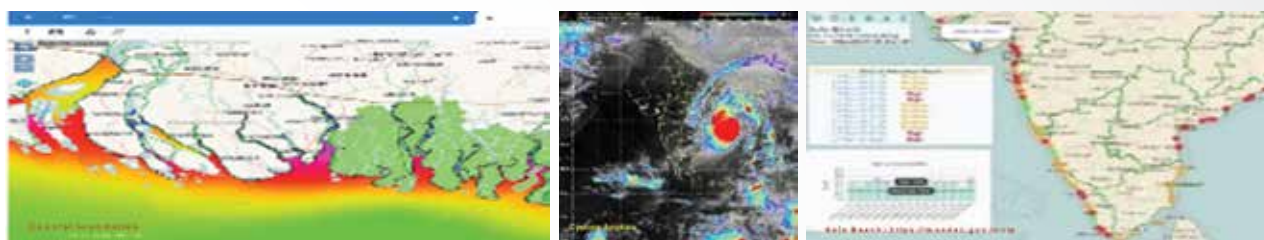


faster downloads. It also provides a quick look into the data archive for users with its catalogue and browse features. There are about 1,01,520 products (~50 tera bytes of data) are uploaded in Bhoonidhi portal and 54700 products are downloaded by users in this year.

### Meteorological and Oceanographic Satellite Data Archival Centre (MOSDAC)

As part of the efforts to develop satellite data based applications in the field of metrology and oceanography following new applications were released on MOSDAC during 2020.

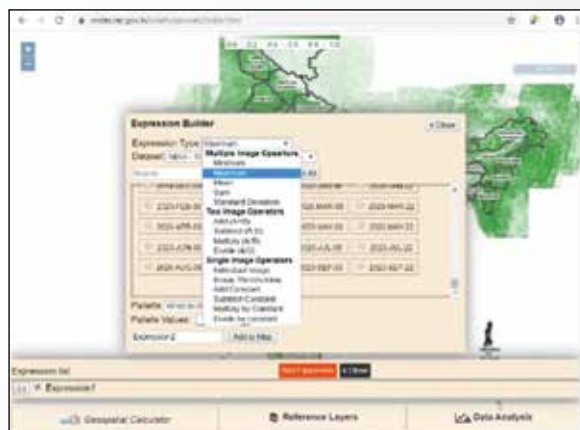
- “**Safe Beach**” application for dissemination of Rip current forecasts for 175 beaches of India
- Web application for monitoring of **Oil spills** and its possible progression direction using Altimeter LCS-Cores and Stretching Directions
- New **State portal** for dissemination of forewarning and alerts



MOSDAC also supported monitoring and prediction of four tropical cyclones **Amphan, Nivar and Burevi** (Bay of Bengal) and **Nisarga** (Arabian Sea), dissemination of **Coastal Inundation** in internet compatible format from SCORPIO and automated E-mail based dissemination of Solar and Wind forecast.

### Visualization of Earth Observation Data and Archival System (VEDAS)

VEDAS portal has provided “**Geospatial Calculator**” as a web processing service that allows user defined single and multiband operations to be performed on a set of images. “**AOI based NDVI profile**” web processing service allows user to draw AOI & get various NDVI profiles for that region. Deep learning based algorithm was developed to calculate and publish urban sprawl of 100 smart cities of India.



### Development of Data Analysis Software

Microwave Data Analysis Software (**MIDAS**) designed and developed by SAC, has received copyright. AdVanced HYperspectral data Analysis Software (**AVHYAS-Ver.1**), an in-house developed tool for the processing, analysis and visualization of multi-/hyperspectral data, is plugged-in with QGIS platform (an open source GIS environment) to have the GIS capabilities. AVHYAS includes modules for atmospheric correction, deep learning classification, data fusion, spectral unmixing, feature extraction, target detection, geophysical applications etc. along with data quality evaluation, pre-processing and basic tools. At present, it can handle data from HySIS, AVIRIS-NG,





Hyperion & ASD sensors, Resourcesat-2/2A & Sentinel satellites. It is planned to upgrade it for future sensors, and also plug-in new algorithms seamlessly.

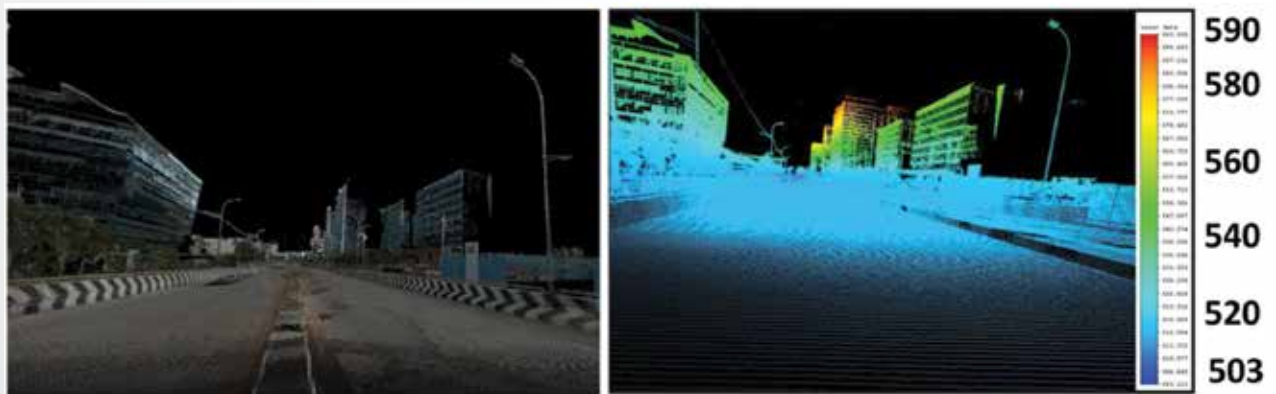
**Aerial Services and Digital Mapping**

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.

**Aerial Services: LIDAR Survey over Godavari : Digital Elevation Model (DEM)** with 1m spacing, Digital Terrain Model (DTM) with 0.35m vertical accuracy, contours at 0.5m interval, orthoimages with 0.5m GSD and 2D Geospatial database in 1:5000 scale is delivered for Tapi river covering 1615 sq.km and is in progress for Godavari river covering 4802 sq.km. Data will be utilized for flood forecasting and flood inundation modelling in selected flood prone reaches of Godavari and Tapi rivers.



**Mobile Mapping System (MMS):** Mobile mapping systems which consists of Laser scanner (1550 nm) and Digital Cameras for 3600 Field of View (FoV) data acquisition is acquired at NRSC. The MMS technology will be used for 3D Building Modeling for urban applications, utility mapping and asset management, Canopy Height Modeling and Biomass estimation for forestry applications, Infrastructure monitoring for roads and railways.



MMS acquired Image of Urban area

MMS acquired point cloud (Elevation-metre)

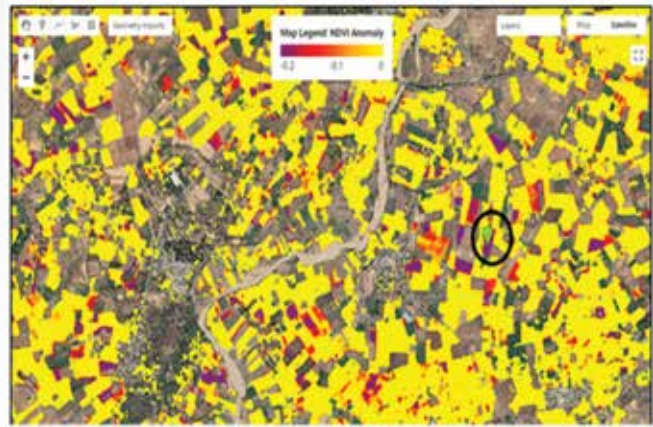
**Remote Sensing Applications**

**Agricultural Sciences and Applications:** District and state-level crop inventory and acreage estimates were made for three new Kharif crops such as Maize, Groundnut, and Soybean over more



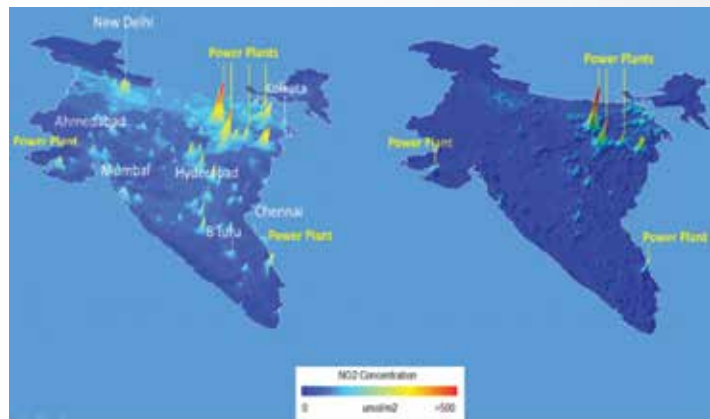


than 100 districts in 5 states under SUFALAM programme. As BIMSTEC region priorities of CEOS chair, ISRO and JAXA jointly mapped 'Aman' (July – Dec.) rice planted area over Bangladesh for a common year, using Opti-SAR combination from Resourcesat-2 AWiFS and ALOS-2 / PALSAR-2 which produced higher accuracy than 'only-optical' and 'only-radar' data. Several value-added agromet products have been disseminated to 7 Agromet Field Units (AMFUs) for aiding agro-met advisories to farmers in Gramin Krishi Mausam Sewa (GKMS) project under MoES. A comprehensive satellite-based geo-spatial assessment of desert locust menace using ecological suitability, crop damage assessment and prediction to Indian summer crops was also done and weekly updates were disseminated. Semi-physical model has been developed for GP-level rice yield estimation in Cuttack, Orissa and was validated with Crop Cutting Experiment (CCE) data. Fodder spectral yield models have been developed for Anand Milk Union. Total green fodder production was estimated to be 14.4 lakh tons for Anand milk union for Rabi 2019-2020.



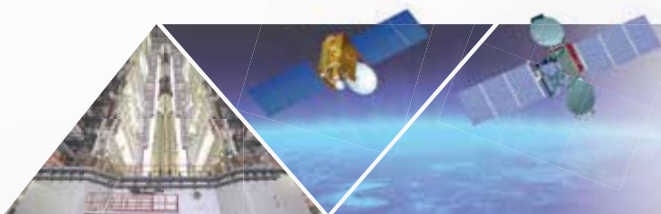
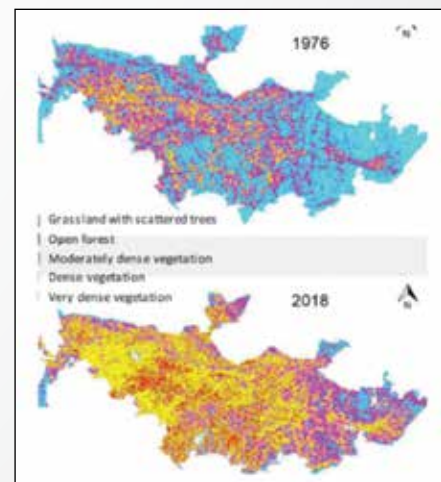
**Environmental Sciences and Applications:**

A scientific study to understand the effects of lockdown on environmental parameters over India, using space-borne and ground based data has been carried out. Proxy measurements of air and water quality have also been probed from Indian and global space-based instruments operating in polar and geostationary satellites. A clear declining trend in the tropospheric NO<sub>2</sub> concentration has been observed in the analysis (city-wise reduction of the order of 69% at Ahmedabad, 44% at Surat), suggesting an effect of reduced anthropogenic activities in Gujarat owing to the lockdown across India. In addition, night-time surface cooling, decrease in forest fire count, crop water demand and increase in productivity (up to 30%) were observed for Rabi crops.



**Monitoring decadal change in vegetation density over Gir National Park and Sanctuary, Gujarat:**

The impact of change in vegetation density on Asiatic lion habitat was studied over Gir National Park and Sanctuary, based on remote sensing data in a joint study with Gujarat Forest Department over a five-decade period. It was found that about 63% of the area has seen a significant increase in vegetation density from 1976



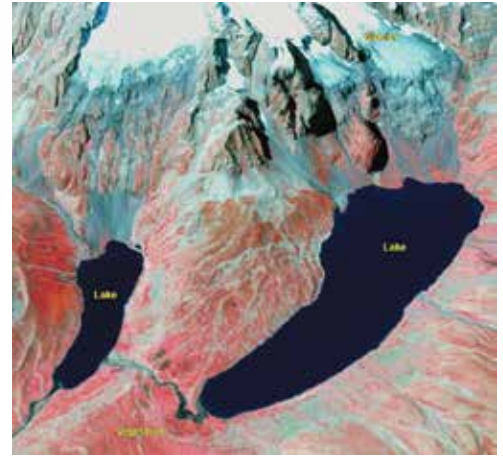


till 2018. The study also highlighted the biodiversity of flora and fauna and can help in forest and wildlife management.

**Land Hydrology research and applications:** Real-time flood forecasting is being disseminated using VEDAS web portal for the Brahmaputra River with hourly discharge using WRF-Hydro model and other meteorological parameters from MOSDAC. The probability of flood inundated zones is forecasted. Monthly, annual and monsoonal discharge of 14 major Indian rivers was analysed for the period 1958-2015. Water quality studies show significant changes in constituents such as Total Suspended Matter, Turbidity, Chlorophyll etc. during lock down period in-comparison to nearby dates of pre-lockdown. Consistent clarity of water was observed over different stretches over Ganga River.

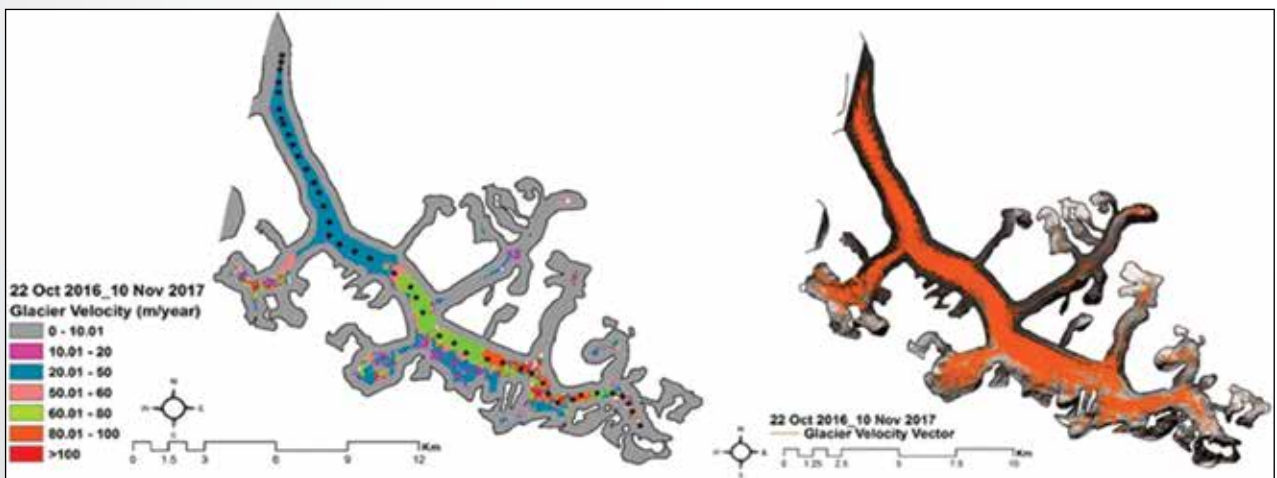
**Cryosphere Science and applications:** Analysis of data produced in a recently concluded project “Integrated Studies of Himalayan Cryosphere have shown that i) there is a decline in Himalayan snow cover produced from AWiFS data at 5 days interval between 2004 and 2020 in the month of October, ii) Himalayan glaciers have lost area between 2000/01 and 2016/17/18 based on the mapping of >5200 glaciers using IRS LISS III/Landsat TM data.

**Glacial lakes and water bodies** of size > 0.25ha are mapped in Indus basin using Resourcesat-2 LISS-IV MX data. Glacial Lake Atlas of Indus River Basin was prepared with the database of 5,335 lakes.



**Glacier surface velocity estimation using Indian EO data:**

Glaciers of the Himalayan mountain ranges plays an important role in supporting and sustaining the perennial nature of all major river basins. The spatio-temporal changes in the area, ice thickness and surface velocity are the direct indicators of glacier health and impact of short and long-term weather and climate changes respectively. Gangotri glacier surface velocity has been estimated by feature tracking technique using the ISRO’s Resourcesat-1, 2 satellites LISS-IV FMX datasets from 2014 to 2017. The mean surface velocity for the main trunk of glaciers varies between 43.3 to 62.5 m/



Gangotri Glacier velocity as estimated from ortho datasets of LISS-IV FMX

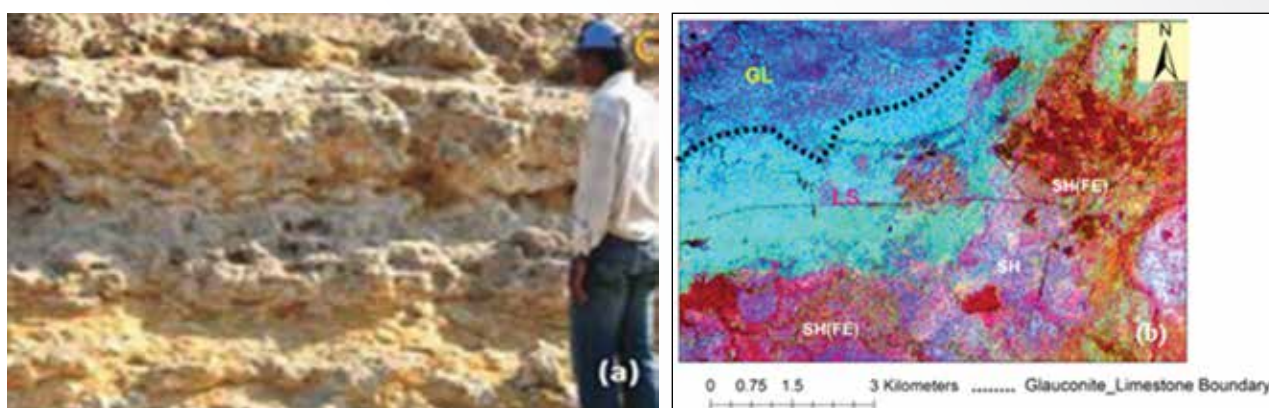




year during the autumn seasons of 2014 to 2017, with a slight increase in surface velocity in the year 2017.

**Geoscience research and applications:** Subsidence affected regions in and around Delhi NCR were extracted from the analysis of InSAR time series data of time period 2014-19. Several subsidence zones located in vicinity of Gurgaon, Dwarka and Faridabad show Line of Sight (LOS) velocity more than 3 cm/year. Shoreline Change Atlas for the entire Indian coast has been prepared. Coastal bathymetry for selected regions along the Gulf of Khambhat has been estimated using ALOS-PALSAR images and are validated using in situ sounding observations.

**Delineating Glauconitic:** Visible Near-Infrared (VNIR) and Shortwave Infrared (SWIR) bands of Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) data was processed for delineating glauconitic bearing zones in fossiliferous limestone. The study proposes the potential use of broadband reflectance spectroscopy in the mineral mapping of sedimentary provinces.



(a) Field Photograph showing glauconitic limestone; (b) Spectral derivative image composite delineating different rock. GL=Glauconitic Limestone, SH=Shale SH(Fe) =Shale (Fe rich)

**Village Level Groundwater Prospect Mapping & Sustainability** on 1:10,000 scale using Geo-spatial and Field Based Techniques: Study has been carried in Halia block, Mirzapur district, Uttar Pradesh to address the micro level groundwater variation and sustainability management plan. Synergetic use of high resolution Earth Observation data and ground based observations, in conjunction with geo-spatial technique were used to address comprehensive development/ management plan for groundwater sustainability.

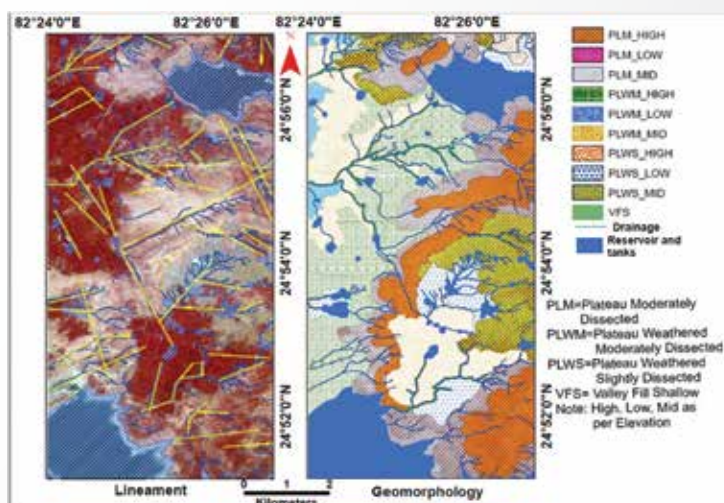


Fig: Ground water (1:10K) prospects mapping initiatives for Halia Block, Mirzapur District, Uttar Pradesh

**AMRUT Cities' Large Scale Urban GIS Database creation:** Large scale (1:4,000 scale) Urban GIS database creation has been completed from Very High Resolution Satellite (VHRS) data for



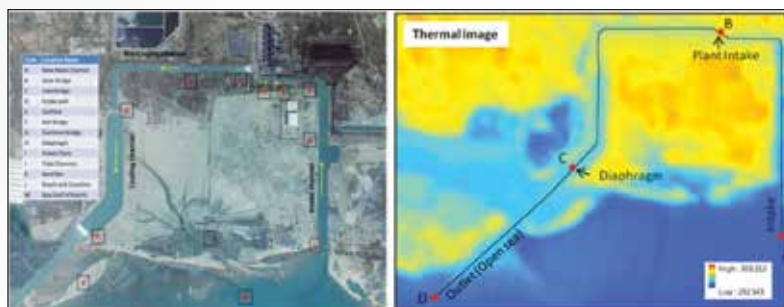




formulation of GIS based Master Plans under sub-scheme of Atal Mission for Rejuvenation and Urban Transformation (AMRUT) at the behest of by Ministry of Housing and Urban Affairs (MoHUA), GOI. Geo-spatial Database creation of 239 AMRUT cities from 20 states / Union Territories have been completed and handed over the data to Urban Local Bodies (ULBs) for ground verification and attribute data collection.

**Discharge Water Temperature Assessment at Sea inlets:**

Coastal Gujarat Power Limited (CGPL) operates a 4000 MW (800 x 5 units) Ultra Mega Power Project (UMPP) in Gujarat as “once through system” using sea water circulation. As per environment

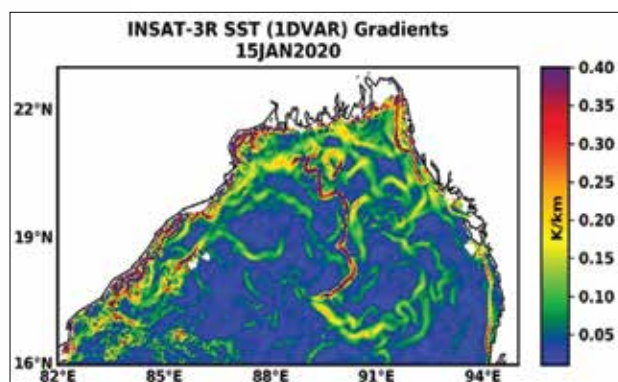


*Measurement of water temperatures in CGPL surroundings*

norms, the discharge water temperature is to be maintained well below the stipulated “delta” rise (+7° C) w.r.t. ambient sea surface temperature at the inlet. To verify that the environmental norm is maintained, satellite based thermal data was used to map channel surface temperature and to create temperature profiles for 11 months (except June) of the year 2018 along the intake and outflow channels (till the sea). Results show that the difference in temperature between intake and outflow channels is ~2° C.

**Geophysical Parameter Retrieval from INSAT 3D/3DR:**

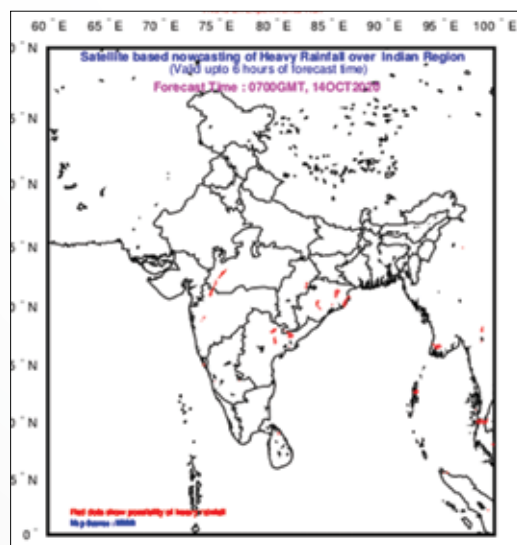
Retrieval algorithms were developed for incremental Geophysical Products (~20) under a MoU between Antrix Corporation Limited and India Meteorological Department (IMD) for the establishment of Multi-Mission Meteorological Data Receiving and Processing System (MMDRPS) facility at IMD, New Delhi. A New physical retrieval algorithm developed for accurate estimation of Sea Surface Temperature (SST) is useful to generate high-resolution front for oceanographic applications.



*Spatial gradient of daily INSAT-DR SST in Bay of Bengal*

**Nowcasting of Heavy Rainfall using INSAT-3D and Alert System:**

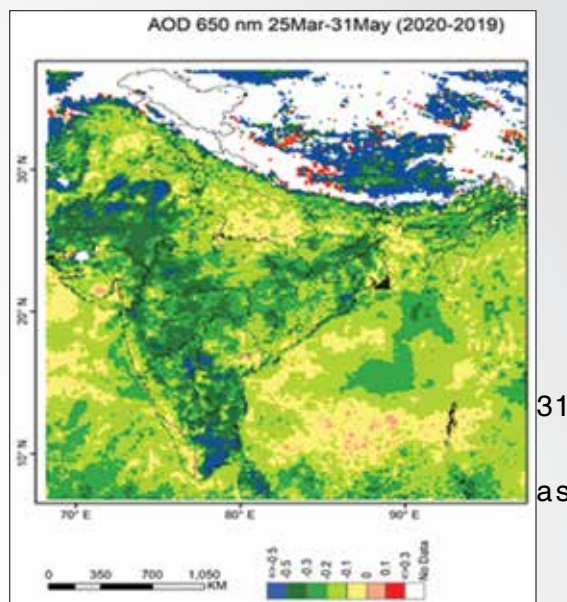
The in-house developed algorithm for Nowcasting of heavy rainfall using INSAT-3D and its alert system over the Indian region, has been successfully installed at IMD in September 2020. The nowcasting algorithm is based on identifying zones of Cloud Top Cooling Rate (CTCR) that surpasses the exceedance thresholds. These thresholds computed at every grid using historical data to fit probability distribution curve for CTCR.



*Satellite based nowcasting*



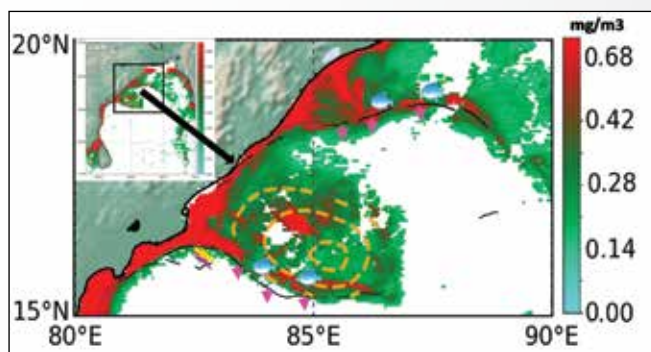
**Aerosol Optical Depth (AOD) observation during COVID-19 induced lockdown period:** During COVID-19 lockdown period there was overall reduction in greenhouse gases emission and reduction of particulate matter aerosol in the lower atmosphere in India. Many of these changes were observed from space based observations. Spatial distribution of INSAT-3D Aerosol Optical Depth (AOD) over India reveals an average reduction in aerosol loading during the lockdown period (25 March – May 2020) by 11–47% as compared to pre-lockdown period (1 January – 24 March 2020) and by 18–34% during the same lockdown time period in 2019.



*AOD Anomaly during lockdown period 2020 with respect to the same time period of 2019*

**Ocean Colour and Biological Oceanographic Studies:** An Optimized Quasi-Analytical Algorithm (OQAA) has been developed to estimate Chlorophyll-a concentration and phytoplankton size class for Arabian Sea. The OQAA algorithm showed significant improvement in the retrieval of Chlorophyll-a in Arabian Sea with a RMSE of 0.16  $\text{mgm}^{-3}$  compared to the operational algorithm, Ocean Chlorophyll (OC4) RMSE of 0.58  $\text{mgm}^{-3}$ . The algorithm will be implemented in the upcoming GISAT-1 & EOS-6 missions for studying the ecosystem structure of Arabian Sea. Seasonal Variability of Coloured Dissolved Organic Matter (CDOM) along Gujarat coastal waters was studied using a new regional algorithm for CDOM absorption at 412nm. The study revealed that CDOM absorption in coastal waters of Gujarat follows the monsoon and peak of CDOM is observed in post monsoon season.

**A New Potential Fishing Zone (PFZ) Identification and tracking algorithm:** A new approach for providing probabilistic PFZ outlook even under cloudy conditions using multi-satellite/multi-sensor parameters has been developed. This technique has also been transferred to INCOIS for operational use.

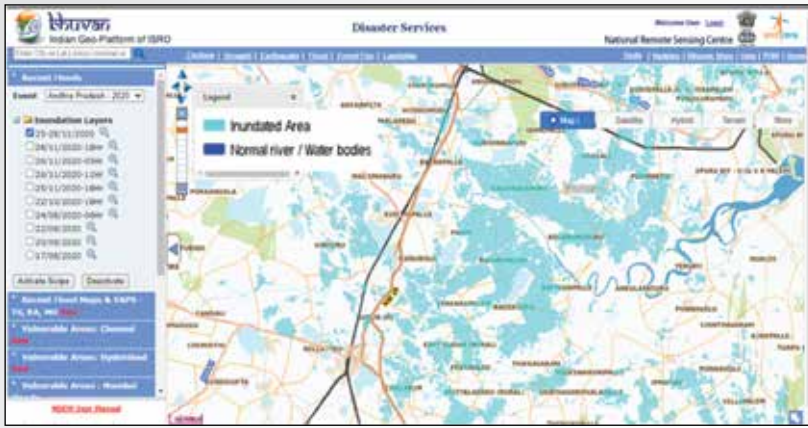


*New PFZ algorithm making use of satellite derived SSTfront (black line), eddies (dashed contours), chlorophyll (colour shade) and wind and current drifts.*

**Disaster Management Support**

**Floods & Cyclones:** Near real-time major flood events mapping and monitoring was carried out using satellite data covering 166 affected districts in 14 States (Andhra Pradesh, Assam, Bihar, Chhattisgarh, Madhya Pradesh, Maharashtra, Kerala, Karnataka, Uttar Pradesh, Gujarat, Odisha, West Bengal, Meghalaya, and Telangana) either by riverine floods or floods due to cyclone induced rainfall during 2020. About 262 flood maps and value added products are prepared and disseminated directly to the user organisations including MHA, NDMA, SDMAs, State Remote Sensing Applications Centers, and through NDEM and Bhuvan Geo-portals.





Village level information – flood inundated areas Nellore District, Andhra Pradesh

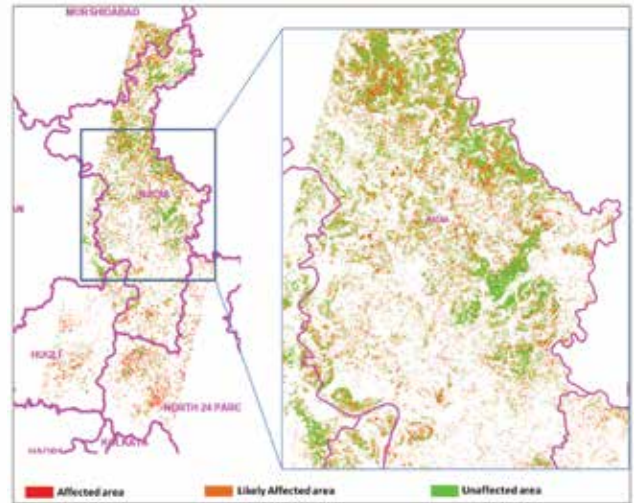


Inundation in Low lying areas Hyderabad

**Crop damage assessment** has been carried out during the flood events in West Bengal, Uttar Pradesh, Assam, Odisha and Bihar State. Amphan, an extremely severe cyclone struck the coast of West Bengal and caused floods in West Bengal and Odisha. Crop damage assessment due to Amphan cyclone induced flood inundation of agriculture fields for Jute crop in West Bengal has been studied.

**Operational Spatial Flood Early Warning:**

Web enabled real-time spatial flood forecast (lead time of 50 Hrs) has been provided for Godavari using space based inputs. Flood inundation simulations models for both the rivers are prepared using ALTM DTM of 1m posting and Carto DEM of 10m posting.



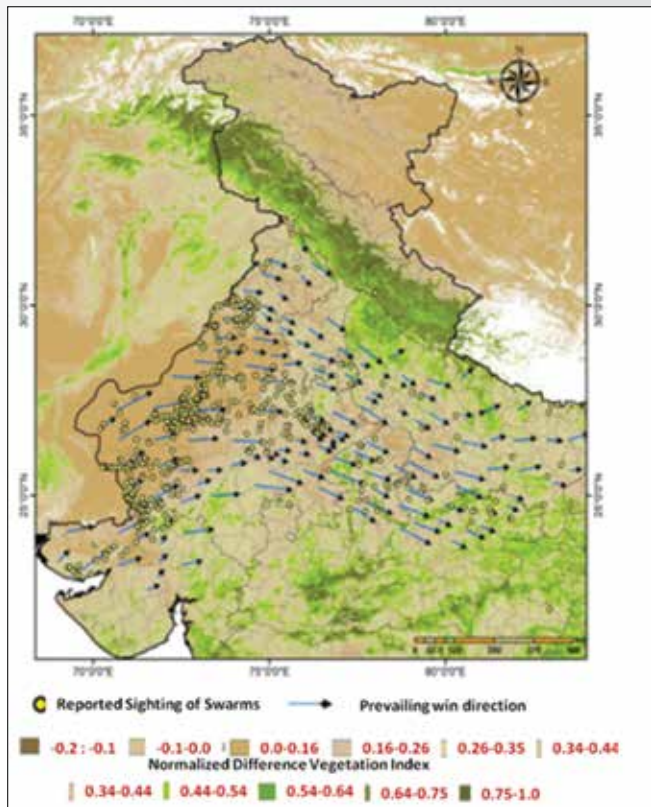
Amphan cyclone induced flood inundation



Flood Inundation Simulation for Godavari River (18 Aug 2020 at 14hrs)



**Locust Surveillance Using Geospatial Technology:** Locust related studies are being carried out for understanding the heuristic prediction of locust swarm trajectory with maps of wind parameters (speed and direction), soil moisture (root zone and sub-surface), accumulated rainfall, land surface temperature, FCC and NDVI data. Locust impact / crop loss analysis is done during the specified period. Knowledge base (like climate and locust relation, understanding the locust behaviour and life cycle events, etc.) is being built along with the Locust Warning Organization (LWO), Jodhpur.



**Landslide Monitoring:** A massive landslide occurred on the early hours of August 07, 2020 in the Pettimudi estate (approximate location: 10°9' 39" N, 77° 0' 39.5" E) near



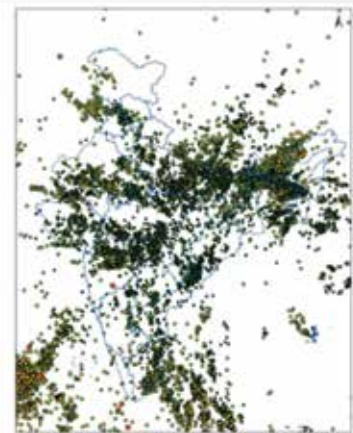
*Heuristic prediction model with inputs like Vegetation status, Wind parameters and existing Locust swarms provided by LWO*

Pettimudi tea estate, Munnar area, in the Idduki district of Kerala. Following the event, the International Disaster Charter (Charter Call 766) was triggered on August 08, 2020. The value added products were generated and uploaded in Charter as well as disseminated to end users.

**Lightning Detection System (LDS) Network:** Lightning Detection Sensor (LDS) network of 27 sensors have been installed at different parts of the country to detect lightning flash occurrences; which is an essential climate variable (ECV). Indian region received very large number of lightning occurrences during 24 and 25 June 2020. Total number of Cloud to Ground lightning flashes were 3912 and 16597 on 24 and 25 June 2020 respectively.



LDS Network & Ranges



Occurrence of Atmospheric Lightening on 24<sup>th</sup> June 2020



## 2.2 Communication Satellite System and Applications

### 2.2.1 Satellite Communication Programme

The communication satellites have been contributing significantly in the socio-economic and strategic activities in the country. At present, there are 17 satellites in operation. The details of the operational satellites are briefed in the following sections.

### 2.2.2 Communication Satellites in Service

**GSAT-8** - GSAT-8 is a 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.

**GSAT-10** - GSAT-10 launched in September 2012, 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 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 07, 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 & 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** - GSAT-9 or South Asia Satellite is realised for the benefits of people of South Asian countries Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal and Sri Lanka. The satellite carrying Ku band transponders 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 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. 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. 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. 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. GSAT-31 is configured on ISRO's enhanced I-2K Bus. It is a communication spacecraft carrying Ku-band transponders. The satellite provides Indian mainland and island coverage.

**GSAT-30** - GSAT-30 was successfully launched on January 17, 2020 from Kourou. GSAT-30 is configured on ISRO's enhanced I-3K Bus. It is a communication spacecraft carrying Ku-band transponders and C-Band Transponders with 36 MHz bandwidth. The satellite provides Indian mainland and islands coverage in Ku-band and wide coverage over encompassing India, Gulf countries, a large number of Asian countries and Australia in C band.

### 2.2.3 Future Communication Missions

**CMS-03** – CMS-03 Spacecraft is configured based on ISRO's standard I-3K Bus. It is a communication spacecraft to be launched onboard GSLV Mk-III. It has Ka x Ka high throughput payload. Presently, the satellite subsystems are under realization.

**GSAT-22, GSAT-23** and **CMS-02** - The three communication satellites GSAT-22, 23 & CMS-02 will be configured with ISRO's standard I-3K Bus. These satellites will carry Ku-band transponders capable of supporting DTH services. The satellite subsystems are under various stages of realization.

**CMS-04 (IDRSS-1) & IDRSS-2** - IDRSS is a satellite constellation to be located in geo-stationary





orbit. The main objectives of IDRSS are:

- TTC, Data, Audio and Video links to Gaganyaan
- TTC links to LEO satellite
- Data transfer from Antarctica Ground Stations

The satellite is configured with data relay payloads operating in S, Ka and Ku bands. The satellite employs for the first time a 2.5 m deployable Cassegrain Antenna System operating in dual frequency bands (S and Ka bands) as well as a 1.5 m fixed Cassegrain Antenna System operating in Ku and Ka frequency bands. The deployable antenna system will have interface with the satellite by means of a deployable, pointing and tracking mechanism along with a S band rotary joint. The satellite bus is configured around I-2K extended bus and will be compatible for launch onboard GSLV Mk-II Launch Vehicle.

**GSAT-32** - GSAT-32 is envisaged as a high-power S-band satellite with enhanced EIRP and G/T to support small size, low power, light weight and cost-effective user terminals. The satellite will be configured on new I-8K bus with 18m S-band Unfurlable Antenna (UFA).

#### 2.2.4 Satellite Communication Applications

A fleet of 17 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 292.5 operational bent-pipe transponders and 25 Gbps high throughput satellite (HTS) capacity. These satellites support the services like television broadcasting, DTH television, telecommunication, VSATs, radio networking, strategic communication and societal applications. The prominent users of the transponders are Government & Strategic users, Prasar Bharati, DTH and TV operators, Public sector units (BSNL, ONGC, AAI, ECIL etc.), private VSAT operators, banking and financial institutions, etc.

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

In order to meet additional transponder requirements from various users, about 74 transponders in Ku-band and HTS capacity of 1.0 GHz 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

Television & DTH are the major services supported by satellite communications. The indigenous GSAT satellites have been major catalyst for the expansion of Television coverage of Doordarshan in the country. Required transponders capacity for Broadcasting sector has been met through GSAT satellites as well as leased capacity on foreign satellites.

Doordarshan is presently operating 36 satellite channels and has a vast network of Studios and terrestrial Transmitters (includes 23 DTTs) of varying power installed throughout the length and



breadth of the country. Doordarshan is using a total of 18.70 Transponders (12.03 C Band & 6.67 Ku Band) of 36 MHz each on GSAT System. Doordarshan has 41 C-Band earth stations for program contribution & distribution of their Channels and one C-Band DTH earth station for providing DTH service to Andaman and Nicobar Islands.

In addition, Doordarshan provides its free-to-air DTH service “DD Free Dish” with coverage over entire country. Free Dish bouquet comprises of 110 TV Channels (including one HD Channel) and 48 Radio Channels.

Apart from Doordarshan the public broadcaster, 4 private DTH operators provide service in India. It is estimated that (TRAI Report : Apr - Jun 2020) there are about 70.58 Million active subscribers availing private DTH services. About 909 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 63 C band transponders are used for supporting Television uplink.

### **Digital Satellite News Gathering (DSNG) and Events Broadcasting**

Doordarshan has inducted 9 C-band DSNG vans equipped with MPEG-4 compliant SD/HD compression chain and spectrum efficient DVB-S/S2 compliant digital modulators. These new DSNG vans are being operated by sharing the existing frequency of C-band DSNGs deployed in DD network. Presently, Doordarshan has 25 C-band and 16 Ku-band Digital Outdoor-Broadcast Digital Satellite News Gathering terminals operating through GSAT satellites. About 8 transponders capacity is being used for DSNG services by all broadcasters.

### **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 radio network is supported using 44 Captive Earth Station & DSNG and 511 Down Link Radio Network Terminals (RNTs). AIR is also Broadcasting 41 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 large number of services on terrestrial connectivity. Satcom links have a major role in banking sectors linking the ATMs with banks.

1565 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 2.85 Lakh 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 Railway, Karnataka Power Transmission Corporation Ltd., etc. apart from private enterprises. In addition, INSAT/GSAT satellites cater to captive government networks of various ministries and strategic agencies.

### Telemedicine

Satellite Communication based Telemedicine is one of the unique application of space technology that is being utilised for the benefit of the society at large. Telemedicine technology utilises Information & 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 doctor to 'see & interact' with the patient live through video links.

ISRO's Telemedicine programme was initiated in the year 2001 as a part of proof-of-concept demonstration. Since then the programme has been connecting various remote & rural medical colleges & hospitals and mobile units to major specialty hospitals in cities and towns using satellite communication. At present, around 210 nodes are operational, which have been upgraded with new Telemedicine and in-house developed interactive software "Daksh". Out of these, 20 Telemedicine nodes are located in very high altitude in Siachen and working at very low temperatures up to -45 degree centigrade.



*Live Interaction between SNM Hospital, Leh & District Hospital, Kargil*

Based on urgent request from Indo-Tibetan Border Police Force (ITBPF), in view of the COVID pandemic & prevailing situation between India & China, a TM node for providing super speciality services to remote nodes was installed at ITBPF Hospital in Leh-Ladakh region. Three more nodes were installed in the remote areas of Leh-Ladakh region as per request received from the Leh Health Department. These nodes are proving invaluable service to our soldiers in the remote posts. The TM node at Panchtarani, near the holy Amarnath shrine in J&K was re-commissioned. Several nodes for strategic users were reactivated/ operationalised after repair/ replacement of faulty items.

Continuing Medical Education (CME) programmes are conducted from DECU studio or from remote user-ends, specially the Defence nodes, in which medical experts/doctors share their knowledge & experiences and interact with the connected remote hospitals. Users have been enabled to conduct CMEs from their respective TM centres. Several CMEs have been conducted by them. Thousands of remote doctors/paramedical staff are trained through continuing medical education (CME) program broadcast using ISRO TM network.





## 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 of two types of terminals, namely, Satellite Interactive Terminals (SITs) and Receive Only Terminals (ROTs). At present, around 44 networks are operational with 24 Hubs. Around 1438 SITs & 33147 ROTs are operational.

The Principal Secretary to the Government of Nagaland commissioned/inaugurated the SCERT Studio for Nagaland Tele-Education network. “Training of Trainers” programme was conducted on Assam TE network. The AMC of seven Hubs and operationalised SITs was continued for the North-East States TE Networks. The revived Jammu & Kashmir TE network is operational and live lectures were conducted from Jammu and Srinagar Teaching-ends. Lectures were transmitted on Karnataka, Haryana, Punjab and Kerala TE networks. Technical consultancy was provided to several user agencies such as Haryana, Punjab, YCMOU, etc. on need basis. New features are being incorporated in Daksh Learning Management System (LMS) and remote support was provided to various users. Standard Operating Procedure document for Daksh LMS was developed for ease of use of software by the users.



*Commissioning of SCERT Studio by Principal Secretary*

## Social Research & Evaluation

Social Research and Evaluation studies such as “Strengthening the Health Sector through Satellite Communication in Andaman and Nicobar Islands”, “Feedback and Content Need Assessment Study on Uttarakhand Tele-Education Network: Special Reference to Undergraduate Science Students”, “Health Information and Communication Needs of Arunachal Pradesh: with Special Reference to Maternal and Child Health”, “Impact Analysis of the Courses Conducted under the IIRS Outreach Programme”, “Usefulness of Geotagging in MGNREGA through GIS Remote Sensing data” etc. were conducted by DECU a unit of ISRO.





## Satellite Meteorology

Satellites provide the essential inputs for the meteorological applications. INSAT-3D and INSAT-3DR (Imager, Sounder, DRT) satellites carrying meteorological payloads are supporting weather forecasting services. The data received from the satellites is processed and disseminated by INSAT Meteorological Data Processing System (IMDPS) at India Meteorological Department (IMD). The system is capable to receive and process the data of both INSAT-3D and INSAT-3DR. The performance of the system during the current year has been maintained to the level of 99% operation efficiency (24x365 basis).

During Recent past, in cases of Kyarr, Maha, Bulbul, Pawan, Amphan, Nisarga, Gati, NIVAR and Burevi Cyclones, warnings were monitored with satellites. Advanced Dvorak Technique (ADT) software has been customized to determine the intensity of Tropical Cyclones. RAPID scanning feature on INSAT 3DR is used during extreme weather events like Amphan, Nisarga, Gati, NIVAR, Burevi, etc.

The Imager payload of INSAT-3D and INSAT-3DR is being used in staggered mode so that effectively 15 minutes temporal resolution is achieved. Sounder payload of INSAT-3DR is operated in such a way that INDIAN land region sector data is covered up twenty times and Indian Ocean region data is covered up four times (04, 11, 16 & 23 UTC) on hourly basis. Satellite observed radiances and winds are now being assimilated to improve their forecast ability.

Data Relay Transponders (DRT) of INSAT-3D and INSAT-3DR are used for relaying meteorological, hydrological, agro-meteorological and oceanographic data from unattended stations to central facilities for assimilation and analysis under various meteorological applications. 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.

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

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 29 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 October 2019 to November 2020, INMCC provided search and rescue support to 9 distress incidents in Indian service area and contributed in saving 184 human lives. During this period, about 913 new radio beacons were added in Indian database. Till date, there are about 1119 registered user agencies and total number registered beacons are more than 16832 in our database. 19<sup>th</sup> Beacon exercises were carried out involving ICG, Navy, DGCA, Indian Air Force and DG (shipping)/SCI during 21 to 23 & 28-01-2020.

Seminars and Workshops on SAR related activities and operations were conducted for AAI, ICG and Defence and other users.

### **MEOSAR project**

ISTRAC is in the process of realizing & operationalizing MEOSAR ground segment (MEOLUT & MCC). The ground segment consists of seven 2.4m antennas associated with SERVO, Down Converter, RF base band, Digital receiver, Orbit determination, MNC, Schedule generation, Location Estimator, MCC and related communication systems.

Proof of Concept (POC) of MEOSAR project is being continued at the new facility. Initial results are available. Test and evaluation of the MEOSAR facilities is in progress. Efforts towards final certification by Cospas-Sarsat organisation, operationalisation are initiated.





### **Distress Alert Transmitter**

ISRO had developed Distress Alert Transmitter (DAT) for fishermen to support emergency message reporting for maritime search and rescue operations. This year, ISRO has upgraded the heritage DAT by interfacing with the NavIC messaging receiver to provide acknowledgement of emergency messages together with information like potential fishing zones and emergency broadcast messages from control stations. This makes the SAR efforts more effective & user-friendly combining both SATCOM & SATNAV features.

### **High Throughput Services**

Interactive communication applications in the recent times are being served through High Throughput Satellites (HTS) across the world. ISRO has launched HTS satellites GSAT-19, GSAT-11 & GSAT 29 operating with multiple spot-beam coverage in Ku & Ka bands. These together provide a capacity of 25 Gbps throughput which is several order higher compared to traditional satellites. These satellites began their service to extend BharatNet connectivity to Gram Panchayats and also to extend cellular connectivity to remote & island regions of the country.

### **South Asia Applications**

Following the announcement made by Honourable Prime Minister of India the South Asia Satellite was realized and launched on board GSLV on May 5, 2017. The SATCOM network established in Bhutan with a dedicated SatCom Hub in Thimphu (Jan 2019), is being used for uplinking two TV channels and 4 Radio channels for Bhutan, connecting the Disaster Management Center, backhauling the critical telecom links and Internet connectivity.

Maldives started to establish a SATCOM network with 35 terminals. The hub support is extended from Delhi for connecting their Islands with Male. Bangladesh started off the utilization with 10 terminals to connect some of their islands. Further, they have recently (Oct 2020) established dedicated network with hub at Dhaka. Afghanistan is finalising the procurement for establishing their own network. M/s BEL is working for establishment of a dedicated satcom network for Sri Lanka Police. They are coordinating with Indian Embassy in Sri Lanka.

### **Mobile Satellite Services (MSS)**

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

Using one-way position reporting system, developed by ISRO experimental projects are implemented in association with Railways and MHA. Real-time Train Information System (RTIS) is implemented by connecting 3000 locomotives. Sub-20m fishing vessel tracking is implemented in Gujarat, Tamilnadu and Puducherry, together deploying 1000 terminals on trial basis. The hardware used in RTIS are shown below:





*Outdoor Unit*



*Indoor Unit*

### **Satellite-based AIS (S-AIS)**

ISRO is working on dedicated space-based sensors to create Maritime Domain Awareness by means of a Satellite-based Automatic Identification System. Development of single-channel AIS receiver for S-AIS has been completed, and development of multi-channel variant is in progress.





## 2.3 Navigation Systems

### 2.3.1 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).

### 2.3.2 GPS Aided Geo Augmented Navigation (GAGAN)

The GPS Aided Geo Augmented Navigation (GAGAN) system is developed by Indian Space Research Organization (ISRO), together with Airports Authority of India (AAI) to deploy and certify an operational SBAS-Satellite Based Augmentation System for the Indian Flight Information Region (FIR), with expansion capability to neighboring FIRs. GAGAN provides a civil aeronautical navigation signal consistent with International Civil Aviation Organization (ICAO) Standards and Recommended Practices (SARPs) as established by the GNSS Panel.

The GAGAN is presently operational with three signals in space (PRN 127, PRN 128, PRN 132) from three GEO satellites viz GSAT-8, GSAT-10 and GSAT-15 respectively. The renewal activities for the allocation of PRN 127 and PRN 128 for a period of 10 years have been completed. GAGAN certification for Navigation Performance level of Approach with Vertical Guidance (APV-1) over India & Required Navigation Performance (RNP 0.1) within Indian Flight Information Regions has been extended for further 24 months with effect from Jul 19, 2020.

Deployment Readiness Test (DRT) of new software was held from Sep 28 to Oct 11, 2020 at Bengaluru and ISRO and DGCA members reviewed the procedures and test results. Technical Review Team (TRT) meeting was held on Nov 05, 2020 to review, provide directions and guidance for GAGAN program.

### 2.3.3 Navigation with Indian Constellation (NavIC)

NavIC is an independent regional navigation satellite system developed and maintained by India. It is designed to provide accurate Position Velocity and Timing (PVT) information service to users in India as well as the region extending up to 1500 km from its boundary, which is its primary service area (5°S to 50°N and 55°E to 110°E). NavIC is providing two types of services, namely, Standard Positioning Service (SPS) and Restricted Service (RS) and is expected to provide a position accuracy of better than 20m ( $2\sigma$ ) over the primary service area and timing accuracy better than 40 ns ( $2\sigma$ ). The IRNSS system consists of Ground Segment, Space Segment and User Segment.

#### (a) Space Segment

The NavIC space segment constellation is configured with seven satellites with three in Geo Synchronous Orbit (GSO) and four in Inclined Geo Synchronous Orbit (IGSO). The constellation has been operational since June 2016. IRNSS-1A and IRNSS-1G are currently being used for short messaging services. The replacement satellite IRNSS 1I (for IRNSS 1A) was launched on April 2018 and is currently operational. NVS-01 is planned as replacement satellite for IRNSS-1G. NVS-01 is under development and it is planned to be launched in 2021-22.





The updated version of IRNSS SPS Interface Control Document (ICD) (version 1.1) has been hosted in ISRO website with information to utilize the services of IRNSS-1I. The Indian Regional Navigation Satellite System (IRNSS) has been accepted as a component of the World-Wide Radio Navigation System (WWRNS) for operation in the Indian Ocean Region by the International Maritime Organization (IMO).

### (b) Ground Segment

- The ISRO Navigation Centers (INC) are operational at Byalalu, Bengaluru and Lucknow. INC1 (Byalalu) and INC2 (Lucknow) together provide seamless operations with redundancy.
- IRNSS Network Timing facility (IRNWT-I) is operational at Byalalu, Bengaluru. The IRNWT-II has been established at Lucknow and is operational since February 2018. Both the Timescales at IRNWT-I and II operate with a difference of 20ns ( $2\sigma$ ) accuracy with respect to UTC. Two Way Satellite Time and Frequency Transfer (TWSTFT) and Global Navigation Satellite System (GNSS) all-in-view methods are used for time synchronization between INC-1 and INC-2 and with National Physical Laboratory India (NPL-I).
- Sixteen IRNSS Range & Integrity Monitoring Stations (IRIMS) are operational with fifteen of these stations located within the country and one at Mauritius. Additional future IRIM stations establishment at Japan and Russia in progress.
- The IRNSS Data Communication Network (IRDCN) with Terrestrial and Very Small Aperture Terminal (VSAT) links is operational with redundancy among all the ground elements.
- The IRNSS Spacecraft Control Facility (IRSCF), monitors and controls the IRNSS satellites and is operational at Master Control Facility (MCF) Hassan and Bhopal. The IRSCF uplinks the navigation data to the satellites in addition to regular TT&C operations. IRSCF stations at MCF-Hassan and Bhopal work as redundant to each other for IRNSS TTC operations.
- Four IRNSS CDMA Ranging (IRCDR) stations are operational at Hassan, Bhopal, Shillong and Jodhpur. These stations are used for two-way ranging of IRNSS satellites. Two additional IRCDR stations are planned at Trivandrum and Port Blair.

### (c) User Segment

ISRO is involved in the development and technology transfer of various types of user receivers. The following types of receiver and receiver technology are being developed.

- FPGA based SPS receiver design and development
- 36 Channel configurable SPS Base Band ASIC based receiver
- G3I NavIC BB Application Specific Integrated Circuit (ASIC) Receiver with Lower Node technology
- Payload Coherency Test Receiver
- Design and development of receivers for new L1 civilian signal.

#### 2.3.3.1 Major Developments

- **Recognition by International Maritime Organisation** - As a part of the objective to enable applications of NavIC in maritime field, ISRO submitted documents related to the performance, test results and applications of NavIC to International Maritime Organization (IMO). Through Director General of Shipping (DGS), ISRO attended the meetings of Maritime Safety Committee







(MSC) and Sub-Committee on Navigation, Communication and Search and Rescue (NCSR) of IMO. In the 102<sup>nd</sup> session of the Maritime Safety Committee (MSC-102) held in November 2020, IMO recognized NavIC as a component of the WWRNS. It stated that NavIC meets the operational requirements to assist in the navigation of ships in ocean waters.



- **Incorporation in Radio Technical Commission for Maritime Services (RTCM) standard** - RTCM Standard 10403.3 defines the standards for Differential Global Navigation Satellite Systems (DGNSS). NavIC L5 successfully cleared all the tests for incorporation into RTCM standard. The Special Committee (RTCM SC-104) during its meeting in May 2020 approved NavIC L5 signal to be included in the RTCM standard. The latest release of RTCM 10403.3 Standards Amendment-1 includes NavIC L5. This will enable NavIC application in the differential GNSS catering to maritime, surveying, construction, asset monitoring, deformation monitoring, geodesy, etc.



- **Incorporation in 3GPP standard** - ISRO in co-operation with members of Telecom Standards Development Society of India (TSDSI) has been working towards inclusion of NavIC in 3GPP standards for assisted GNSS in the 4G. In 2019, 3GPP had adopted Work Item for inclusion of NavIC into the 4G standard. As part of the Work item activity, NavIC Receiver Compliance Performance Standards were submitted to 3GPP. During its 110<sup>th</sup> meeting of RAN-4 held in June 2020, 3GPP approved inclusion of NavIC in Release 16. This step will enable advanced positioning features like indoor positioning, better battery efficiency, fast position fix, etc. with NavIC satellite system.



- **NavIC in Mobiles:**

To enable the use of NavIC in mobile phones, efforts are being channelized with the following stakeholders.

- a. **Chip Manufacturers:**

Major mobile chipset manufacturers (Qualcomm, Mediatek) have released mobile processors which are NavIC enabled. These releases have started since January 2020.

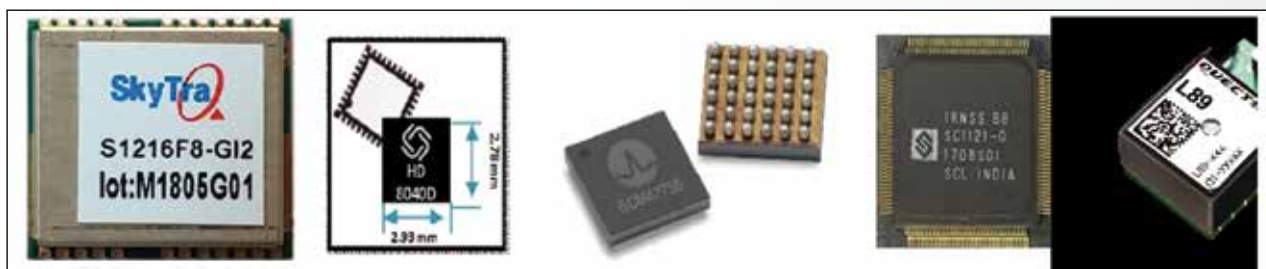
- Qualcomm – Snapdragon 460, 662, 690, 720G, 765, 865, 888
- Mediatek – Dimensity 800, 1000





- **NavIC in low power GNSS chips:**

ISRO has provided technical support to chip manufacturers like Allystar, Trimble, Quectel, Skytraq, U-Traq, Accord, Broadcom, etc. to enable inclusion of NavIC in their GNSS chips. Due to this, all these manufacturers have support for NavIC L5 signal in their latest chips. This has facilitated usage of NavIC L5 in many civilian applications including vehicle location tracking. However, newer applications like wearable devices, personal trackers, IoT devices, etc. which require small form factor and very low power are generally catered to by single frequency (L1) modules. The wearable devices market in India is anticipated to expand at the rate of ~26% per annum (source: market reports). In order to proliferate NavIC in this sector, all the subsequent satellites will feature L1-band signal in addition to the legacy L5 and S bands. ISRO conducted an interface meeting with all the major chip manufacturers in March 2020 and introduced them to the new L1 signal. ISRO is sharing all the relevant technical details with the chip manufacturers to facilitate inclusion of NavIC L1 into low power GNSS chips at the earliest.



- **NavIC Messaging Service:**

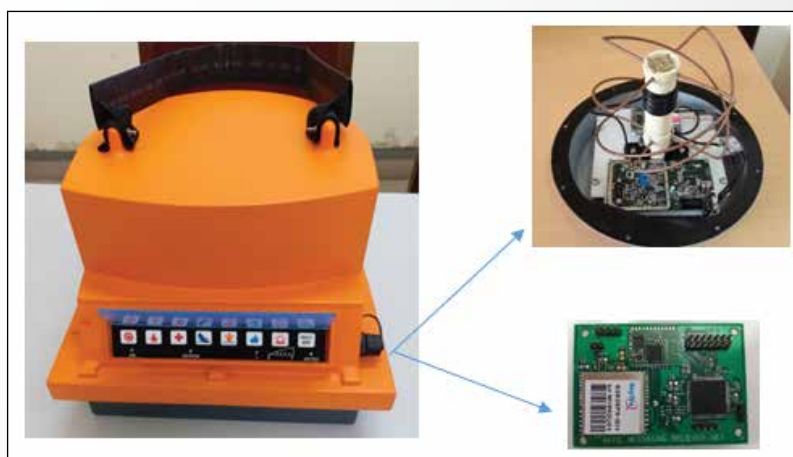
- a. **NavIC Messaging Receiver:**

Indian National Centre for Ocean Information System (INCOIS) is effectively using the NavIC messaging service to broadcast alerts messages such as cyclone, high wave etc. and provide information on Potential Fishing Zone (PFZ) for the fishermen venturing into deep sea.

ISRO has become part of an initiative by the National Disaster Management Agency (NDMA) to evolve a Common Alert Protocol (CAP) for major natural disasters like landslides, earthquakes, floods, heavy rains, avalanches, etc. NavIC Messaging System has been recognized as an effective means of disseminating the alert messages and is taken up for phase-1 implementation.

- b. **Second Generation Distress Alert Transmitter (SG-DAT):**

ISRO developed Second Generation Distress Alert Transmitter (SG-DAT) by integrating the features of NavIC Messaging Receiver (NMR) and Distress Alert Transmitter (DAT). In this





system, 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 has been established at ISTRAC along with the existing COSPARSARSAT ground system. SG-DAT terminal prototype development is completed and technology has been transferred to six industries through NSIL for commercial deployment.

- **NavIC based Timing applications** - ISRO and NPL are assisting Department of Consumer Affairs to establish one primary timescale (stratum 0) at Bengaluru and five secondary timescales (stratum 1) at Ahmedabad, Bengaluru, Bhubaneswar, Faridabad and Guwahati. These timescales will be integrated and operate with in-house ISRO's timescale software suite. The system architecture has been finalised and cleared for procurement.

These timescales will provide accurate IST dissemination across India and would ensure national security and enhances cyber security resilience.

- **NavIC Performance Evaluation** - NavIC performance is evaluated on quarterly basis and the performance evaluation reports are uploaded to the ISRO website on regular basis. Five reference receiver locations are identified in North, South, East, West and Central regions of the country to carry out the detailed performance evaluation. NavIC dual frequency SPS signals are used to check the performance from the user perspective. The achieved position accuracy is better than 10m ( $2\sigma$ ).

NavIC - GPS (Global Positioning System) - SBAS (Satellite Based Augmentation System) user receivers are being procured by Satellite Navigation Programme (SNP) for performing the NavIC SPS signal performance evaluation in NavIC service area. Presently the acceptance testing of receiver is in progress. These receivers will be deployed across India for remote navigation data collection and performance evaluation.

- **Incorporation of NavIC in Interoperable Space Service Volume (SSV)** - The Space Service Volume (SSV) provides definition for interoperable GNSS SSV for space users and space receiver manufactures. ISRO is a part of the task team constituted under International Committee on GNSS (ICG) comprising of all GNSS service providers. Analysis and simulation(s) have been carried out for evaluating the availability / signal strength of GNSS satellites for space users. Based on the simulation study, the SSV booklet version-1 has been released by United Nation Office for Outer Space Affair (UNOOSA).
- **Indo-US Technical Working Group (TWG)** - Indo-US GPS-NavIC Technical Working Group (TWG) meeting held on Mar 13, 2020 for completion of NavIC L1 signal interoperability coordination. NavIC orbital and power transmission parameters have been updated in the PRN code applications with the power sharing of 42-58% between data and pilot components and shared with ISRO for further coordination.



- **NavIC in Defence Expo 2020**

NavIC was showcased under the theme “Digital Transformation of Defence” in Defence Expo held in Lucknow from 5<sup>th</sup> to 8<sup>th</sup> Feb 2020. The Hon. Prime Minister of India visited the NavIC stall on 5<sup>th</sup> Feb 2020. NavIC products including inhouse developed RS receiver, timing receiver, distress alert transmitter, etc. were displayed in the exhibition.



### 2.3.4 Future Missions

The current NavIC satellite constellation comprises of six operational navigation satellites and two satellites for messaging services. It is planned to realize five navigation satellites viz., NVS-01/02/03/04/05 as replacement to the satellites in the current constellation. NVS-01 satellite is in developmental stage and it will be placed at IRNSS-1G. These satellites shall be located at the existing orbital slots and ensure continuity of NavIC services.

NVS-01/02/03/04/05 will be configured with navigation payloads in L5 & S bands and ranging payload in C-band similar to existing IRNSS satellites. Additionally, it is proposed to incorporate a new interoperable civil signal in L1 frequency in the navigation payload. These replacement satellites, with a targeted mission life of minimum 12 years.





## 2.4 Space Science and Planetary Research Systems

### 2.4.1 Space Science and Planetary Research

India's first mission dedicated for astronomy has completed its design life of five years in September, 2020. Data from AstroSat is widely utilized for the study of various fields of astronomy, from galactic to extra-galactic and from users from all over the world. The first interplanetary mission from India, Mars Orbiter Mission (MoM) has completed six years in orbit. Chandrayaan-2, India's second mission is providing useful data. India's first mission to study Sun is being prepared for a next year launch.

ISRO is actively supporting novel research projects in the fields of atmospheric science, astronomy and planetary exploration by providing both technical and financial assistance to various universities and research institutes. In addition to the ongoing programs, feasibility studies of scientific experiments for future space missions are undertaken at many ISRO/DOS centers.

The major activities carried out under space science and planetary research during the year 2020 are summarised below.

#### 2.4.1.1 AstroSat

India's first observatory class satellite dedicated for AstroSat and capable of observations over a broad band from UV to high energy X-rays has completed five years of its design life in September, 2020. A one day workshop was organised to commemorate the occasion on 28<sup>th</sup> September, 2020. Dr K Sivan, Chairman, ISRO/ Secretary, DOS inaugurated the event and eminent personalities from ISRO and other research centers from India participated in the event.



*Chairman, ISRO and Scientific Secretary, ISRO participating in the workshop on Five years of AstroSat. Participants in the meeting (right).*

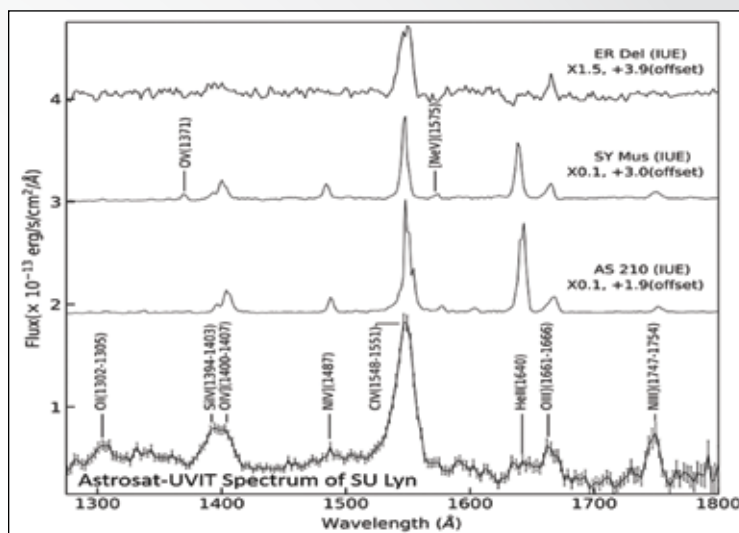
AstroSat is currently servicing 1480 users from 48 countries. In 2020, data from AstroSat has resulted in 36 publications (from April 2020 to December 2020). One of the major results is the well noticed discovery of UV photons from very early universe. During this time, AstroSat has made 220 unique observations.

AstroSat works as a proposal based observatory. A call soliciting proposals under A10 was issued in the beginning of the year. At present, the proposals received under AO10 are serviced from 1<sup>st</sup> October, 2020.



Some of the major AstroSat results/ discoveries during this period are,

- Discovery of UV photons from the very early universe called epoch of re-ionization by UVIT onboard AstroSat.
- First detection of main-sequence stars in the bulge of Andromeda galaxy.
- Resolving the mystery of a symbiotic system SU Lyn by AstroSat.



*AstroSat/UVIT spectrum of SU Lyn showing several emission lines. Spectra of other three symbiotic stars are shown for comparison.*

**Funding for AstroSat Data utilization** - To encourage AstroSat data utilization, limited funding is

made available to universities and research institutions from India. In the first year a total of twelve proposals got selected and in the second batch another ten proposals got selected for funding. Around five publications came out of these funding from the first year itself. A review for monitoring the progress of the project was conducted in June 2020.

#### 2.4.1.2 Mars Orbiter Mission

Mars Orbiter Mission (MOM), the first interplanetary mission of ISRO, completed six years in its orbit on September 24, 2020 well beyond its designed mission life of six months. Scientific analysis of data being received from the Mars Orbiter spacecraft is in progress. Thirty scientific papers have been published so far in peer-reviewed journals. MOM-MENCA data for the period from Sep 2017 to Sept 2019 was released to public through ISSDC website: <https://mrbrowse.issdc.gov.in/MOMLTA/>. More than 6800 users have registered and about 25800 downloads of science data has been carried out so far.

#### 2.4.1.3 Chandrayaan-2 Mission

Chandrayaan-2 mission was launched on 22<sup>nd</sup> July 2019 and inserted into the lunar orbit on 20<sup>th</sup> August 2019. The spacecraft had three components: Orbiter, Lander and Rover. Though the soft-landing attempt of lander/ rover was not successful, the orbiter was successfully placed in the 100km lunar orbit.

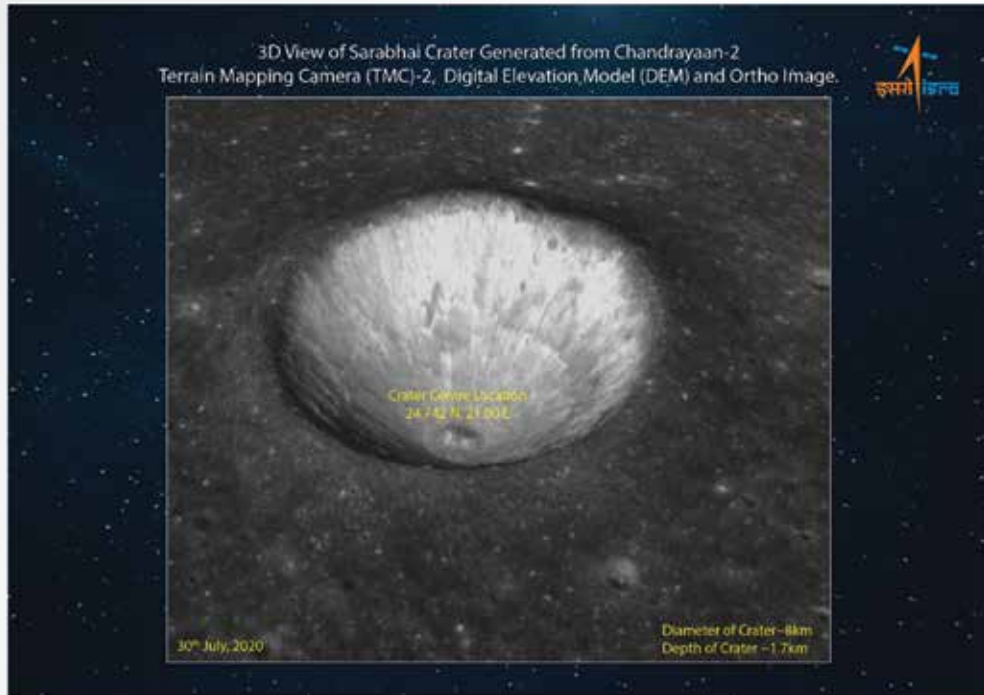
The major scientific goals are to expand the lunar scientific knowledge through detailed study of topography, mineralogy, surface chemical composition and tenuous lunar atmosphere leading to a better understanding of origin and evolution of the Moon. The orbiter completed one year around the Moon and all the eight payloads are operational. The first observations have demonstrated payload capability to contribute significantly to lunar science. Some of the salient results from different payloads are as follows:



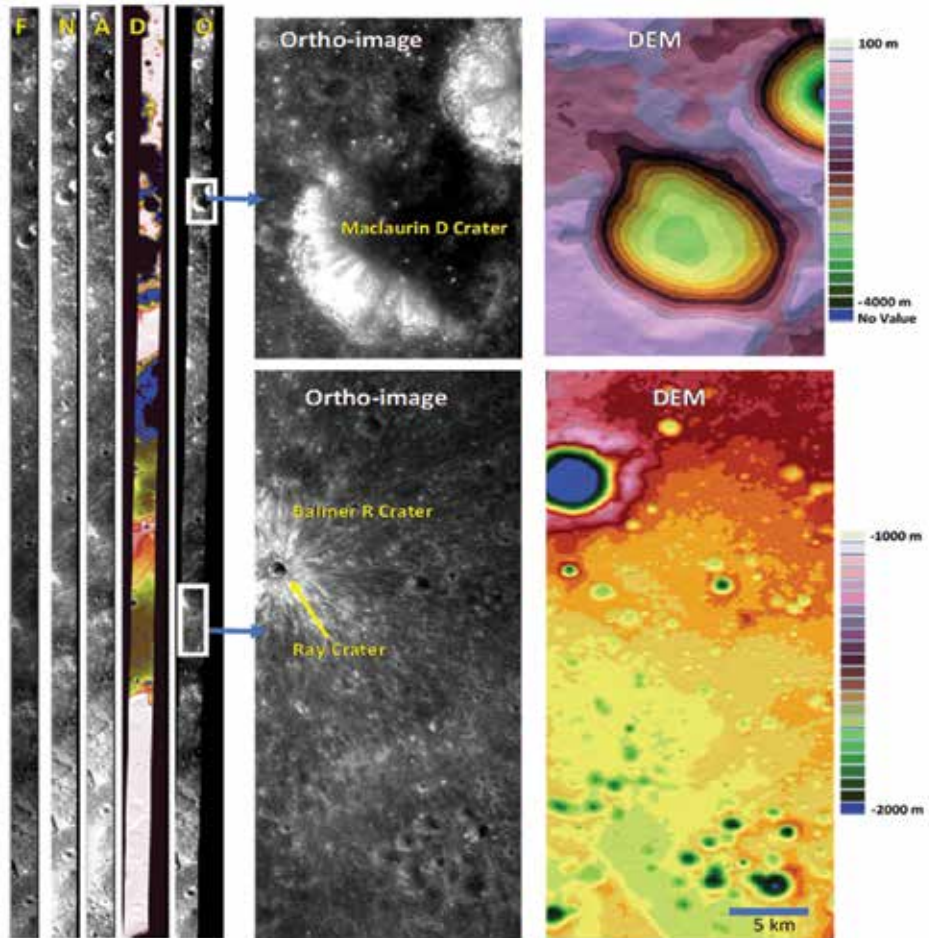


**(a) Terrain Mapping Camera – 2 (TMC-2)**

Sarabhai crater imaged by Terrain Mapping Camera-2 was released during the Valedictory function of Vikram Sarabhai Centenary program.



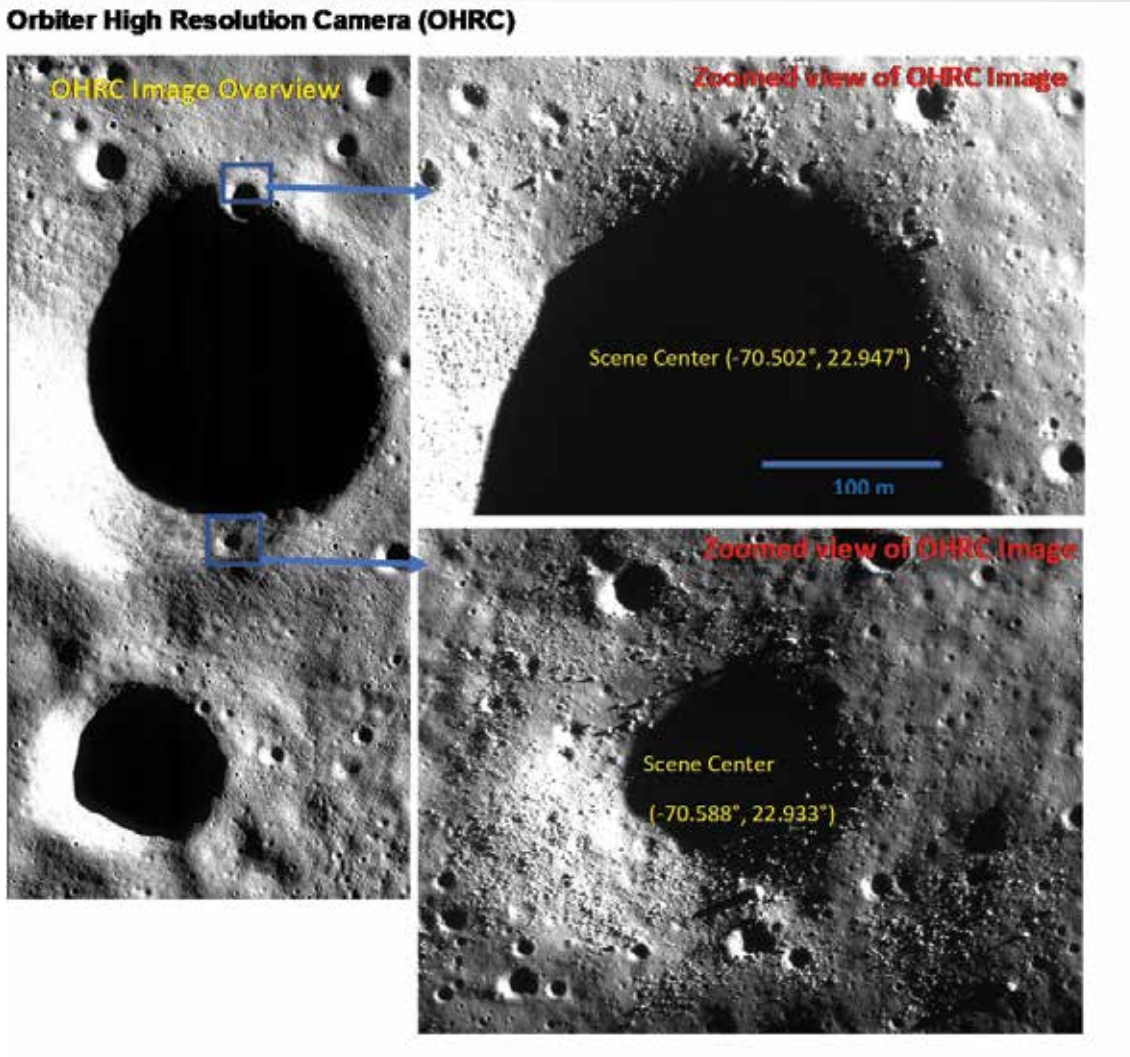
B-K basin region is located on the east limb of the moon in the near side close to Mare Fecunditatis. This area is of scientific importance as it contains a type of light plains deposit that appears to lie on the top of an ancient basaltic surface. The image shows Balmer 'R' and Maclaurin 'D' craters. The one km diameter ray impact crater system is clearly visible in the image. The Digital elevation Model (DEM) has been generated from the stereo triplets (Fore, Aft and Nadir camera images).



*Balmer-Kapteyn (B-K) basin region. The scene center of the DEM and ortho-images are 69.386 E longitude and 14.473 S latitude.*



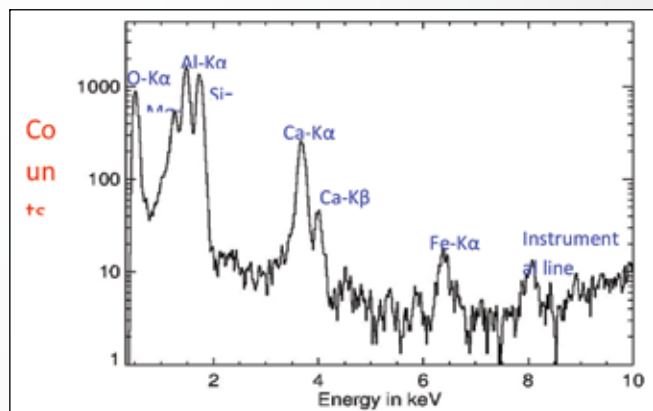
**(b) Orbiter High Resolution Camera (OHRC)**



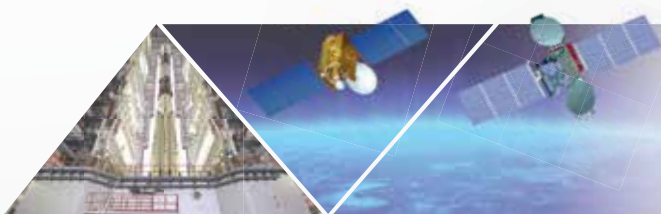
Boulders can be easily identified using OHRC images due to its very high spatial resolution. Hundreds of boulders, ranging from 1m to 50m in diameter, are distributed within an ejecta close to the crater rim. Apart from characterizing the landing sites, the OHRC images allow scientists to study boulder populations in the region of interest and help them interpret geologic features and derive geologic history for a region.

**(c) Chandrayaan-2 Large Area Soft X-ray Spectrometer (CLASS)**

On 29<sup>th</sup> of May, the Sun flared to a level of C9.3, the second strongest flare of 2020 and CLASS observed the secondary X-rays from fluorescence on the Moon. The X-ray spectrum shows direct and clear spectral signatures of major refractory elements (Aluminium and Calcium) from the highland region with additional evidence for lower amounts of Mg and Fe.



*fluorescence spectrum from Moon measured in CLASS from an area in the southern farside highlands (~ -35 to -66 lat, 121 long)*



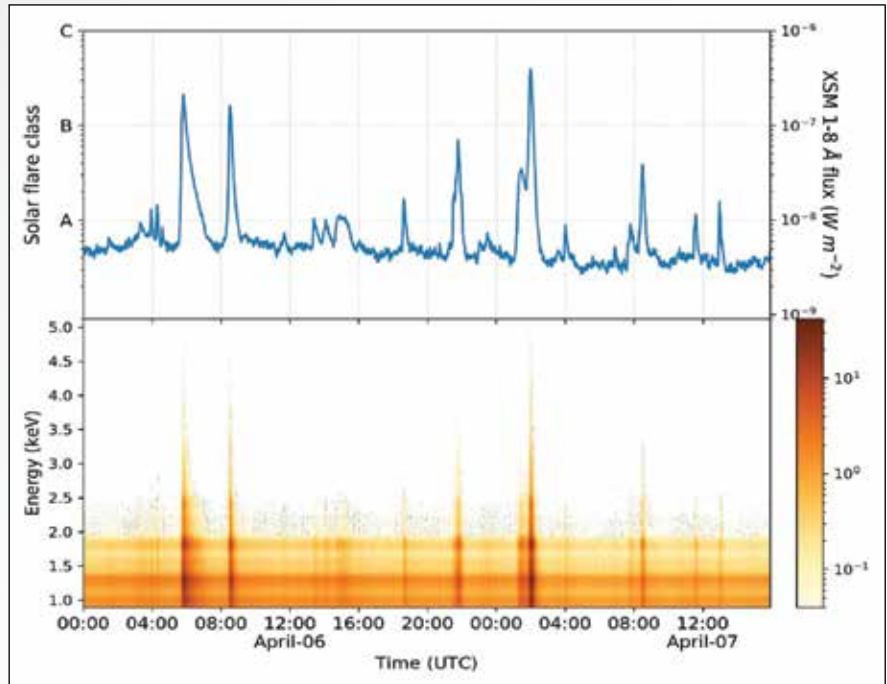




**(d) Solar X-ray Monitor (XSM)**

XSM has observed several flares, including many low-intensity events. Modeling these spectra with theoretical models help us in understanding the evolution of physical properties of the Solar Corona during solar flares.

X-ray flux measurements (top panel) from XSM during 06-07 April 2020, when a series of flares were detected, including three B-class flares. The bottom panel shows the dynamic spectrum (spectrum measured for every point in the top panel, plotted along the vertical axis) during the same period.

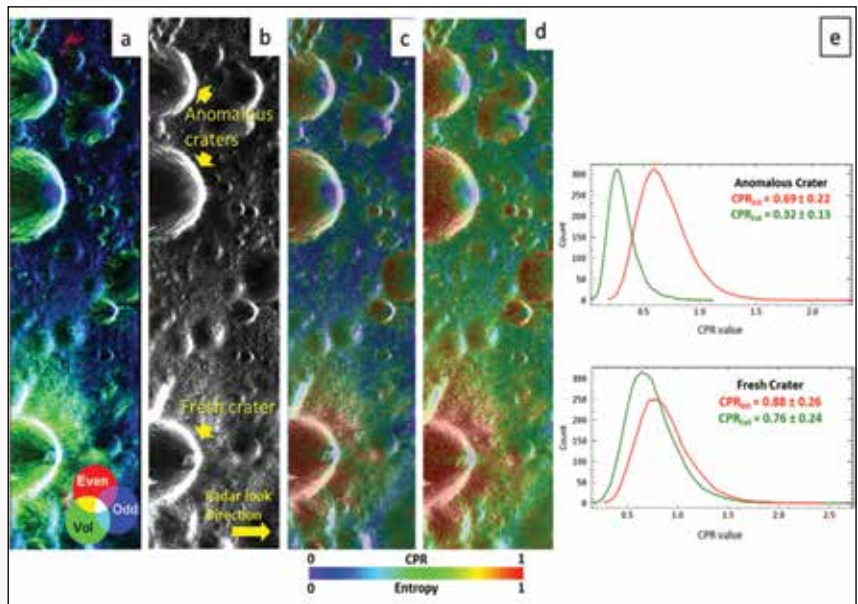


X-ray flux measurements (top panel) from XSM during 06-07 April 2020, when a series of flares were detected, including three B-class flares. The bottom panel shows the dynamic spectrum (spectrum measured for every point in the top panel, plotted along the vertical axis) during the same period.

**(e) Dual Frequency Synthetic Aperture Radar (DFSAR)**

DFSAR with its capability to acquire images at multiple incident angles with multiple polarization modes, has been imaging the lunar surface at both L and S-band wavelengths. In addition, full-polarimetric imaging capability of DFSAR will be able to provide new insights into the nature and distribution of lunar water-ice deposits.

L-band polarimetric SAR image of a part of Peary crater (88.6° N, 24.4° E) in the lunar north pole (a) Yamaguchi decomposition image showing even-bounce, odd-bounce and volume scatterers in the RGB planes; (b) total backscatter intensity image; (c) circular-polarization ratio (CPR) image overlaid on intensity image, (d) polarization entropy image overlaid on intensity image and (e) distribution of CPR in the interior and exterior of fresh and anomalous craters.



L-band polarimetric SAR image of a part of Peary crater (88.6° N, 24.4° E) in the lunar north pole (a) Yamaguchi decomposition image showing even-bounce, odd-bounce and volume scatterers in the RGB planes; (b) total backscatter intensity image; (c) circular-polarization ratio (CPR) image overlaid on intensity image, (d) polarization entropy image overlaid on intensity image and (e) distribution of CPR in the interior and exterior of fresh and anomalous craters.



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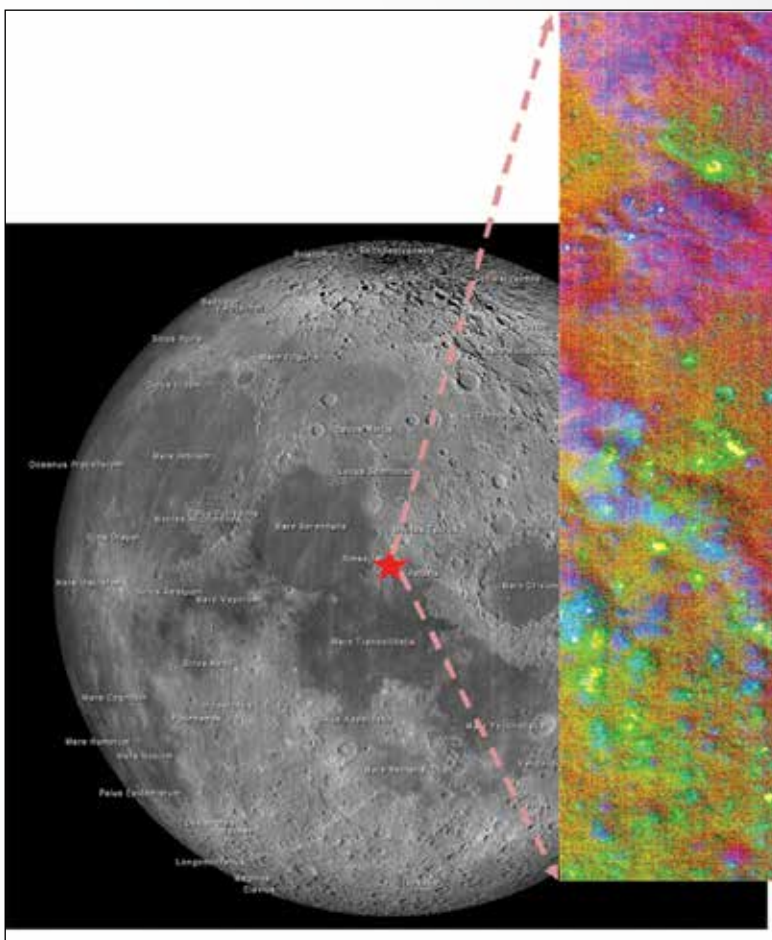
Above figure shows images of various radar parameters over a part of Peary crater lying within a permanently shadowed region (PSR) in the lunar north pole, derived from DFSAR L-band polarimetric data. The analysis of the radar parameters shows that some of the secondary craters within Peary have anomalous circular polarization ratio (CPR) values associated with anomalous scattering entropy and volume scattering within the crater interiors, and are ideal candidates for bearing water-ice.

**(f) Chandra’s Atmospheric Composition Explorer – 2 (CHACE-2)**

CHACE-2 has detected signatures of Argon-40 at 100 km altitude. Over the 6 months, CHACE-2 had observations in different orbit geometries covering dawn-dusk and noon-midnight sectors so that the local time variation could be addressed. These results confirm the day night variations observed by Apollo surface instrument locally and will further generate global distributions which will be for the first time.

**(g) Imaging IR Spectrometer (IIRS)**

IIRS has been mapping the lunar mineralogy in the 0.8-5  $\mu\text{m}$ . An example of the mineralogical diversity of lunar highland crust at the mare-highland transition zone of Mare Tranquillitatis is shown below. The false colour composite (FCC) is generated by assigning the integrated band depth at 1  $\mu\text{m}$  as Red channel, 2  $\mu\text{m}$  as Green and the 1.535  $\mu\text{m}$  albedo as Blue channel. In such FCC, the dark-coloured minerals enriched exposures appear in green to yellow to orange, whereas the matured highland soil and mafic-free plagioclase-bearing anorthositic rocks appear in blue to purple.



*Courtesy: Clementine*  
False color composite showing the compositional diversity at Mare Tranquillitatis imaged by IIRS (80 m/pixel). The bluish regions are anorthositic (light-coloured plagioclase-bearing monomineralic rock) in nature and the areas highlighted in yellow-green are the exposures enriched in dark-coloured minerals (mostly silicates).





## (h) Dual Frequency Radio Science Experiment (DFRS)

Radio Occultation is a widely used technique for sounding the atmospheres of planets. The dual frequency radio science experiment uses X and S band to sound the ionosphere of the Moon assisted by the radio receiver at the ground station IDSN. The refraction of the radio signals measured from multiple occultation events, can provide evidence of the presence of steady or time-dependent changes in the neutral and ionized components above the surface.

### 2.4.1.4 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 Lagrange point L1 in the year 2022.

From the Lagrangian point L1, the phenomena of the sun will be continuously monitored by Aditya-L1. The following objectives 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
- Observe the in-situ particle and plasma environment providing data for the study of particle dynamics from the Sun
- Development, dynamics and origin of CMEs
- Magnetic field topology and magnetic field measurements in the solar corona (not planned by any mission so far)
- Drivers for space weather (origin, composition and dynamics of solar wind)
- Solar spectral irradiance (UV) variations and dynamics of chromosphere.



*Participants of first Aditya-L1 Science Meet with Scientific Secretary-ISRO*

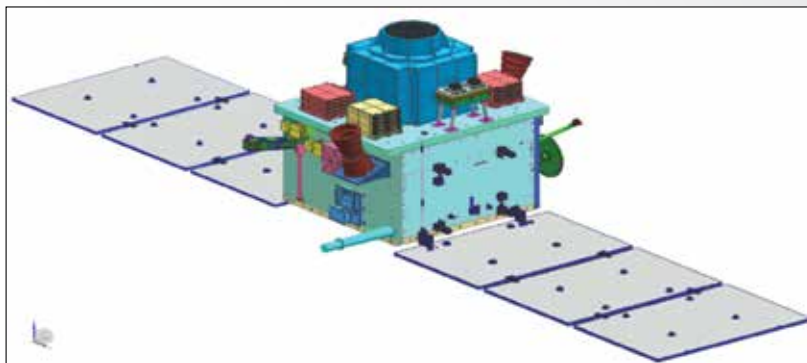


To meet the above mission objectives, the spacecraft is configured with seven payloads. Four payloads will continuously observe the sun and the remaining three will be used for in-situ measurements. All payloads are at various stages of development and testing.

To maximize the science return from Aditya-L1, First Aditya-L1 Science Meet was conducted during March 6-7, 2020 in Bangalore by ISRO HQ.

#### 2.4.1.5 X-ray Polarimeter Satellite (XPoSat)

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



*XPoSat spacecraft (deployed configuration)*

be carrying two scientific payloads, POLIX (Polarimeter Instrument in X-rays) and XSPECT (X-ray Spectroscopy and Timing). The primary payload POLIX will provide the polarimetry parameters (degree and angle of polarization) of bright astronomical sources in the energy range of 8-30 keV photons while XSPECT will give spectroscopic information of soft X-rays in the energy range of 0.8-15 keV. Both the payloads are at different stages of development.





## 2.5 Space Transportation System

### 2.5.1 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.

### 2.5.2 Major Events

- **Polar Satellite Launch Vehicle (PSLV):** Polar Satellite Launch Vehicle (PSLV), the Indian operational launcher, completed its 52<sup>nd</sup> launch, further proving its 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.
  - ◆ *PSLV-C49 / EOS-01:* The mission was successfully accomplished with DL variant of the vehicle on November 7, 2020, injecting EOS-01 satellite and 9 Nos. of customer satellites.
  - ◆ *PSLV-C50 / CMS-01:* The mission was successfully accomplished with XL variant of the vehicle on December 17, 2020, injecting CMS-01 satellite into GTO orbit.
  - ◆ Future Missions of PSLV that are slated for launch in 2021 includes PSLV-C51/Amazonia-1, PSLV/EOS-04, PSLV/EOS-06.
- **Geo Synchronous Satellite Launch Vehicle (GSLV):**
  - ◆ Future Missions of GSLV planned to be launched in 2021 are GSLV-F10/EOS-03, GSLV-F12/EOS-05, GSLV-F14/NVS-01. These missions are in various stages of realisation.
  - ◆ *GEV for Orbital Re-entry Experiment (ORE):* Launch with 1:8 scale RLV, targeted in first quarter of 2022.
- **GSLV Mk III M2/Chandrayaan-3:** Trajectory design has been completed. All hardware, avionic packages and segments of S200 motors are ready. L110 & C25 stages integration activities are in progress.
- **Human Rating of GSLV MkIII (Gaganyaan Programme):** Launch vehicle structures were redesigned towards meeting the human rating factor 1.4. Quad redundant NGC system is in qualification stage. Fail-op, Fail-safe criteria has been complied for critical systems. Digital stage controllers and Electro mechanical actuators are employed in S200, L110 and C25 stages. System level tests for S200 CE commenced. Integrated vehicle health monitoring system (IVHM) has been inducted. Subassembly preparations commenced.



- **Small Satellite Launch Vehicle (SSLV):** The objective is development of a vehicle capable of launching mini, micro or nano satellites (10 to 500kg class) into 500km orbit. Configuration is 2m in diameter and 34m in length with lift off weight of ~120 Ton with three solid propulsion stages and liquid propulsion based Velocity Trimming Module (VTM). The first developmental flight is planned in the first quarter of 2021.

- ◆ *SSLV-D1:* SS2 and SS3 motors, igniters and SS2 flex nozzle assembly. VTM thrusters, propellant tanks and propulsion components realized and made ready for D1 flight.



*SPBR+SPLA assembly HES & MS flight motor casting SS3 Motor structural test SCBS structural test*

- **Reusable Launch Vehicle (RLV):** The objective is to demonstrate technologies for developing a wing body reentry 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 launch vehicle and aircraft.

- ◆ *RLV Landing Experiment:* It is planned for beginning of 2021. 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. It will glide, navigate towards the runway and land with a landing gear in near a place Chitradurga in Karnataka. New systems like Landing gear, Parachute, Hook beam assembly, Radar Altimeter and Pseudolite were developed and qualified.



*RLV main Landing gear*

*RLV Hook Beam qualification*

*RLV Avionics bay mechanical Integration*

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

- ◆ *Rohini Sounding Rocket flights:* 4 numbers of RH 200 sounding rockets were launched from TERLS



*RH 200 launch*





resulting in 182 consecutively successful launch. Inducted 0.5Ah Hybrid capacitor for powering sequencer & pyros and HTPB based Propellant in Booster and Sustainer Motors in lieu of PVC based propellant.

- ◆ *RH560MkIII Sounding Rockets Experiment (SOUREX) Programme:* 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. Launch is targeted in first quarter of 2021 from SDSC. The Booster & Sustainer motors and avionics systems are in advanced stages of acceptance tests. Electrical harnessing of avionic system has been commenced. The TriMethyl Aluminium (TMA) chemical payload and scientific payloads (Electron Density & Neutral Wind Probe – ENWi & Langmuir Probe - LP) are in the testing phase.

- ◆ *RH300MkII / IAD:* As a forerunner to recovery of spent stages of launch vehicles, a technology demonstration of Inflatable Aerodynamic Decelerator (IAD) is configured. Qualification hardware of IAD system in polychloroprene coated Kevlar fabric, support structure and gas bottle based inflation system configuration, with revised packing constraints were realised. Ground tests for inflation carried out. Options for stability are under study. The flight test is targeted for first half of 2021.



*IAD qualification hardware*

- **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. 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 (AR6.0), new structural elements and full-fledged autonomous avionic & NGC systems.





## 2.6 Capacity Building

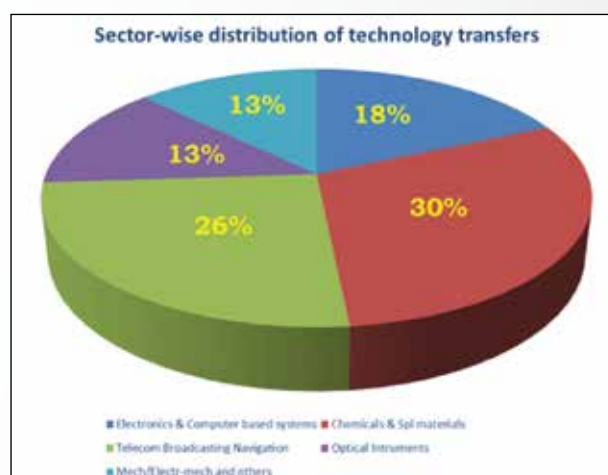
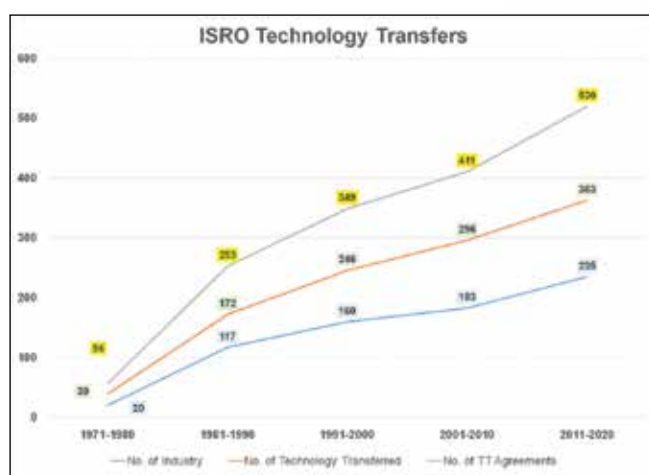
ISRO undertakes various capacity building activities like advanced technology developments towards indigenization, human resource development through various training programs, collaborative research with academia, industry and research institutes, technical facility & infrastructure development, partnering with industries for technology transfer and MoU with government entities & other reputed institutes for sharing technology know-hows.

### 2.6.1 Technology Management

#### 2.6.1.1 Technology Transfer

ISRO has transferred more than 363 technologies to around 235 industries across India. The current year also saw some notable technologies being licensed to Indian Industries for commercialisation, societal application and regular production.

As per the recent Cabinet approval, responsibility of transferring technology to industries lies with NSIL (commercial arm of DOS). Accordingly, ISRO have entered into an MOU with NSIL for transfer of ISRO's technologies. Further, ISRO have transferred around 20 technologies to NSIL and also in the process of transferring around 50 more technologies. NSIL will fix the Technology Transfer (TT) fee based on commercialization potential, market conditions, etc. and enter into agreements with the interested industry.



ISRO has compiled the Interest Exploration Notes [IENs] of active technologies available across ISRO centres and published in ISRO website.

#### 2.6.1.2 Intellectual Property Rights

ISRO has around 144 active patents, 66 nos. of copyrights and 13 nos. of trademarks. During the reporting period around 19 patent applications and 1 copyright application are filled, 14 fresh patents were granted and 105 active patents were renewed. Presently, 97nos. of patent applications are under various stages of examination and 23 undergoing drafting by the patent attorneys before their eventual filing at the patent office. Internationally, 2 fresh international PCT applications were filed related to Li-Ion technology. Further, Canadian and USA patents for TRISP were granted in July 2020 and August, 2020 respectively. 10 nos. of fresh copyrights were granted to DOS related to software category. A Design application related to trophy, filed in 2016 was granted, with validity





till April, 2026. ISRO's active IPRs have been compiled and made available on ISRO website.



### 2.6.1.3 Indigenisation

Launch vehicles & satellites use various critical materials & components which are space qualified. Even though Indian industries are supplying a majority of the materials, few critical materials & 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 vehicles 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 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.

### 2.6.1.4 Research & Development (R&D) activities

Indian Space Research Organisation is no longer confined to the launching of satellites, but it has been constantly expanding its role in Research & Development activities as well. Research and development activities at various centres for the year 2020 are highlighted below:

**IIRS** - IIRS has played a significant role in contributing towards major operational and research programmes of ISRO, and in the process, has maintained an interface with other ISRO Centres. IIRS is recognised as a Research Centre for carrying out Ph.D. by the universities. IIRS actively contributed the research in the areas of photogrammetry, SAR / InSAR / PolSAR remote sensing, LiDAR and image processing publishing a number of publications in peer-reviewed journals and conferences besides the contribution of chapters to books, contributing to the space program of the country for societal benefits.

**LEOS** - Research and development programme includes development of miniature sensors, High accuracy Active Pixel Sun Sensor (APSS), Multi-layer thin film system, CNT coatings, miniature star tracker, Vision Sensors, Detectors, MEMS devices, Segmented Mirror Telescope optics and advanced optics for future spacecraft mission.

**NARL** – The research and development activities at NARL focus on radio and optical remote sensing instruments, ionosphere and space physics, atmospheric structure and dynamics, clouds and precipitating systems, climate change, aerosols, radiation, trace gases and weather forecasting. Fifty four research papers have been published in peer reviewed journals.



**SAC** - SAC has embarked very early in realizing indigenous technologies for complex payload systems. SAC has been actively pursuing the self-reliance in all critical space technologies with a two-pronged approach- Advanced R&D/ Technology Development and Scientific research on futuristic technologies. More than 200 projects are being pursued under In-house TDP/R&D programme.

**URSC** - Various project linked Research & Development activities as well as new and advanced technologies are actively being pursued in all area of satellite systems at various technical entities in the Centre. At present 459 developmental activities are under various phases of realization in the Centre, out of which 341 are technology development projects while 118 are other developments related to new processes & methodology of satellite realization.

**VSSC** - The Centre pursues active research and development and has developed core competence in various disciplines including aeronautics, avionics, materials, mechanisms, vehicle integration, chemicals, propulsion, space ordnance, structures, space physics and systems reliability.

### 2.6.1.5 Productionisation and Industry Interface at various ISRO Centres

Indian Industry has been the backbone for all the programmes of ISRO. Considering the future ISRO programmes and advanced space missions in anvil, ISRO always strives to increase the participation of Industry in all the programmes by leveraging their strength in focus areas of interest. In parallel, ISRO also encourages industry in finding commercial applications/spin-offs by making use of ISRO developed technologies through a robust Technology Transfer mechanism. Given space is an exclusive field, there is a ample scope for implementing innovative practices for achieving the dramatic results through qualified start-ups. ISRO brings in the opportunities for industry participation in Space activities.

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 sub-system and interface elements, transducers etc. are regularly being carried out at various industries.

Towards capacity building, a MoU for Mutual Cooperation, with emphasis on aviation Meteorology and Weather nowcasting/forecasting, was signed with Indian Air Force (Directorate of Meteorology).

Indian Industries are actively involved in the realization of various satellite systems. While URSC continues to source its requirements of fabrication, testing and assembly support from Indian Industries, various initiatives/activities such as realisation of Avionics Hardware, Solar Panels and Batteries, Heat Pipe, HMCs & RC Networks, Harness fabrication, Telemetry, Telecommand Control Processor, Solar Array Simulators, Power Control Unit and Stimuli Generator were undertaken during the year 2020.

Gap areas are identified and worked out strategies to meet the production and testing requirements. AP level qualification trials completed as part of outsourcing of Ammonium Perchlorate and Sodium Perchlorate. Two parties are developed for processing/delivery of segments for PS0MXL motors.





Flex Seals realized through alternate party. Additional vendors developed for realisation of Avionics systems, Light alloy structure assembly machining, large size ISO grid structures, PSOMXL hardware, E40CDV20 Al.IVD and MOS2 coated fasteners.

## 2.6.2 Academia Interface and Sponsorship Research

### 2.6.2.1 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, Guwahati, Roorkee and Delhi; 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 Capacity Building Programme Initiatives, ISRO is also in the process of setting up 6 Regional Academic Centre for Space (RAC-S), a regional level Initiative in the different 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 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. ISRO has already signed MoUs with MNIT, Jaipur (Western region), Gauhati University, Guwahati (North-Eastern Region), NIT Kurukshetra (Northern Region) and NITK Surathkal (Southern Region).

The collaboration with Centre for Nano Science and Engineering (CeNSE) at IISc caters to the requirements of ISRO in the areas of nanotechnology and nanoscience. The Centre is providing support for the R & D activities, utilization of nanofabrication and characterization facilities by the various centres of ISRO, in addition to training/capacity building.

Further, in order to enhance greater participation and contributions from academia in addition to the ongoing Respond activities, a Centre of Excellence (CoE) on “Advanced Mechanics of Materials” has been set up at IISc. The Centre aims at pursuing advanced research in the areas of materials especially on 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.

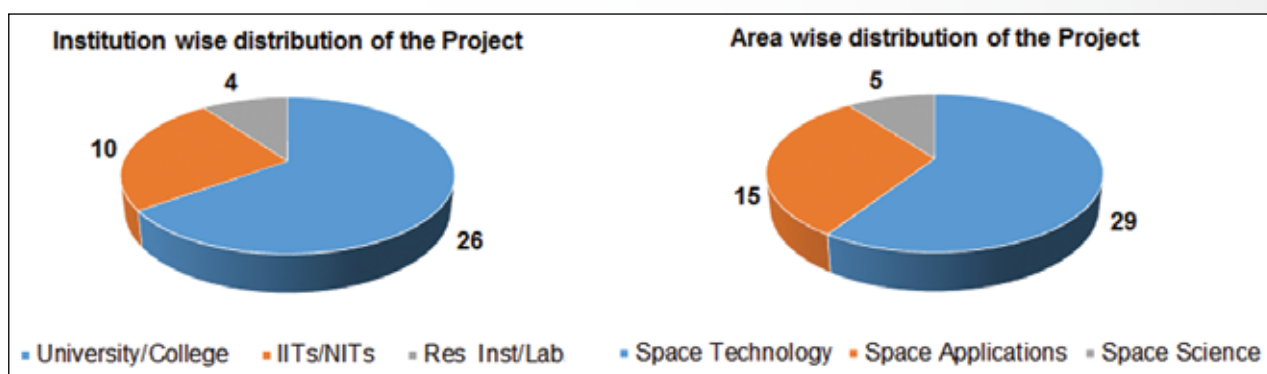


Also, conferences, workshops and publications, which are of relevance to space programme, are also being supported. RESPOND also participated in the National Mission Uchchar Avishkar Yojana (UAY).

### Activities

During the period, RESPOND supported 6 New Projects and 43 ongoing projects and six Space Technology Cells. In addition, 1 ISRO Chair, 3 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, 26 Universities/Colleges, 10 IITs /NITs and 4 Research Institutes/ Laboratories were involved in R & D projects. Further, during the year, large number of projects have been supported in the area of Space Technology (29) followed by Space Application (15) and Space Science (5).



**Projects at Space Technology Cells (STC):** During the period, RESPOND has supported 59 new project and 97 ongoing projects pertaining to six Space Technology Cells. Under STCs, 65 projects have been successfully completed during the year.

Details are given in the table below:

SI. No	Name of the STC/JRP	No. of Projects (2019-20)		
		New	Ongoing	Completed
1.	IISc Bengaluru	14	15	22
2.	IIT Madras	2	25	14
3.	IIT Bombay	8	9	7
4.	IIT Kanpur	12	15	13
5.	IIT Kharagpur	10	33	9
6.	IIT Roorkee	13	0	0
	<b>Total</b>	<b>59</b>	<b>97</b>	<b>65</b>

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

- *Experimental Characterization of Rocket exhaust flow over Launch Pad Configuration* - Under





this project, Development and experimental analysis of launch vehicle ignition on the launch pad in scale model using Scheliren technique was carried out. Interaction of supersonic jets during the initial transients of rocket motors is simulated and the shock interaction is visualized. The results were used for finalizing the configuration of Third Launch Pad and will be useful further for Launch pad configuration studies.

- *Development of Pulse Doppler Processing algorithms for MOTR (Multi Object Tracking Radar)* - The project has successfully developed Algorithms that has enhanced the knowledge of Pulse Doppler Processing. End to end simulation of radar signal processing chain up to velocity extraction using coincidence algorithms for multiple targets in MATLAB was successfully carried out. These algorithms are ready for deploying in radar signal processor being developed for future radars.
- *Development of Web based Tools for online/offline inclusion of value added services and analysis on BHUVAN for High Resolution Satellite Imagery* - Under this project, a user friendly interface (online/Offline) is developed and deployed in Bhuvan Server. It enables the user to select a region of interest from BHUVAN map for identification of minute features like trees, minor roads etc.
- *Astrophysical S-factor from nuclear reactions with a rare isotope beam of Be* - The project has led to the increased understanding of the properties of sun and better understanding of solar eruptions. Project findings are useful for understanding the standard solar model and nucleosynthesis.
- *Arrays of high responsivity III-nitride solar blind UV detectors* - Under this project, record performance AlGaN –based, solar-blind, ultraviolet, lateral and vertical geometry detectors are realized on c-plane sapphire and silicon substrates are realized and attempted to establish a crystalline quality to device performance correlations for them. Further, linear arrays of such detectors are realized and their uniformity is assessed. The project is expected to significantly benefit the development of high efficiency UV detectors and their arrays.
- *Development of customized software for the data management related to integration of cryo Upper stage (CUS-SOFT)* - Under this project, CUS-SOFT software is developed which can be used to get the data from the corresponding stakeholders, process the information and store the end results. The software will reduce the manual document workload of the engineers and other stakeholders by 90%. The software is installed in a PC connected with Intranet and the source code is also submitted to IPRC and is being used in realization of CUS Stage.
- *Characterization of Aerosols, Black Carbon and Radiative forcing over Urban environment of Ahmedabad and Gandhinagar City, Gujarat India* - Under this project, a systematic scientific study was carried out and it involved routine systematic in-situ measurements of particulate air pollutants including particulate matter of size  $\leq 2.5$  (PM 2.5) and Black Carbon (BC) aerosols along with a very important parameter of Aerosol Optical Depth (AOD).The insitu data is being used in algorithm development for PM2.5 estimations over Ahmedabad city. The collected data and results of the study are also useful inputs for Sensor Systems Studies for developing indigenous sensors for aerosols monitoring from space.
- *Development of a Direct Simulation Monte Carlo (DSMC) Code for High-Speed High Knudsen Number Flows* - The project has successfully developed 2D and 3D DSMC code for high speed,



high knudsen number situations to simulate re-entry flows in the upper atmosphere. Flow over actual re-entry vehicle models was simulated to predict heat fluxes. Parallelized 2D and 3D codes for re-entry flows at high Kn were delivered to ISRO.

- *Hands-free gesture control for 3D data visualization by immersive image navigation* - The project has successfully developed a configurable multi-modal multi-sensor platform for Hands Free gesture detection to control an immersive image navigation system. The framework has been installed successfully at ISRO.
- *Hybrid rockets for sounding rocket applications using Hydrogen peroxide as oxidizer* - The project aimed at conceiving the design of a sounding rocket. Hybrid rocket motor with HTPB based fuel and hydrogen peroxide as oxidizer was successfully realized. The combustion efficiency of up to 90% was achieved.
- *Development and characterization of catalyst for HAN (Hydroxylammonium Nitrate) monopropellant & Design and building of a batch reactor for screening catalytic decomposition of various monopropellant* - Under this project, extensive research was carried out on the preparation of HAN. New cerium oxide based catalyst, the best for high temperature HAN thrusters was synthesized. Also a batch reactor was built to evaluate the efficiency of catalyst for repeated use prior to its testing in thruster.

### 2.6.2.2 Space Technology Incubation Centers

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 Space Technology Incubation Centres in all 6 regions of our Country viz. Central, East, North, North-East, South and West regions.

This will enable the young academia to realize their innovative ideas / research aptitude into space grade components/elements that can be utilized for space applications, and guide them towards setting-up the start-ups. These future start-ups will have a potential in creating job opportunities.

In line with the objective, three S-TICs have been established at NIT Agartala (North-East region), NIT Jalandhar (North region) and NIT Tiruchirappalli (South region). A total of 23 Technology Development Projects (TDPs) related to ongoing Space Science and Technology are progressing satisfactorily at these S-TICs. Suitable experts from various ISRO / DOS Centres /Units /Labs are continuously mentoring the students and providing valuable inputs to faculty members associated with the activities related to these TDP's. The progress of TDPs are reviewed quarterly and necessary guidance and technical supports are provided as and when required.

### 2.6.2.3 Veer Surendra Sai Space Innovation Centre, VSSUT, Burla, Sambalpur, Odisha

A Memorandum of Understanding (MoU) has been signed on August 25, 2020 between ISRO and Veer Surendra Sai University of Technology, Burla, Sambalpur for establishment of Veer Surendra Sai Space Innovation Centre (VSSSIC) at VSSUT campus.

The objective of this Space Innovation Research Lab is to promote research and development in the domain of Space Science and Technology and encourage students of the eastern region of our country to explore modern developments in the related field.





#### 2.6.2.4 IIST-related activities

Further, to coordinate joint research activities between ISRO centres and IIST, akin to the Caltech-JPL model, a dedicated framework has been put in to place, with CBPO, ISRO HQ as a focal point. An Advanced Space Research Group [ASRG] was created to identify application oriented research problems of importance to ISRO centres and matching with the interests of IIST faculty. An Empowered Overseeing Committee [EOC] was constituted to review and approve the proposals.

#### 2.6.3 Outreach Activities

Streamlined guidelines for outreach, along with a Outreach Policy were prepared and were reviewed by Program Steering Group - Capacity Building [PSG-CB], Program Coordination Board-Capacity Building [PCB-CB] and Program Management Council - Capacity Building [PMC-CB]. Specific categories for public outreach and student outreach, including themed merchandise, have been identified. Further, with departmental approvals, the same shall be put up in public domain for implementation with participation of all stakeholders – within ISRO as well as external agencies.

##### 2.6.3.1 IAA-ISRO-ASI Symposium on Human Space Flight

Indian Space Research Organisation (ISRO), International Academy of Astronautics (IAA) and Astronautical Society of India (ASI) jointly organised an ‘International Symposium on Human Spaceflight Programme’ at Bengaluru during January 22- 24, 2020 under the theme ‘Human Space Flight and Exploration – Present Challenges and Future Trends’. More than 500 delegates, including national and international technical experts in human spaceflight related technologies from space agencies, astronauts, representatives of International space industries and academic institutes, young professionals and students participated in the Symposium.

The Symposium was inaugurated by Prof. K VijayRaghavan, Principal Scientific Advisor to Government of India in the presence of Dr K Sivan, Chairman, ISRO on 22<sup>nd</sup> January, 2020. Honourable Prime Minister of India, Shri Narendra Modi conveyed a special message to the participants of the symposium. In his message, he highlighted that the benefits of India’s Space programme are shared with entire world in line with India’s wisdom of “Vasudaiva Kutumbakam (World is one family in Sanskrit).

The ‘Heads of Space Agencies Panel’ had the space agency chiefs from India and Romania and heads of the human space flight programme of CNES (France), NASA (USA), JAXA (Japan), ASI (Italy), and ROSCOSOMS (Russia). The agency heads made deliberations on the progress and future plans of respective Space Agencies under the changing landscape and economics of human spaceflight and deep space exploration. Mr Jean-Yves Le Gall, President CNES addressed the gathering on January 24, 2020 on the Indo-French partnership in human space flight. Another significant event in the Symposium was the ‘Astronaut Panel’ held on January 23, 2020 with the participation of five astronauts from France, Germany, Russia, USA and UAE and the panel was moderated by Air Commodore (Retd) Mr Ravish Malhotra. The astronauts presented reminiscence of the space flight, challenges in technical, physiological and psychological aspects of humans during spaceflight.

The Symposium received good response from the Industries. One exclusive industry panel was also organised to give an opportunity for Indian and foreign space industry leaders to discuss on





their perspectives on human spaceflight and exploration. 19 invited and plenary lectures were delivered by eminent experts in Human spaceflight area from USA, Russia, France, Japan, Italy, Germany and UAE. Around 100 contributed technical papers were presented by the delegates from different countries under 5 major topics, namely, Challenges, Enabling Technologies, Ground Systems, Scientific and Societal Relevance, Policy Aspects and Economics of human spaceflight.

In order to give special focus on young generation, an exclusive student session was held on January 23, 2020. 60 selected students of premium academic institutions across the country participated in the session and 10 selected papers were presented by students.

During this event, IAA presented the IAA award for best book in engineering science to Dr K Sivan, Chairman ISRO / Secretary DOS for the book titled 'Integrated Design for Space Transportation System' co-authored by him along with Dr B N Suresh. The three-day Symposium has enabled exchange of information among the delegates on the latest trends in human spaceflight exploration.



*Participants of Heads of Agency Panel*

### 2.6.3.2 Vikram Sarabhai Centenary Programme

The yearlong Vikram Sarabhai Centenary Programme was concluded on 25<sup>th</sup> September, 2020 on virtual mode with Honorable President of India recorded message along with senior dignitaries from DOS & DAE and Dr Sarabhai's family. The yearlong programme was a grand success and events were conducted at more than 106 locations across the country, which included lectures by eminent speakers, exhibitions, competitions, quizzes, selfie corners. Six mobile exhibition units were realized and taken to rural schools across the country.



### 2.6.3.3 Satish Dhawan Birth Centenary Programme

DOS celebrated the Prof. Satish Dhawan's birth centenary on 25<sup>th</sup> September, 2020 through virtual mode with participation of all ISRO Centre/units. It was indeed a very befitting tribute to a visionary Prof. Satish Dhawan, who provided a firm foundation and a stable structure to the Indian space programme. DOS / ISRO. A photo album was also released on the occasion.

### 2.6.3.4 World Space Week Celebration

World Space Week (WSW) Celebrations 2020 with the theme "Satellites improve Life" was organized during October 4 - 9, 2020. As a part of WSW celebration, ISRO centres organised various competitions and lecture programs in a virtual mode owing to the pandemic restrictions.







### 2.6.3.5 ISRO Cyberspace Competitions - 2020 (ICC-2020)

ISRO Cyberspace Competitions - 2020 (ICC-2020) has been organised for the young minds of our country by involving them in various online competitions showcasing their potential talents in the domain of Space Science and Technology, during the COVID-19 challenging times, when physical meetings were near-impossible. The program has been aimed to tap the creativity, innovative ideas and harness the unbound imagination of school students towards Space Science and Technology. Results of ICC-2020 was announced online on September 25, 2020 during the valedictory function of Vikram Sarabhai Centenary Programme.

### 2.6.3.6 Other Outreach activities

- **Adoption of Atal Tinkering Labs [ATLs]:** To further enhance student outreach, DOS in the process of adopting 100 ATLs across the country, distributed as per location of ISRO centres. A focal point at each ISRO centre shall interface with ISRO HQ to encourage interaction and mentorship from scientists/engineers across ISRO with students through ATLs.
- **IIRS Outreach Programme - Live & Interactive Courses - IIRS** distance learning programme is an innovative approach of mass scale capacity building on Remote Sensing, GIS and GNSS technology and its application. Under this programme network of 2660 institutions in India is setup out of which 1631 Institutions joined the IIRS outreach network in year 2020. IIRS conducted various courses this year and specially organized programs during COVID-19 lockdown period. IIRS has conducted 29 online courses/workshops during January 2020 to November 2020 by using E-CLASS platform (<https://eclass.iirs.gov.in>).





## 2.7 Gaganyaan – Human Space Flight

Gaganyaan is the first project taken up by HSFC for demonstrating human spaceflight capabilities. It is the maiden manned mission of ISRO which involves development of a host of new technologies and activities that need to be taken up concurrently across all ISRO Centres within the stipulated schedule. The objective of Gaganyaan is to carry a crew of three to Low Earth Orbit (LEO), perform a set of predefined activities in space, and return them safely to a predefined destination on earth.

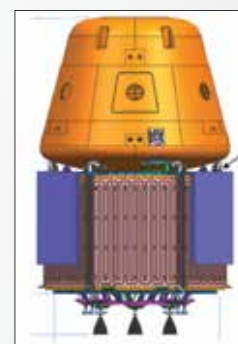
New systems are required to undertake human spaceflight namely Human rated launch vehicle, Crew Module (CM) system, Service Module (SM) system, Crew Escape System (CES) and Environmental Control and Life Support System (ECLSS). The crew selection and training, development of human centric products, human rating certification system, dealing with man-machine interfaces are other domains of manned space flight that is addressing concurrently.

The human rating of GSLV MKIII has already been initiated at VSSC. The launch complex system at SDSC-SHAR and ground infrastructure are being augmented towards accommodating the crew activities. Communication network including ground based and space-based systems is planned to provide near 100 % coverage during various phases of mission viz., ascent, on-orbit, re-entry and descent. Selection of crew for the first mission has been completed and crew training activities are in progress at Russia in association with Indian Air Force. Plan of action is in place towards realization of human centric products with the assistance of Defence Research and Development Organisation. An Inter-agency committee for recovery of crew with Indian navy in lead role has been constituted and the committee has initiated the crew recovery related activities.

Many tests are planned to validate launch vehicle technologies. These tests are planned before the launch of first unmanned flight. Such as:

- Test Vehicle Mission for Escape System Qualification
- HS200 static test
- Vikas Engine Hot Test
- CE20 Hot Test

**Orbital Module:** The configuration of Orbital module is finalised and all sub-systems have been identified. OM comprises of two systems namely **Crew Module** and **Service Module**. The preliminary design reviews of all systems have been completed. Based on the design outcomes, certain configuration changes have been made in orbital module and with this, design review is progressing in all Centres.



*Orbital Module*

**Crew Module:** CM is realised with a conical structure to house crew, ECLSS, avionics and crew seat. The Crew module internal layout has to satisfy many conflicting requirements like ergonomics, comfortable volume for crew, orientation of crew considering physiological constraints, grouping of sub-systems for ease of access, crew intervention features and so on. Layouts for ECLSS, avionics and other systems are finalised. Preliminary design review documents of all subsystems are released.



*Crew Module*

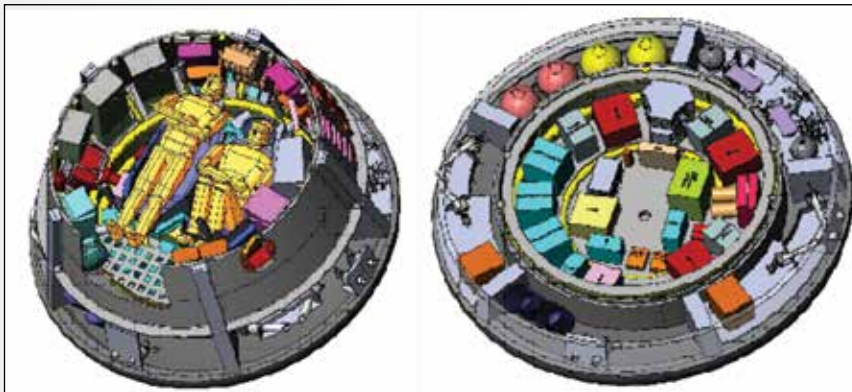




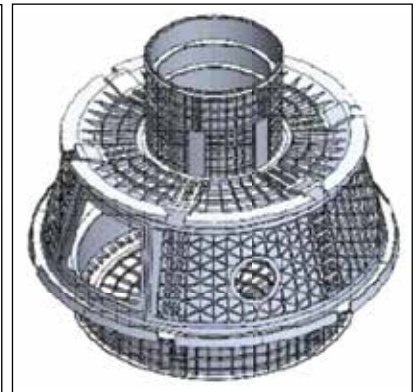
**Service Module:** Hexagonal configuration of the structure including the attachments at the FE and AE are finalised. Number of solar panels and wings are finalised based on the power requirement and realisation for the first unmanned mission is initiated. All the layout for ECLSS, avionics, sensors and antenna are finalised. Development model has been realized for propulsion system. Preliminary design review documents of all subsystems in Service Module propulsion system are released.

**Systems Engineering:** Multiple options of laying out avionics and other systems within the Crew Module without affecting the free volume required for the crew has been studied. The packaging studies took into consideration various aspects such as, ensuring specified center of gravity location to derive the required aerodynamic performance, accommodating three numbers of main parachutes chosen to reduce the module impact velocity, orientation of the crew seat to better withstand the acceleration levels during entire flight duration, all aspects of ergonomics that assure easier reach of systems to be operated by the seated strapped crew, aspects of assembly and integration.

Based on the outcome of preliminary design review of all systems, certain changes were brought in the Orbital module to meet the design constraints.

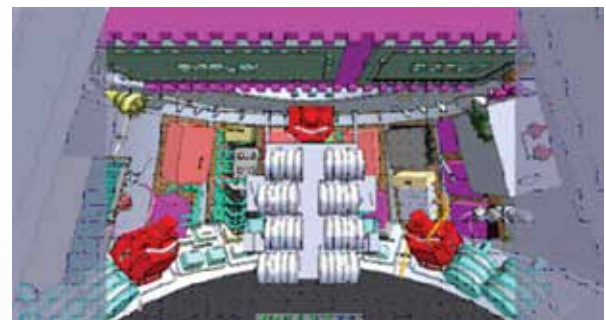


*CM Layout configuration*



*3.1m dia. CM configuration*

**ECLSS:** This is a system of systems and ISRO is developing it for the first time. The ECLSS has Cabin Pressure Control System (CPCS) to maintain the cabin pressure within limits, a Thermal and Humidity Control System (THCS) to keep the temperature inside CM within acceptable limits comfortable for the crew and an Air Revitalization System (ARS) for removing carbon dioxide and odour from the cabin. All the ground servicing of ECLSS will be carried out SDSC. The realisation of THCS through industry is progressing fast. In the Unmanned flight, the crew conditions like heat release, breathing, sweating etc will be simulated by a Human Metabolic Simulator (HMS). The configuration and requirements of HMS have been finalised.



*Accommodation layout of ECLSS in CM*





**Overall Mission Planning:** Detailed mission studies covering all aspects of Gaganyaan end-to-end mission were taken up and mission strategies and sequence for nominal and several abort scenarios were generated.

**Parachute Systems:** The Crew module uses a two stage parachute in redundant mode to ensure the impact velocity within limits even under worst case condition. There will be many air drop tests, Integrated Air Drop Test (IADT) from helicopter and parachute level tests.

**Shield for protection from Orbital debris:** Micro Meteoroid and Orbital Debris (MMOD) environment in the chosen orbit of Gaganyaan has been estimated and suitable mitigation measures planned.

**Assembly and Integration:** Configuration of Mechanical Ground Support Equipment (MGSE) for CM and SM integration activities has been completed. SM, CM and OM check out configuration is finalised. Handling and transportation schemes have been worked out.

**System Reliability and Quality:** The year witnessed the evolution of the human rating certification mechanism based on the recommendation of a national level specialist committee constituted by Chairman, ISRO. Accordingly, the Human Rating Certification Board was constituted at ISRO HQ and dedicated certification Groups/Divisions have been identified in all major ISRO Centres. As part of certification, two new areas have been introduced in ISRO - process for Route to Certification (RTC) to ensure traceability and Probabilistic Risk Assessment (PRA) based assessment for estimating residual risks in every system. HSFC has taken the lead role in finalising the procedures, interacting with external agencies, identifying software and conducting workshops/lecture series to familiarise both RTC and PRA in all ISRO centres.

The “Human rating Certification plan for Gaganyaan Mission” document has been prepared to ensure that the launch vehicle and other systems are absolutely safe to transport the crew to the orbit and bring them back to Earth. It specifies the need for well-defined standards for the specifications and requirements and also a robust certification mechanism.

**Crew Training:** After a rigorous Crew selection process for Gaganyaan mission, four Test Pilots from Indian Air Force were selected for undergoing training. Generic spaceflight training for the Crew trainees commenced at Gagarin Cosmonaut Training Centre (GCTC), Russia in the month of February 2020. After the completion of Training at GCTC, Russia, the crew trainees will be trained for mission specific training in India.

**Crew Training Simulators:** Towards development of simulators to impart Gaganyaan mission specific training to the crew, activities for in-house realisation and alternately realisation through external vendors have been initiated.

**Launch pad modifications for Unmanned/Manned mission:** The present launch pad at SHAR requires certain modifications to meet the requirements of Gaganyaan. Crew access arm detailed design was completed. Ground emergency escape system is in final stage of completion.

**Telemetry, tracking and telecommand systems:** The overall network coverage ratios for different combinations of network configurations involving ISRO stations, external stations, IDRSS were worked out. The scheme for tracking the SM debris during the descent phase is worked out for





descent tracks which are visible to SHAR radars. Identification of suitable radars for other descent tracks is under progress. NDA is signed with AWS for proceeding with technical information exchange for external station TTC support for on-orbit phase.

**Crew Recovery:** All possible landing points of crew module in sea, corresponding to different nominal and contingency situations have been worked out for planning and co-ordinating the crew and crew module recovery activities. Inter-agency Committee for Recovery Operations (ICRO) was formed by Chairman ISRO and preliminary discussions on recovery requirements was held with Indian Navy.

**Collaboration:** Contracts have been signed with M/s Glovocosmos, Russia for consulting support for medical examination and selection of candidates for Indian astronauts, providing space flight related training for the Indian astronauts, wind tunnel testing for making wind profiles, feasibility of integrating Russian flight equipment into Gaganyaan Life Support and Thermal Control System and supply of flight suit, crew seat and view port.

Contracts have been signed by VSSC with Romania and Canada for wind tunnel testing of launch vehicle.

Seven MoUs were signed with DRDO for human centric products and services like Space food and waste disposal system, wearable health monitoring system (bio vest) and emergency survival kit, development and qualification of fire suppression system, medical kit and solution for oral hygiene as well as assistance for radiation dosage assessment through blood samples of crew, ear muff with active noise cancellation, providing anthropometry database of Indian aircrew for future mission requirements and yoga training for crew, radiation level estimation, simulation, monitoring and attenuation for Crew Module and development of parachutes for Crew Module. Joint working groups and ISRO-DRDO coordination team have been monitoring of the progress of work.

**MoUs for Microgravity experiments:** Microgravity experiments are planned in Unmanned missions. The experimental payloads are developed by different academic institutes of India and five MoUs have been signed with them after short listing the probable institutes.

- Spaceflight-induced changes in kidney stone formation in *Drosophila melanogaster* from IIST
- Investigating the effects of microgravity on SIRT1 mediated control of cellular and organismal physiology from TIFR
- Conducting crystallization experiments under microgravity conditions from CSIR
- Developing passive two-phase heat spreader for hotspot mitigation in microgravity of space from IIT-Patna
- Studying interfacial instabilities in microgravity conditions from JNCASR

The payload design and development activities are progressing well.

A national level Gaganyaan Advisory Council (GAC) was constituted for seeking guidance and enhance inter agency co-ordination. The second meeting of GAC was held during January 2020 to review the status of Gaganyaan project and identify lead agencies to co-ordinate for crew recovery operations.



## 2.8 Facilities / Infrastructure

Creation of new infrastructure across ISRO centres, in line with programmatic requirements and long term goals of organisation, is a major exercise.

### Infrastructure at different centres

**HSFC: Information Resource Centre (IRC)** - As a repository of knowledge and to disseminate information to all, an Information Resource Centre (IRC) was inaugurated by Chairman, ISRO.

**IIRS:** 1.5 acres of land reclaimed from the valley area behind Auditorium building. 100 Rooms Vikram Sarabhai Hostel was fully furnished and made operational. 150 Kg bio gas plant was installed to generate gas from kitchen waste. Electrical substation building at pump house was constructed. Rain water harvesting pits were provided as part of water conservation measures. Passenger lift and ramp in GIS building was provided as part of welfare measures to persons with disabilities. Several buildings were renovated including International Hostel, Guest House and Campus Clinic. New Academic block (G+2), Slope protection works in NE slopes and GID buildings are in progress.



*Reclaimed Land behind Auditorium building*



*Vikram Sarabhai Hostel*

### IPRC

- Automation of Leak Check Facility at Cryo Engine Integration Facility
- Establishment of Pickling and Passivation Facility for surface treatment of CUS & CE20 pipe assemblies
- Establishment of Integration Clean Room exclusively for Gaganyaan CE20 Engine
- Commissioning of Multi Axis CNC Tube Bending Machine
- Commissioned Precision high capacity Coordinate Measuring Machine (CMM)



*Clean Room for Gaganyaan CE20 Engine integration activities*





**ISTRAC:** Three new Major Civil Works have been realized viz., MEOSAR, RDA and BL-5. Construction of 18m dia antenna supporting structure and facility building (Civil, PH, Electrical and A/c works) at IDSN Campus, Bangalore are going on, 11m dia antenna supporting structure and facility building (Civil, PH, Electrical and A/c works) at ILF Campus, Lucknow and 11m dia antenna supporting structure and facility building (Civil, PH, Electrical and A/c works) at IDSN Campus, Bangalore have been completed.

**LEOS:** New facilities planned/installed during this period includes High Accuracy Star Simulator (HASS) setup, Portable Dynamic Multi Star Simulator (DMSS), Optical Grinding Machine, 2-Spindle Type Smoothing and Polishing Machine, CNC Wire Cutting Machine, Thermal Shock Chamber and 2-Axes Motion Simulator.

### LPSC

- Integrated Cryogenic Engine manufacturing facility (ICMF) is being established for realisation of cryogenic and semi Cryogenic Engines which will be alternate source to the existing suppliers.
- Establishment of Integrated Titanium Alloy Tank Production Facility (ITPF)



ICMF



ICMF Main Hangar

- Establishment of Integrated Lab for Flow Control Valves and Control Systems (ILFC).
- Golden Jubilee Library - The activities of new Golden Jubilee Library which started in November 2018 is nearing completion.
- Inauguration of LPSC Facilities by Chairman, ISRO on 08<sup>th</sup> June 2020 - Shri. K. Sivan, Chairman, ISRO through a digital platform inaugurated significant infrastructure facilities as a part of capacity building at LPSC, Valiamala.
- New Administrative building for Recruitment and Hindi section.
- Modernized Proto Fabrication Facility, with improved machine layout, working environment, housekeeping solutions etc is established to enhance the production and efficiency.



- **Transport Building:** Dedicated facility to strengthen Transport Operation and Maintenance activities with a carpet area of 386 sq.m.
- **IATF-ST Assembly and Test Lab** with a carpet area of 890 sq.m is established for Assembly & testing of AOCS (10N/22N). Facility has a production capacity of 240 thruster per annum. Special features include Two Assembly lines for Assembly & Testing of both 10N & 22N thrusters simultaneously. Major facilities available are Assembly & Test Facility, Special Process Facility (SPF), Assembly related Inspection Lab, Assembly related Machining Facility, Bonded Stores, Flight component stores and Discussion room.
- **IATF-ST – High Altitude Testing (HAT STAND)** is dedicated for hot testing of AOCS (10N/22N) Thrusters @ 240 per annum.
- **IATF-ST sea-level test facility** is established in Valiamala near IATF facilities for the purpose of testing Injectors of Pressure fed bipropellants ( $N_2O_4$  & MMH) Engines/Thrusters upto a thrust level of 2 Tonnes. This will be used for conducting the Injector characterization testing of PS4 Engines, presently being carried out at IPRC.
- **Gaganyaan Components Assembly and Test Facility (GCAT)** is envisaged for testing of fluid control components for Cabin Pressure Control System of Gaganyaan.



**NRSC:** Established a Solar power plant of 600 kWp (500 kWpas Ground Mounted and 100 kWp as car port) and the solar power generation reached a total of 1.2 MW power generation from all NRSC campuses.

**SAC:** SAC facilities include highly sophisticated payload integration laboratories, electronic and mechanical fabrication facilities, environmental test facilities, Image processing and analysis Labs, Antenna test facilities etc. Augmentation and maintenance of existing facilities is undertaken periodically. During the reporting period, following activities were completed:

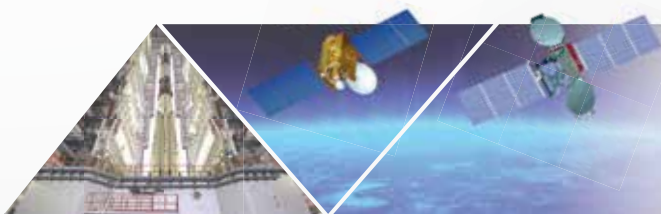
- **Restoration of Compact Antenna Test Facility:** Restoration of CATF reflector optics, positioning system, anechoic environment and integration of instrumentation setup with



CATF Facility



Positioner







fully automated data acquisition and analysis software were completed successfully through indigenous efforts. Various indigenous vendors were developed and Dependencies on foreign vendors is completely removed. In-house software was developed for data analysis and diagnostic purposes. Planar array antenna of RISAT-2A is tested in this newly restored facility.

- *UV-C Sanitizer Systems:* Design and Development of UV-C based Sanitization Box and Garment Sanitization Chamber were carried out for in-house use.



UV-C Box



UV-C Chamber

- *Establishment of new class-room facility with modern teaching aids:* A new class room facility was established with latest teaching aides towards augmenting the capacity of employees learning infrastructure.



#### SDSC SHAR

- *Augmentation of Solid Motors Production Facilities Project (ASMP):* SDSC SHAR is responsible for production of solid motors/segments for the booster Stage (S139) and upper stage (HPS3) for ISRO's operational launch vehicles – PSLV & GSLV at the Solid Propellant Space Booster plant (SPROB). A new ASMP project has been approved for realization of 29 new facility buildings simultaneously in a time period of 24 months to meet PS1 and PS3 solid motors requirement of 12 PSLV & GSLV launches per year.

*Status* - Equipment erection and commissioning of all the facilities is targeted for completion by September-2021 in a progressive manner.

- *PSLV Integration Facilities (PIF):* A new PSLV Integration Facilities (PIF) project has been approved:
  - ◆ PSLV Integration Facility with:
    - \* Integration building for vehicle integration upto fourth stage.
    - \* Service building for MLP refurbishment works after launch.
    - \* Mobile Launch Pedestals (MLP) – 3 Nos - one for vehicle integration at FLP- MST, one for vehicle integration at PIF and one for MLP refurbishment works at service building.
  - ◆ Bogie System with rail track & hauler for bogie (SPU).
  - ◆ Check out systems & Pneumatic systems for electrical & leak checks.
- *SSLV Launch Complex-* The Indian Launch Vehicle Programme has attained a level of maturity today to launch 4.5 t class of satellites to GTO through GSLV MkIII. To meet the current market demands of small satellite launches, ISRO is developing a new generation launch vehicle called



Small Satellite Launch Vehicle (SSLV) capable of injecting small satellites (up to 500 kg) into 500 km circular Low Earth Orbit. Existing launch pads at SDSC SHAR Viz., First Launch Pad (FLP) and Second Launch Pad (SLP) are lined up for meeting launch demands of PSLV, GSLV & GSLV Mk-III launches, thus realisation of exclusive launch pad for SSLV is inevitable. Proposed SSLV Launch Site will meet the demands of launching SSLV launch vehicle at shorter interval.

- *Gaganyaan Launch Complex & Recovery Systems (GLCRS)* - Gaganyaan Launch Complex & Recovery Systems project is planned at SDSC SHAR towards enabling Human Space Missions from Second Launch Pad (SLP) and realization of associated Crew facilities. In order to meet the requirements of Gaganyaan mission and associated qualification tests viz., static test of HS200 & CES motors, Integrated Air Drop Test (IADT), Pad Abort Test (PAT) and Test Vehicle Project (TVP), new facilities (Orbital Module Preparation Facility (OMPF), Crew quarantine facility and Range control centre) & systems are being realized and few existing facilities are being augmented in SDSC SHAR.
- SDSC SHAR is also augmenting its infrastructure to meet the requirements of increased launch frequency.

**URSC** - The Centre is equipped with state-of-the-art technical facilities and capital-intensive infrastructure to realize complex and advanced satellites for various applications. Augmentation of existing facilities and establishment of new facilities at URSC main campus and ISITE campus is undertaken to meet the programmatic requirements of various satellite missions.

The major Technical Facilities/Infrastructure established/under establishment in the Centre is summarized below:

- The main entrance ‘The Gateway to URSC Campus’ was redesigned as a grand, imposing & elegant structure to emphasize the character of the campus and to provide enhanced security. The landscape was redesigned, facilitating additional plantation in keeping with the ‘Go Green Campaign’. Rear gate entrance structure was also designed similar to the main gateway structure in a smaller scale within available area. All these improvements were designed without compromising the aesthetics and functional aspects.



*New Gateway to URSC Campus*



*Rear side entrance to URSC*

- Due to Covid-19 pandemic situation, Mission Analysis Centre (MAC) facility and newly established Remote Spacecraft Checkout Centre (RSCC) at URSC were upgraded to function as prime Control Centre facilities for EOS-1 LEOP operation. All essential facilities like establishment of communication links with SHAR, MCF & ISTRAC for satellite commanding, telemetry reception, voice and countdown time reception, SCHEMACS, WEB SCHEMACS and integrated display of satellite telemetry were set up to support this mission. With the prime team deployed at MAC, URSC and backup team at Control Centre (ISTRAC/MCF), EOS-1 LEOP phase operations



were successfully carried out. Thus EOS-1 was the first satellite mission handled from URSC in this manner. CMS-01 will follow the same operations and it is proposed to use the same methodology for future GEO & LEO missions.



- Establishment of 1.2m thermal vacuum chamber, thermal cycling chambers, ultraclean oven, high vacuum bake out oven and shock machine were completed during the period.
- Upgradation of Test and Evaluation Lab to carry out card and package level testing of avionics systems and establishment of RF/Pulsed DC sputtering system for dry lubrication activities was also completed.
- Establishment of Solar Panel & Battery Fabrication Facility, Dynamic Test Facility, Subsystem Magnetic Measurement Facility at ISITE Campus are in progress. Simultaneously installation of 6T shaker system at subsystem level Vibration Test Facility at ISITE campus is underway.
- Activities towards the establishment of Multijunction solar cell (Indigenization & Productionization) Project at Tumkur is also under progress.
- In addition to this, periodic upgradation /replacement of existing instrument/equipment installed at various labs and facilities in URSC main and ISITE campuses are in progress to support the satellite realization activities.



Test & Evaluation Lab

## VSSC

- *Trisonic Wind Tunnel Project:* Final design of Hydraulic, Instrumentation & Control and Schlieren systems are nearing completion. Settling chamber is in advanced stage and systems such as airline, air drier and ejector pipelines received. Procurement of major elements such as Compressor and flex plate are concluded. Fabrication of all (6 nos.) of pressure vessels completed and erection is under progress. A temporary boat jetty is planned to be constructed at TERLS to transport the oversized consignments. Technical advancements of the tunnel are dual test section inserts, Mach number settings using diffuser choke, ejector system, test section plenum blow-off using ejectors, first of its kind low noise pressure regulating valve, jet simulation leg and PIV. The tunnel is scheduled for the first blow down by end of 2021.





Site erection of 4.5m dia x 50m long (6 nos.) air Storage Vessel



Air drier



Settling chamber

- PSLV Production Complex (PPC), New Electronic bonded store, Fluid energy mill for ultrafine AP are operationalized. PCM Production Hub (40 Chemicals) and Integrated pilot scale process facility for energy systems is getting ready. Multi-disciplinary Product Engineering Laboratory (MPEL) is operational with FDM 3D printer, Blue light 3D scanner, Humidity control chamber, Mechanical work bench and tools, LVAD test setup, platform for smart limb testing, electrical instruments etc.



SMT reflow facility



Split Hopkinson's Pressure bar



Multi-disciplinary Product Engineering Lab

- Test setup/facilities made ready for Dielectric property measurement under high temperature and high field strength (5kV/mm), Apparatus to measure thermal conductivity of fluids (ISROSENE) at high temperatures and pressures, 150W CO<sub>2</sub> Laser ignition facility, Green and hybrid propulsion test facility, Split Hopkinson's Pressure bar (SHPB) for high strain rate testing, PEARL facility for pyrophoric igniter processing, new 6kV EBW machine, SMT reflow facility, Dry-Film Laminator in PCB Fabrication etc.





## 2.9 Space Situational Awareness and Management

### Directorate of Space Situational Awareness and Management (DSSAM)

Space Situational Awareness (SSA) related activities has been grown within ISRO and DSSAM serves as a nodal point for interactions/collaborations between all agencies foreign and domestic in this domain. The main objectives of DSSAM 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.

### Project NETRA

The project NETRA is envisaged to establish one radar in North-East region, one telescope at Hanle, Ladakh and a control centre at Peenya, Bengaluru.

The ISRO SSA Control Centre was formally inaugurated by Dr. K. Sivan, Chairman, ISRO/ Secretary, DOS on 14<sup>th</sup> December, 2020.



The control centre is to function as a hub of all SSA activities within India. Dedicated labs are to be set up in this control centre for Space Debris mitigation and remediation, compliance verification of UN/IADC guidelines and various R&D activities in SSA.

The R&D activities will encompass space object fragmentation and break up modelling, space debris population and micrometeoroid environment modelling, Space Weather studies, Near Earth Objects and planetary defence studies etc.

Apart from the observational facilities to be installed, 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.

### National Collaborations

1. ISRO entered an MoU with Indian Institute of Astrophysics (IIA) for cooperation in the fields of SSA and Space Sciences
2. ISRO entered an MoU with Aryabhata Research Institute of Observational Sciences (ARIES) for cooperation in the field of SSA.

### International Collaborations

1. ISRO being an active member of the Inter-Agency Space Debris Coordination Committee (IADC), ISRO delegation attended the 38<sup>th</sup> IADC meeting through Video Conference mode 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".
3. ISRO entered MoU with University of Texas, USA for scientific collaboration in the area of SSA.





## 2.10 Quality Management

Space is unforgiving and space technology calls for the most meticulous compliance to quality requirements. Rugged quality practices are in vogue at ISRO/DOS towards ensuring that no defect goes unnoticed. It is the combination of the strengths of quality practices and the multi-tier review mechanism that is demonstrated through the success of missions. It is these very aspects that make ISRO's workhorse PSLV renowned, the world over, for its reliability. With DOS/ISRO making steady progress in the development of Human spaceflight mission-Gaganyaan, the avenues for pushing the envelope in the area of quality and reliability have grown by leaps and bounds in the year 2020. A few significant strengths of the quality systems in vogue and a few salient achievements of the quality teams spread across DOS/ISRO Centres/Units are elaborated in this section.

### Culture of Quality

Quality is the cornerstone for all verticals of ISRO namely space applications, satellites, ground support systems and launch vehicles. All the aspects of design, development, realization, testing and certification are carried out with a specific eye on quality. Quality control teams keep a close watch on each and every aspect of system realization. Independent Quality Assurance teams meticulously scrutinize the details and provide unbiased and bold assessment on all the hardware/software realized at all internal and external work-centres (Industry partners from public and private sector) of ISRO/DOS. Think-tank level review teams comprising of experts brainstorm all the details before giving the go ahead for not just the final launch but also at all identified intermediate stages.

### Absolute Quality Programme (AQP)

Absolute Quality Programme initiated during the year 2018 is the flagship programme of ISRO/DOS towards sustaining and further enhancing the quality culture of ISRO. The essential theme of Absolute Quality Programme for operational space systems is "Quality is doing right, when nobody is looking at". Focus on operational missions and involvement of not just the quality teams, but each and every individual of ISRO sets AQP apart as an unprecedented initiative. Dedicated APEX committees, chaired by respective Directors of Centres/Units, are already in place towards ensuring a positive implementation of this initiative.

With the roll out of APEX review/special sessions of AQP, ten Centres/Units have been covered under this umbrella. These Centres/Units are VSSC, LPSC, URSC, SDSC, SAC, NRSC, PRL, NESAC, IPRC and LEOS. The quality teams of these Centres/Units also conducted AQP sessions at their respective external sub-contractors' worksites.

### Quality Day

In order to reinforce, reinvigorate and rekindle this culture of quality amongst the employees, Quality Day is celebrated every year. Several initiatives including exhibition on quality related innovations and products, quiz competition, invited talks by eminent personalities, talks by young engineers of ISRO and a host of other interactions were conducted this year also at various ISRO Centres/Units. In the light of COVID-19 restrictions, many of these initiatives were conducted in an online/digital mode completely.





## Directorate of Systems Reliability and Quality (DSRQ)

In addition to the quality control and quality assurance teams deployed across DOS/ISRO Centres/Units and external work-centres, a completely independent and dedicated directorate-DSRQ, based at ISRO Headquarters, works towards identifying and addressing systemic quality improvements across ISRO Centres/Units/external work-centres. This directorate is completely independent of the management of Centres/Units of ISRO/DOS and reports directly to Chairman, ISRO/Secretary, DOS. DSRQ shoulders the responsibility of sharing of best practices amongst ISRO Centres and Units through an inter-centre forum named Integrated Product Assurance Board (IPAB). Generation of ISRO Technical standards through interaction with various ISRO experts, propagation of Absolute Quality Programme and other quality outreach initiatives, independent assessment on launch vehicle/satellite missions are also championed by DSRQ.

## ISRO Technical Standards (ITecS)

DOS/ISRO has taken up the initiative of documenting the rich heritage and knowledge base of space systems acquired over the last five decades. This institutional memory is being preserved for posterity in the form of ISRO Technical Standards (ITecS). Six ITecS documents have already been released earlier and this year the ISRO Technical Standard on “Product Realization Life Cycle and Acceptance Procedures for Spacecraft Bus Electronic Systems” was generated and published.



Another three ITecS documents were also finalized and are ready for publication.

Another set of five documents are in advanced stage of finalization. Several other documents are also in various stages of generation and review.

## ISRO Projects

The quality teams of ISRO/DOS worked towards ensuring the quality control and quality assurance of the launch vehicle systems, satellite systems, range systems and TTC network for the following operational missions launched/prepared for launch in the current year.

PSLV C49/ EOS-01 Mission

PSLV C50/ CMS-01 Mission

GSLV F10/ EOS-03 Mission

One unique feature of the missions this year is the development and utilization of Virtual Launch Control Centre (VLCC) which enabled remote checkout of the launch vehicle systems while minimizing the number of experts travelling to Sriharikota. All remote operations were carried out without compromising on the rigour of testing towards ensuring the quality of the vehicle systems. This is ISRO's answer to the pandemic and the restrictions it imposed. The quality teams worked extensively towards the evaluation, qualification and implementation of this new normal. Similar remote capabilities were developed and implemented by the satellite teams as well. Quality teams also specifically focused on the shelf life related aspects of various systems for these launches considering the larger than usual preservation period of these systems due to the pandemic.



### **Other salient achievements of the quality teams**

The quality teams at ISRO/DOS Centres/Units also worked extensively towards the developmental activities with respect to the upcoming missions and other developmental/operational missions planned in the future. They carried out extensive analysis and enabled the qualification of several novel space systems, unique processes and state of the art processing facilities/equipment/laboratories across ISRO/DOS. Some of the major achievements include process qualifications for new generation Star Sensor optics assembly, space telescope mirrors and payload components & subsystems, indigenization activities for atomic clock and Travelling Wave Tube Amplifier, qualification of payload as well as spacecraft hardware, design and development of critical software tools, On-orbit observation tracker tool design, Product Verification and Evaluation of meta file information on par with the global high resolution data products for mono and multispectral high resolution imagery products, qualification process for high resolution Komsat chips, high resolution thermal targets for radiometric calibration, establishment of microwave data calibration facility under PAN-India network, ISO:9001:2015 certification of National Remote Sensing Centre (NRSC) and Space Application Centre (SAC) for all domains of work, etc.

Quality teams also extensively supported the development of several key technologies including semi-cryogenic engine/stage, re-usable launch vehicles, air breathing propulsion as well as Rohini Sounding Rockets for scientific/experimental purposes. Initiatives towards further improvement of the operational systems (launch vehicle, spacecraft, ground systems and space applications) were also taken up as the department's quest for continual improvement. Progress was made with respect to the human rating, mission assurance, certification, risk assessment, quality policy and procedures for the prestigious Gaganyaan mission. Quality teams are also playing a significant role in the development of Human Rated Launch Vehicle (HRLV) and its associated Test Vehicles towards embedding high levels of quality and reliability into these novel endeavors. Quality teams have also taken up significant technology development programmes specifically targeted towards enhancing the quality and reliability of space systems. The teams also continued to issue quality alerts from time to time. Quality teams also worked towards the post flight analysis of previous operational launch missions.

### **Representation at International/Multi-lateral fora**

The quality teams of ISRO/DOS were well represented at the following significant fora during the period:

- Included as member in IEC TC80 for development of standard "IRNSS – Receiver equipment – Performance requirements, methods of testing and required test results".
- IAA Symposium on Human Space Mission.
- Bureau of Indian Standards TED-14 meeting on Unmanned Aerial Vehicles (UAVs),
- International Space Conference on "Ushering the New Era for Indian Space Sector" From 15 to 17, September, 2020.
- National Conference of "Multi-Disciplinary Design, Analysis and Optimization".







### Quality in the era of space reforms

This year saw the initiation of the unlocking of the space sector in India heralding unprecedented opportunities for the private sector as well as the demand for hand-holding to be done by ISRO/DOS towards several aspects including quality and reliability. The revision in the scope of responsibilities of NSIL also opened up new vistas and greater responsibilities for the quality and reliability teams. The quality teams are already on the job towards addressing the demands which are likely to come up with respect to quality and reliability in the new space era.



## 2.11 Occupational Health & Safety

Some of the critical operations in the Space program are hazardous in nature and require 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 a well-defined Occupational Health and Safety management system. 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

- Ensured the adequacy of safety systems in ISRO Centres/Units to prevent / meet any unforeseen incidence.
- As per the directives from Secretary (Security), Cabinet Secretariat based on the review of DOS Crisis Management Plans-2019, revised the both DOS Crisis Management Plan (Disabling of Satellites)-2020 and DOS Crisis Management Plan-2020 covering readiness to handle various crises.
- Completed safety audit of all facilities of NESAC, Shillong.
- Promoted safety awareness by organizing 49<sup>th</sup> National Safety Day event across ISRO Centres/Units and distributed Safety posters, National Safety Calendars to all Centre/Units of ISRO to promote safety awareness.
- Prepared and released “Safety Manual on Protection against Non-Ionising Radiation-DOS:ISRO:SP:112” to provide knowledge on preventing hazards due to Non Ionising Radiation.
- Represented ISRO in the 81<sup>st</sup> STEC (Storage and Transport of Explosives Committee) meeting held at DRDO Bhawan, New Delhi.
- Prepared a report on Occupational Health requirements specific to each ISRO Centre/Unit with the active participation of ISRO/DOS medical officers.
- **COVID-19 Protocols:**
  - ◆ DOHS took proactive steps for preventing the spread of Covid-19 by releasing DOHS Health Alerts on Corona Virus with a demo & use of sanitizers at all access control gates, and recommended for disabling the biometric access system.
  - ◆ Prepared and circulated the following Covid-19 protocols to all Centres / Units:
    - \* Standard Operating Procedure for restarting launch campaign activities at SDSC, SHAR.
    - \* Protocol for restarting of facilities and operations in ISRO Centres after COVID-19 Lock-Down.
    - \* Post lockdown Health and safety protocols for ISRO HQ employees.
    - \* Protocols for using X-Ray scanning machine.





- \* Protocols for using HVAC systems.
- \* Protocols for Launch Campaign Activities in ISRO.
- \* Protocols for X-ray baggage scanning in ISRO Centres.
- \* Protocols for Disinfecting Vehicles in ISRO Centres.
- \* Protocol for Vehicle cleaning.
- \* Air Travel Protocols for ISRO Employees.
- \* Protocol for International travelers.





## 2.12 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 is becoming wider and diverse, in tune with ISRO's achievements and enhanced capabilities.

Till date, ISRO and India signed space cooperative documents with space agencies of 59 countries (Afghanistan, Algeria, Argentina, Armenia, Australia, Bahrain, Bangladesh, Bhutan, Bolivia, Brazil, Brunei Darussalam, Bulgaria, Canada, Chile, China, Egypt, Finland, France, Germany, Hungary, Indonesia, Israel, Italy, Japan, Kazakhstan, Kuwait, Maldives, Mauritius, Mexico, Mongolia, Morocco, Myanmar, Nepal, Nigeria, Norway, Peru, Portugal, Republic of Korea, Russia, Sao-Tome & Principe, Saudi Arabia, Singapore, South Africa, Spain, Sri Lanka, Sultanate of Oman, Sweden, Syria, Tajikistan, Thailand, The Netherlands, Tunisia, Ukraine, United Arab Emirates, United Kingdom, United States of America, Uzbekistan, Venezuela and Viet Nam) and 5 multinational bodies (European Centre for Medium Range Weather Forecasts – ECMWF; European Commission, European Organisation for the Exploitation of Meteorological Satellites - EUMETSAT, European Space Agency – ESA; South Asian Association for Regional Cooperation - SAARC).

In order to intensify the existing space relations and also to establish new relations with other nations in the peaceful uses of outer space, 6 cooperative documents with Space agencies of 6 countries are signed this year. They are: (1) Memorandum of Understanding (MoU) between the Government of India and the Royal Government of Bhutan on cooperation in the peaceful uses of outer space (2) MoU between India and Nigeria on cooperation in the exploration and uses of outer space for peaceful purposes (3) General MoU for academic and research cooperation and exchange between National Atmospheric Research Laboratory (NARL) and Research Institute for Sustainable Humanosphere, Kyoto University, Japan (4) Plan of Cooperation between ISRO and Israel Space Agency on Electric Propulsion System (5) Specific Cooperation Agreement between ISRO and Mexican Space Agency (AEM) on forest fire management using earth observation data and capacity building; and (6) Agreement between IIST and University of Colorado for cooperation in developing InspireSat1 satellite.

India and USA intensified their space cooperation and carried out many activities during this period. Significant progress has been made in the joint realization of microwave remote sensing satellite mission, 'NASA-ISRO Synthetic Aperture Radar (NISAR)' by conducting various technical review meetings by NASA's Jet Propulsion Laboratory (JPL) with ISRO's UR Rao Satellite Centre (URSC) and Space Applications Centre (SAC). Many important meetings to discuss the schedule and implementing plan was conducted in virtual mode including that of NISAR Joint Steering Group; NISAR Travel Working Group; NISAR Remote Access Working Group and NISAR Senior Management. An ISRO built L- and S-band Airborne SAR (ASAR) was flown over the United States aboard NASA's aircraft during November - December 2019 and data acquisitions were made in 92 sites. ASAR repeat flight campaigns are being planned for spring and summer 2021. Both agencies are working for an implementing arrangement to carry NASA's Laser Reflectometer Array (LRA) in Chandrayaan-3. ISRO-NASA Joint Working Group on Human Spaceflight Programme (HSP) is exploring collaboration opportunities.





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 India’s astronaut candidates were selected and deputed to Russia in February 2020 for medical examination and general astronaut training. 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) and realization of engines for use in Indian launch vehicles.

As part of Indo-French space cooperation, ISRO and CNES have completed the feasibility study to realize an earth observation satellite mission with thermal infrared imager, ‘TRISHNA’ and are working towards finalizing an implementing arrangement for the joint development. Both agencies have also finalized all interface control documents for accommodating CNES’s ARGOS instrument in ISRO’s OCEANSAT-3 satellite. ARGOS instrument has been delivered at Bangalore for integration with the satellite. Discussions on establishing NavIC reference station in France and CNES Scintillation receivers in India are also progressing well. ISRO-CNES HSP Working Group had a number of discussions on medical aspects of human spaceflight and finalising an implementation arrangement to formalize cooperation in the field of space medicine.

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; and establishing ISRO’s NavIC reference station in Japan. Both agencies have completed the feasibility study for a joint lunar polar exploration mission and are currently finalizing the Phase-A study report.

ISRO and European Space Agency (ESA) are finalizing implementing arrangement concerning network and operations cross-support to support each other’s satellite missions.

As announced during the visit of the Honorable Prime Minister of India to Bhutan in August 2019, India and Bhutan are working towards jointly realising a small satellite, targeted for launch in 2021. This satellite will be based on ISRO Nano Satellite (INS) bus and will carry imaging payload developed by ISRO and Digipeater developed by Bhutan. As part of this, four Engineers from Bhutan are being offered on-the-job training on satellite integration and testing. An Implementing Arrangement for realizing the joint satellite will be signed shortly.

ISRO and Mexican Space Agency (AEM) have agreed to cooperate in the area of capacity building in forest fire management using earth observation data. Mexican officials will be attending courses on satellite remote sensing applications in India in 2021.

ISRO and Israel Space Agency (ISA) have exchange required technical details on cooperation in Electric Propulsion System (EPS). It is proposed to fly ISA’s EPS in ISRO’s small satellite.

Australian Space Agency (ASA) has agreed to support ISRO in establishing a Transportable TTC Terminal for the Gaganyaan mission at Cocos island in Australia. Both sides are working out the modalities and finalizing a cooperative document to formalize the same.



ISRO is working on a programme to support Association of South East Asian Nations (ASEAN\_ member states to receive and process data from Indian remote sensing satellites and also to provide training in space science, technology and applications for the benefit of ASEAN Member Countries. Under this, a new ground station will be established in Vietnam and the existing Indonesian station will be augmented.

Joint Working Group meetings on space cooperation with space entities of UAE (August 17, 2020); Tajikistan (August 31, 2020); Bolivia (September 15, 2020); Morocco (September 28, 2020); France (September 30); Kazakhstan (October 27); Italy (October 15); Argentina (December 2, 2020); Egypt (December 23, 2020) were organised through videoconference.

Chairman, ISRO/ Secretary, DOS has participated (through videoconference) in : (i) BRICS Head of Space Agencies meeting held on July 15, 2020; (ii) First G20 Space Economy Leaders meeting (Space20), organised by Saudi Space Commission (SSC) on October 07, 2020 as a side event of the G20 summit; (iii) Heads of Space Agency Plenary at the International Astronautical Congress (IAC) - Cyber Edition on October 12, 2020; and (iv) ASCEND event on “Meeting Global Challenges in Partnership for the Benefit of Humanity” organized by American Institute of Aeronautics and Astronautics (AIAA) on November 18, 2020.

An International Symposium on human spaceflight and exploration was organized by ISRO in association with International Academy of Astronautics (IAA) and Aeronautical Society of India (ASI) during January 22-24, 2020 at Bengaluru with the theme of ‘human spaceflight – present challenges and future opportunities’. More than 500 delegates, including national and international technical experts in human spaceflight related technologies from space agencies, astronauts, representatives of International space industries and academic institutes, young professionals and students participated in the Symposium. Heads of space agencies, Astronauts and eminent experts from USA, Russia, France, Japan, Italy, Germany and UAE have participated in this event.

As the Chair, ISRO organised the 34<sup>th</sup> Plenary of Committee on Earth Observation Satellites (CEOS) virtually during October 20-22, 2020. About 130 officials from 62 member agencies and associated organisations have participated.

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 (CSSTEAP) at Dehradun. As of now, there are more than 2975 beneficiaries from 109 countries. CSSTEAP celebrated 25<sup>th</sup> anniversary of its establishment, through a virtual meeting, on November 02, 2020. Senior dignitaries, diplomats and alumini from India, Indonesia, Kazakhstan, Kyrgyz Republic, South Korea, Nepal and Sri Lanka have participated and highlighted the achievements of CSSTEAP in last 25 years.

ISRO Technical Liaison Unit (ITLU) has been established at the Indian Embassy at Moscow and an ISRO official is posted as Consular (Space) to coordinate India’s space related activities in Russia and adjoining region.

ISRO continues to play an active role in the deliberation of the United Nations Committee on





the Peaceful Uses of Outer Space (COPUOS). ISRO also actively participates in the meetings of prominent multilateral fora including International Astronautical Federation (IAF), International Academy of Astronautics (IAA), International Institute of Space Law (IISL), Committee on Earth Observation Satellites (CEOS), International Society for Photogrammetry and Remote Sensing (ISPRS), Coordination Group on Meteorological Satellites (CGMS), International Committee for Global Navigation Satellite Systems (ICG), Committee on Space Research (COSPAR), International Space Exploration Coordination Group (ISECG) and Inter-Agency Space Debris Coordination Committee (IADC).

### **Space Activities Bill related**

The process of formulation of the Space Activities Bill has made significant progress this year. Department of Space has obtained the opinions from two legal experts on the overall text of the bill and on the changes required in the bill in view of the establishment of INSPACe. The draft is undergoing the required revision to integrate the suggestions from legal experts.



## 2.13 Space Commerce

### Antrix Corporation Limited

Antrix Corporation Limited (ANTRIX) is the commercial and marketing arm of ISRO established in 1992. It is wholly owned by the Government of India and has its Corporate Office in Bangalore, India. Under the administrative umbrella of the Department of Space, ANTRIX markets space products and services from ISRO and other Indian Space industries to domestic and international customers.

#### Remote Sensing Data and Services:

The global marketing of IRS data is being pursued in collaboration with its international partners. Currently, Antrix markets IRS data and services from Resourcesat-2, Cartosat-2S and Oceansat-2 satellites and archived imagery from past missions. The currently operational IRS Ground Stations (IGS) are GAF AG, Germany for Oceansat-2 and Resourcesat-2.

#### SATCOM

Satellite Communication is touching common man's life in a bigger and better way – for entertainment, Bank ATMs, distance learning, live news coverage, telemedicine etc. Especially during the COVID-19 pandemic, technology has evolved and online connectivity is the only key to stay connected with friends, families, schools, offices, doctors etc. Based on the need projected by DOS, Antrix is providing commercial satellite based services to various Indian users, across a wide cross section of private, public, Government and strategic sectors, through 85 foreign leased transponders for a multitude of applications like DTH, VSAT and Cellular Backhauling etc. SATCOM business segment continues to be a major revenue earner for the company amounting to approx. 60% of the operating revenue.

Antrix being in Space Sector is currently exploring new business opportunities under the space domain as ISRO's Transponder leasing, Launch services and Mission support, business segments which were handled by ANTRIX, has been transferred to M/s. New Space India Limited, a newly formed PSU under Department of Space.

### NewSpace India Limited (NSIL)

NSIL got incorporated on March 6, 2019, as a wholly owned Government of India Undertaking/ Central Public Sector Enterprise (CPSE), under the administrative control of Department of Space (DOS). NSIL has been Categorized as a Schedule 'A' CPSE by Department of Public Enterprises (DPE) on Feb 6, 2020. During the first year of operation, the company achieved a commendable performance bringing in a total turnover of Rs 321.59 crores with a total profit (before tax) of Rs 68.57 crores.

Summary of major business activities of NSIL are given hereunder:

#### A. Launch Services

During the FY 2020-21, NSIL has signed two Launch Service Agreements for launching customer satellites, as a co-passenger, on-board Polar Satellite Launch Vehicle (PSLV). NSIL is in discussion with International customers for dedicated launch/ co-passenger missions on-board PSLV and Small Satellite Launch Vehicle (SSLV).







Under a commercial agreement with International customers, NSIL has so far launched a total of 31 customer satellites onboard PSLV-C47, C48 and C49 missions.

NSIL would be launching Amazonia-1 satellite from INPE, Brazil onboard PSLV-C51 during February 2021. Amazonia-1 which is an optical earth observation would be the primary satellite in the PSLV-C51 mission. In addition, in the same mission, NSIL would also launch the first nano satellite Anand, built by Indian Space Startup, M/s Syzygy Space Technologies Pvt Ltd (PIXXEL India). Anand is an Earth Observation nano satellite.

### ***B. PSLV Production through Indian Industry***

Towards realization of 5 PSLV's through "Indian Industry", NSIL released Expression of Interest (EoI) and the proposals received from various Indian Industry partners were evaluated. NSIL is now in the process of releasing the Request For Proposal (RFP) to the short-listed Indian industry partners, for the same.

### ***C. SATCOM Services***

NSIL, as part of SATCOM Services, is provisioning the transponders in C, Ku and Ext- C band on-board INSAT/ GSAT satellites to various customers for meeting several applications need viz. DTH, VSAT, TV, DSNG. NSIL is also provisioning transponder capacity on Foreign satellite on a back-to-back arrangement to Indian users.

### ***D. Mission Support Services***

NSIL is closely working with global ground station operators to provide Mission Support Services for Satellites and Launch vehicles. NSIL will be providing Mission Support Services for the Amazonia-1 Mission of INPE, Brazil for Launch and Early Orbit Phase of Operation and emergency support.

### ***E. Technology Transfer/ Spin-off***

NSIL has been mandated to transfer the Technologies emanating from R & D activities of ISRO/ DOS Centers/ Units to Industries for the larger benefits of stakeholders in the ecosystem. At present, NSIL has signed 13 Technology Transfer Agreements till date for transferring ISRO developed Technologies to Industry.

NSIL, by utilizing the Technical Services of Semi-Conductor Laboratory (SCL) of DOS, is provisioning ASICs, Systems/ Sub-systems to its customers.



## 3. Resource Management

### 3.1 Budget

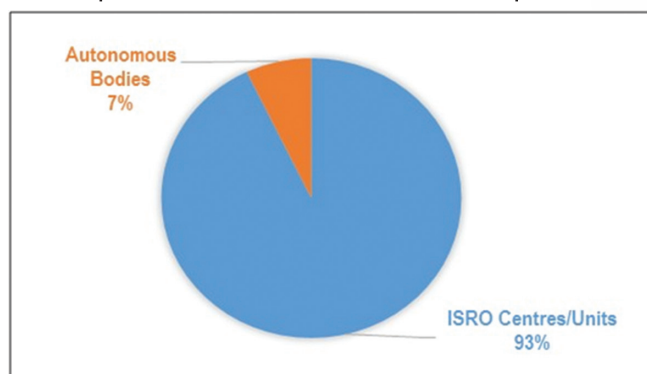
#### Budget at a Glance

(Rs. in Crores)

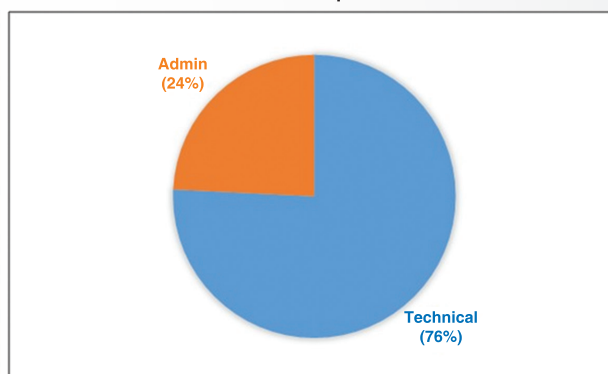
Sl. No	AREA	BE 2020-2021	RE 2020-21	BE 2021-22
1	Establishment Expenditure	230.17	172.80	186.47
2	Space Technology	9,761.50	6,540.85	10,250.16
3	Space Applications	1,810.00	1,190.50	1,476.85
4	Space Sciences	265.00	188.51	274.50
5	INSAT Satellite Systems	750.50	771.88	329.61
6	Other Central Expenditure	662.30	635.46	1,431.50
	<b>Grand Total</b>	<b>13,479.47</b>	<b>9,500.00</b>	<b>13,949.09</b>

### 3.2 Human Resource

The total approved sanctioned strength of the Department as on 01.03.2020 is 20122, out of which 18702 is sanctioned strength of ISRO Centres/Units and 1420 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:



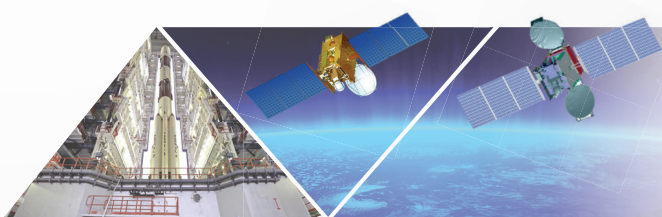
DoS Sanctioned Strength



Technical Staff v/s Admin Staff

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 and is continued during the year. However, due to Covid-19 impact and related restrictions there has been delay in completing the process. However, revised mechanism have been evolved to complete the ongoing recruitment process and initiation of recruitments for next calendar year.

Further, specialised recruitments, based on the Centres requirements, are made by respective Centres/Units. The campus recruitments at reputed institutes are continued and selections are under process.

ISRO/DOS has been absorbing bright graduates from the Indian Institute of Space Science and Technology (IIST) on successful completion of the B.Tech/Dual degree programme, meeting the benchmark set. The tenth batch of students, who were admitted to B.Tech/dual degree during September 2016 at IIST have graduated during September 2020 and a total of 97 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 281 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.

Due to Covid-19 impact and restrictions, training activities have been reframed with required



infrastructure suiting to online administration of the same and resumed starting from September 2020 onwards.

### 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 31.10.2020)

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.	<b>GENERAL:</b> Total Number of Employees						
	(i) Male Employees	7812	297	2328	872	1224	1231
	(ii) Female Employees	1813	154	206	824	69	269
B.	<b>SCHEDULED CASTES/ SCHEDULED TRIBES:</b>						
	(i) Number of Scheduled Caste Employees	693	50	419	249	199	303
	(ii) Number of Scheduled Tribe Employees	174	18	115	105	97	73
C.	<b>PERSONS WITH DISABILITIES (PWD):</b>						
	(i) Number of persons with disabilities existing						
	1. Deaf & Dumb	12	1	17	7	12	5
	2. Blind	3	0	0	1	1	6
	3. Partially Blind	1	0	1	9	1	8
	4. Orthopaedically handicapped	116	10	75	45	25	14
	(ii) Number of Persons with disabilities appointed during the year 2020						
	1. Deaf & Dumb	0	0	0	0	3	0
	2. Blind	0	0	0	0	0	1
	3. Partially Blind	0	0	0	0	0	1
	4. Orthopaedically handicapped	0	0	0	0	2	1
D.	<b>EX-SERVICEMEN:</b>						
	(i) Number of Ex-servicemen existing	14	5	39	40	36	232
	(ii) Number of Ex-servicemen appointed during the year 2020	0	0	0	0	10	9





<b>E. OTHER BACKWARD CLASSES:</b>							
(i) Number of OBCs existing	1926	61	1164	414	671	538	
(ii) Number of OBCs appointed during the year 2020	34	4	13	1	51	55	
<b>F. APPRENTICES TRAINING:</b>							
(i) Number of Apprentices trained during the year 2020 - 2021	1787						
(ii) Number of successful apprentices out of (i) above	610						
(iii) Number of apprentices appointed as regular employees during the year 2020 - 2021 (as on ....)	19						

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

TABLE - I

Sl. No	Centre/Unit	Total Strength of Employees 2020-21	Strength of SC Employees 2020-21	Strength of ST Employees 2020-21
1	DOS/ISRO HQ	445	53	23
2	VSSC	4705	365	55
3	URSC	2685	304	108
4	SDSC-SHAR	2209	342	126
5	SAC & DECU	2090	186	138
6	LPSC	1279	139	28
7	NRSC	861	111	43
8	ISTRAC	438	63	13
9	MCF	306	36	16
10	ADRIN	159	16	0
11	IIRS	85	11	5
12	PRL	271	13	7
13	SCL	573	108	4
14	NARL	71	17	1
15	NESAC	46	2	4
16	IIST	100	3	0
17	HSFC	96	6	0
18	IPRC	680	138	11
	<b>TOTAL</b>	<b>17099</b>	<b>1913</b>	<b>582</b>



**STATUS OF PERSONS WITH DISABILITIES IN DOS/ISRO**

**TABLE - II**

SI No	Centre/Unit	Total Strength of Employees 2020-21	Strength of Persons with Disabilities	Classification of Employees with Disabilities			
				Deaf & Dumb	Blind	Partially Blind	Orthopedically Handicapped
1	DOS/ISRO HQ	445	6	0	0	1	5
2	VSSC	4705	108	21	5	14	68
3	URSC	2685	64	14	1	5	44
4	SDSC-SHAR	2209	54	2	3	0	49
5	SAC & DECU	2090	45	6	2	0	37
6	LPSC	1279	31	8	0	1	22
7	NRSC	861	23	4	0	0	19
8	ISTRAC	438	11	0	0	0	11
9	MCF	306	5	1	0	0	4
10	ADRIN	159	3	0	0	0	3
11	IIRS	85	5	0	1	0	4
12	PRL	271	5	1	0	0	4
13	SCL	573	4	0	0	0	4
14	NARL	71	1	0	0	0	1
15	NESAC	46	0	0	0	0	0
16	HSFC	96	0	0	0	0	0
17	IIST	100	1	0	0	0	1
18	IPRC	680	12	0	0	0	12
	<b>TOTAL</b>	<b>17099</b>	<b>378</b>	<b>57</b>	<b>12</b>	<b>21</b>	<b>288</b>

**STATUS OF REPRESENTATION OF EX-SERVICEMEN IN DOS/ISRO**

**TABLE - III**

SI No	Centre/Unit	Total Number of Employees in Group - C 2020-21	Total Number of Ex-Servicemen in Group - C 2020-21
1	DOS/ISRO HQ	96	4
2	VSSC	693	148
3	URSC	417	13
4	SDSC-SHAR	566	21
5	SAC & DECU	372	13
6	LPSC	206	42
7	NRSC	132	14
8	ISTRAC	47	7
9	MCF	47	2
10	ADRIN	16	2





11	IIRS	5	1
12	PRL	19	0
13	SCL	57	1
14	NARL	8	0
15	NESAC	2	0
16	HSFC	2	0
17	IIST	0	0
18	IPRC	108	19
	<b>TOTAL</b>	<b>2793</b>	<b>287</b>

### WOMEN EMPLOYEES IN DOS/ISRO

TABLE - IV

SI No	Centre/Unit	Total Number of Employees 2020-21	Number of Women Employees 2020-21	
			Scientific & Technical Staff	Administrative Staff
1	DOS/ISRO HQ	445	25	113
2	VSSC	4705	541	459
3	URSC	2685	583	146
4	SDSC-SHAR	2209	126	125
5	SAC & DECU	2090	269	77
6	LPSC	1279	95	108
7	NRSC	861	145	59
8	ISTRAC	438	74	36
9	MCF	306	33	7
10	ADRIN	159	31	9
11	IIRS	85	18	4
12	PRL	271	29	20
13	SCL	573	41	20
14	NARL	71	5	5
15	NESAC	46	8	3
16	HSFC	96	4	8
17	IIST	100	20	6
18	IPRC	680	41	42
	<b>TOTAL</b>	<b>17099</b>	<b>2088</b>	<b>1247</b>



## ECONOMICALLY WEAKER SECTION (EWS) IN DOS/ISRO

### TABLE - V

Sl No	Name of the Centre	Total Number of Vacancies occurred during the period from January 2019 to 31.10.2020	Total Number of Vacancies identified for EWS
1	DOS/ISRO HQ	43	1
2	VSSC	292	15
3	URSC	204	15
4	SDSC-SHAR	181	14
5	SAC & DECU	75	4
6	LPSC	109	8
7	NRSC	62	3
8	ISTRAC	52	4
9	MCF	33	1
10	ADRIN	3	0
11	IIRS	0	0
12	PRL	15	1
13	SCL	23	0
14	NARL	0	0
15	NESAC	12	0
16	HSFC	151	8
17	IIST	0	0
18	IPRC	88	2
19	ANTRIX	4	0
	<b>TOTAL</b>	<b>1347</b>	<b>76</b>







## 4. Others

### 4.1 Space in Parliament

Indian Space Programme continued to attract the attention of both the Houses of Parliament. Questions were answered in Parliament during January 2020 - December 2020 as shown below:-

Questions	Budget Session 2020		Monsoon Session 2020		Total	
	3 <sup>rd</sup> Session of 17 <sup>th</sup> Lok Sabha	4 <sup>th</sup> Session of 17 <sup>th</sup> Lok Sabha	251 <sup>st</sup> Session of Rajya Sabha	252 <sup>nd</sup> Session of Rajya Sabha		
		L.S.	R.S.			
Starred Questions	1	0	0	0	1	0
Unstarred Questions	12	12	4	7	16	19
<b>Total</b>	<b>13</b>	<b>12</b>	<b>4</b>	<b>7</b>	<b>17</b>	<b>19</b>

The Questions were with respect to Human Space Flight Mission, Approving Navic, GSAT-30, ISRO Developing Technology, Young Scientists Programme, Chandrayaan-III, Space Debris, Homegrown Satellites, Reusable Launch Vehicle, Earth Observation Satellites, Space Missions of ISRO, Launching Satellites, New Space Objects, Solar Mission Aditya-L1, Setting up of New Rocket Launch Pads by ISRO, First Unmanned Test Mission By ISRO, Female Humanoid Robot for Space Mission, Research and Development of Space Technology and Applications, Progress to Launch GISAT-1, Spacecrafts Launched by the Country, Launching of Manned Satellite to Moon, Earth Observation Satellites, Prime Minister's Vision for Indian Space Programme, Web Portal for Monitoring Government Projects, Space Program of India vis-à-vis China, Private Sector Participation in Space, Space Technology, Space Launch Centre in Tamil Nadu, Rocket Launching Port, Funds for Space Exploration Programmes, Private Initiative in Space Exploration, Space Applications, Private Sector Participation in Space Sector, Scientists of Indian Origin joining ISRO from Foreign Space Agencies, IN-SPACE and Private Sector Innovation in the Space Sector, Status of Space Applications Programme at ISRO, etc.

During the year 2020, Parliamentary Committee on Welfare of Other Backward Classes undertook a study visit to Goa on 15.01.2020 and held interactions with representatives of the OBC Employees Welfare Unions/Associations of ISRO and with representatives of DOS and ISRO regarding measures undertaken to secure representation of OBCs in recruitment and for their Welfare.

Department-related Parliamentary Standing Committee on Personnel, Public Grievances, Law & Justice (Rajya Sabha) undertook a study visit to Bengaluru on 17.01.2020 and held discussions with representatives of Department of Space/ISRO on Vigilance Administration in respect of DOS/ISRO.



## 4.2 Vigilance

Category of employees	Types of cases	Cases pending as on 01.10.2019	Cases received during the period 01.10.2019 to 30.09.2020	Total (Col. 3+4)	Disposed during 01.10.2019 to 30.09.2020	Pending (Col. 5-6)
1	2	3	4	5	6	7
Group-A & Group B (Gazetted)	Disciplinary (Non-Vigilance)	9	3	12	3	9
	Disciplinary (Vigilance)	7	0	7	3	4
Group-A (Non-Gazetted)	Disciplinary (Non-Vigilance)	1	1	2	0	2
Group-B (Non-Gazetted) & Group C	Disciplinary (Non-Vigilance)	8	6	14	10	4
	Disciplinary (Vigilance)	1	0	1	0	1
	<b>TOTAL</b>	<b>26</b>	<b>10</b>	<b>36</b>	<b>16</b>	<b>20</b>





### 4.3 Progressive use of Hindi

- This year was a challenging year for Official Language Implementation also, as was for other Programmes of the Department. During COVID-19 pandemic situation, implementation of Hindi in the Department of Space (DOS) continued with the same vigour. The Official Language Implementation Committees (OLICs) held their quarterly meetings to review the progressive use of Hindi. DOS/ISRO and its Centres and Units also participated in the meetings of Town OLIC constituted in respective Towns. Modern communication tools and techniques were used for meetings/reviews.
- The process of reconstituting Joint Hindi Advisory Committee (JHAC) of DOS and DAE is under process in the Department. The tenure of the JHAC of DOS and DAE ended on 30.06.2019. After receiving all the required nominations, the file is sent to PMO for approval. After obtaining the approval, action for conducting the meetings of JHAC will be initiated.
- 42<sup>nd</sup> meeting of Central Official Language Implementation Committee was held on 02.11.2020 under the Chairmanship of Secretary, DOL. In this meeting, OSD, DOS, Branch Secretariat, New Delhi and Sr. Hindi Officer, DOS, Br. Sec., New Delhi participated.
- Every year, Department organizes the meeting of Departmental Official Language Implementation Committee to review the progressive use of Official Language in all the Centres/Units of DOS. Due to COVID-19 situation, the said meeting could not be convened this year. However, QPRs of all the Centres/Units were reviewed, and letters regarding this along with observations/suggestions were sent to the concerned Centres/Units.
- Responsibilities of holding Secretariat for **TOLICs** are undertaken by URSC, Bangalore, MCF, Hassan and SCL, Chandigarh of the Department.
- All the Centres/Units of the Department located in 'A', 'B' and 'C' region achieved the targets of correspondence set by the Department of Official Language.
- During the year, Department and its Centres/Units purchased Hindi books for their Libraries, in accordance with the target set by DOL.
- During the year, Department spent the amount of money for the publication of advertisements in Hindi in various newspapers in according to instructions issued by DOL.
- In order to implement Hindi in more meaningful and effective manner, and to evaluate the progressive use of Hindi in DOS/ISRO Centres/Units, an Annual Inspection Programme was drawn up by the Department. Due to COVID-19 pandemic, the inspections were carried out this year through online mode. 33 out of 34 Inspecting Officers have successfully carried out their inspection and 33 out of 35 offices have completed their inspection programme which was completely planned online.
- Internal inspection of various Sections in ISRO HQ and in the Centres/Units was carried out to increase the use of Hindi in day to day work. Sections in DOS/ISRO HQ doing the best implementation of Official Language were awarded. They were awarded shields and certificates.
- Training programmes in Hindi through Hindi Teaching Scheme under Correspondence courses continued in the Department. The percentage of employees possessing working knowledge of





Hindi in all the DOS/ISRO Centres/Units considerably increased more than 80. The Centres/Units were requested to prepare an action plan for imparting training to the remaining employees and to complete the training programme at the earliest within the time schedule stipulated by DOL.

- Employees, who have successfully completed their language training programmes appeared for the final exams in November 2020.
- Hindi Day, Hindi Week, Hindi Fortnight/Hindi Month and Hindi Workshops were organised, in all DOS/ISRO Centres/Units, during which competitions in Essay Writing, Noting and Drafting, Typing, Quiz, Poetry Writing, Singing etc. were conducted. These competitions were organised for Hindi speaking and non-Hindi speaking employees separately. The prizes were also awarded separately for both the categories. Due to COVID-19 pandemic situation, all the competitions were conducted this year following all the guidelines issued in connection with COVID-19 situation including online competitions.
- In order to implement the recommendations of the previous Joint Hindi Advisory Committee regarding propagation of Hindi from house-to-house, family members of the employees were also invited during Hindi Fortnight celebrations in some Centres/Units of the Department and there was an overwhelming response.
- Children of the employees, who secured highest marks in Hindi in class X & XII (Final Examination) were awarded Cash Prizes and Certificates.
- The Department always plays an active role in the activities of Town OLIC. It conducts various programmes under the auspices of Town OLIC. Due to the pandemic situation, TOLIC did not organize any program this year.
- 11<sup>th</sup> edition of 'DISHA', in-house magazine of DOS/ISRO HQ was published during the year and consolidation of content has already been initiated for the next issue.
- In house Hindi magazines were brought out by various Centres/Units of the Department. As per the instructions issued by Government of India all the Centres/Units have been advised for its digital release.
- Several Pamphlets, Panels/Posters connected to ISRO's launches like GSAT-30 Mission, GSLV MKIII D2, PSLV-C47 Cartosat-3 Mission, PSLV-C48 RISAT-2B Mission, PSLV C49 were prepared in Hindi. ISRO celebrated Vikram Sarabhai Centenary Programme during the year. In this connection, various brochures on Vikram Sarabhai were brought out in Hindi.
- ISRO conducts several outreach programmes related to space activities in order to reach out to the common man and student community. ISRO celebrated Vikram Sarabhai Centenary this year. In this connection, many outreach Programmes, exhibitions and mobile exhibitions, where panels and posters in Hindi were exhibited, were organized throughout the country.
- 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 which are updated in bilingual regularly. DOS/ISROHQ, SAC, VSSC, LPSC, SDSC also have internal web pages on intranet.





- 'Hindi Month Incentive Scheme' under which the Officers/Employees doing maximum work in Hindi during the Hindi month are awarded continued during the year. New incentive scheme of the Department "Space Official Language Implementation Scheme-SOLIS" also continued during the year and employees of DOS/ISRO HQ and its Centres/Units were awarded Cash Prizes & 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. This year 06 (Six) books from various ISRO Centres/Units were received in the Department. These books are forwarded to the Members of the Committee for their reviews and comments. After the review process, publication of these books will be arranged.
- Every year, various Centres/Units of the Department conduct Technical Seminars in Hindi on various subjects. In these seminars, a session on Official Language is also included. Seminar Souvenir is also brought out in electronic/Book form. But due to COVID-19 and the austerity measures taken by the Department, Technical Seminars were not conducted this year.
- Employees of DOS/ISRO Centres/Units also participated in the activities on progressive use of Hindi organised by various voluntary Organizations, Town OLIC and also by Regional Implementation Office. On 05.03.2020 TOLIC (O-2), Bengaluru conducted Joint Orientation Programme and Kavi Sammelan for all the member offices of all the TOLICs of Bengaluru region.
- Space Science Glossary of the Department is available in electronic form and is uploaded on website for use by general public.
- On 8<sup>th</sup> December 2020, inspection of DOS, Branch Secretariat, New Delhi was carried out by the Second Sub-Committee of the Committee of Parliament on Official Language.
- In the Department, the task of inclusion of Hindi in COINS and, the web version of COWAA is underway at SDSC, SHAR Shriharikota.

## AWARDS:

### National Level -

- For Best implementation of Official Language, Department of Space was conferred the "**Rajbhasha Kirti Puraskar**" (1<sup>st</sup> Prize) this year. It is a matter of great pride that the Department has been getting awarded with this prestigious award consecutively for the last 5 years.
- The Half yearly Hindi magazine "AKSH" of ISRO Inertial System Unit (IISU) has been selected for "**First Prize**" as the best In-house magazine in region 'C' under "**Rajbhasha Kirti Puraskar Scheme**".





## 4.4 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 – 2019-2020(English / Hindi )
- Human Resources
- Citizen Charter
- Public Grievances
- Suo-Motu disclosure of official tours of Joint Secretary level officials and above
- Suo-Motu Disclosure of Directory of employees of ISRO HQ/DOS
- Organisation, functions and duties
- Powers and duties of the Officers and Employees
- Procedures followed in the decision making process, including channels of supervision and accountability
- Norms set by the Department of Space for the discharge of its functions
- Rules, regulations, instructions, manuals and records of the Department of Space used by its employees for discharging their functions.
- Statement of the categories of documents held by the Department of Space or under its control
- Particulars of arrangements for consultation with or representation by the public in relation to the formulation of policies and implementation thereof by Department of Space
- Statement of Boards, Councils, Committees and other Bodies and as to whether meetings of such boards, etc., are open to public, or the minutes of such meetings are accessible to public.
- Budget 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 December 2019 to November 2020, 1926 applications were received and information were disseminated under the provisions of the RTI Act. 172 Appeals were received by the First Appellate Authority and 10 appellants approached the Second Appellate Authority, i.e., Central Information Commission.



## 4.5 Audit Observation

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

Sl. No	Year	No. of Paras/PAC 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 1 <sup>st</sup> time	No. of ATNs sent by the Ministry and awaiting vetting by Audit	No. of ATNs sent but returned with observations and Audit is awaiting their resubmission by the Ministry	No. of ATNs which have been finally vetted by audit but have not been submitted by the Ministry to PAC
1	2	3	4	5	6	7
1	Report No.12 of 2016 (Para No.5.1) Computerisation in administration, finance and related areas	One	Nil	Nil	Nil	Nil
2	Report No.12 of 2016 (Para No.5.2) Implementation of Telemedicine Programme	One	Nil	Nil	Nil	Nil
3	Report No.12 of 2016 (Para No.5.3) Wasteful expenditure on material for propellant tanks	One	Nil	Nil	Nil	Nil
4	Report No.12 of 2016 (Para No.5.4) Loss due to delayed commissioning of equipment	One	Nil	Nil	Nil	Nil







5	Report No.12 of 2016 (Para No.5.5) Unfruitful expenditure on consultancy services	One	Nil	Nil	Nil	Nil
6	Report No.12 of 2016 (Para No.5.6) Non-levy of labour welfare cess on construction work payment	One	Nil	Nil	Nil	Nil
7	Report No.33 of 2016 Management of Launch Services	One	Nil	Nil	Nil	Nil
8	Report No.17 of 2017 (Para no.6.1) Management of VSAT Services	One	Nil	Nil	Nil	Nil
9	Report No.17 of 2017 (Para No.6.2) Irregular Expenditure on Pre-Project Activities	One	Nil	Nil	Nil	Nil
10	Report No.17 of 2017 (Para No.6.3) Lack of Financial Prudence and improper contract Management in the Delivery of Commercial Spacecraft	One	Nil	Nil	Nil	Nil



11	Report No.17 of 2017 (Para No.6.4) Infructuous Expenditure in purchase of ecologically fragile land	One	Nil	Nil	Nil	Nil
12	Report No.02 of 2018 (Para No.7.1) Operationalisation of Satellite navigational system	One	Nil	Nil	Nil	Nil
13	Report No.02 of 2018 (Para No.7.2) Infructuous expenditure on Software Development	One	Nil	Nil	Nil	Nil
14	Report No.6 of 2020 (Para No.5.1) Grant of additional increments	Nil	Nil	One	Nil	Nil
15	Report No.6 of 2020 (Para No.5.2) Silicon carbide mirror development facility	Nil	Nil	One	Nil	Nil
16	Report No.6 of 2020 (Para No.5.3) Creation of posts without approval of competent authority	Nil	Nil	One	Nil	Nil





17	Report No.6 of 2020 (Para No.5.4) Residency period for promotion fixed at lower than prescribed level	Nil	Nil	One	Nil	Nil
18	Report No.6 of 2020 (Para No.5.5) Management of civil works	Nil	Nil	One	Nil	Nil

## B. Summary of important audit observations during 2020

### 1. C&AG Report Union Government, Scientific Departments Report No. 6 of 2020 Para 5.1 titled “Grant of Additional Increments”

Department of Space did not take action for more than five years on the advice of Ministry of Finance to consider immediate withdrawal of payment of two additional increments being granted to its Scientists/Engineers. This resulted in payment of ₹251.32 crore towards continued grant of the two additional increments during the period December 2013 to March 2019 in 15 test checked centres and Autonomous Bodies under the Department.

### 2. C&AG Report Union Government, Scientific Departments Report No. 6 of 2020 Para 5.2 titled “Silicon Carbide Mirror Development Facility”

Indian Space Research Organisation, Bengaluru and International Advanced Research Centre for Powder Metallurgy, Hyderabad established a Silicon Carbide Mirror Development Facility without ensuring that the technology for development of the mirrors was either proved or validated. The facility created could not produce the required quality of mirrors during its entire operational life of 10 years despite expenditure of ₹47.12 crore incurred on its establishment and maintenance.

### 3. C&AG Report Union Government, Scientific Departments Report No. 6 of 2020 Para 5.3 titled “Creation of posts without approval of competent authority”

Department of Space created 955 posts in administrative cadres without obtaining approval of the competent authority and filled them up by promotion of employees working in lower posts. Expenditure of ₹235.05 crore was incurred on the salaries of employees in the higher posts, a part of which was paid from the deposit projects of the department, which was contrary to the Government rules and procedures.

### 4. C&AG Report Union Government, Scientific Departments Report No. 6 of 2020 Para 5.4 titled “Residency period for promotion fixed at lower than prescribed level”

Department of Space did not obtain the approval of the competent authority for fixing the minimum residency period for promotion of its Group A officers at a lower than prescribed level



which resulted in pre-mature grant of promotions and payment of pay and allowances in the higher scales to the extent of ₹1.29 crore in 13 test checked.

**5. C&AG Report Union Government, Scientific Departments Report No. 6 of 2020 Para 5.4 titled “Management of Civil Works”**

Management of civil works in five centers of Department of Space was deficient resulting in time overrun of 109 days to 1,142 days and cost overrun of ₹37.62 crore. Besides, there were cases of irregular payment of cost escalation, short levy of compensation for delay in work by contractors, short levy/collection of statutory recoveries and extra payments, etc. having total financial implication of ₹12.08 crore.





## Milestones

### 1962

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

### 1963

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

### 1965

- Space Science and Technology Centre (SSTC) established in Thumba

### 1967

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

### 1968

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

### 1969

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

### 1972

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

### 1972-76

- Air-borne remote sensing experiments

### 1975

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

### 1975-76

- Satellite Instructional Television Experiment (SITE) conducted

### 1977-79

- Satellite Telecommunication Experimental Project (STEP) carried out

### 1979

- Bhaskara-I, an experimental satellite for earth observations, launched (June 7, 1979)
- First Experimental launch of SLV-3 with Rohini Technology Payload onboard (August 10, 1979). Satellite could not be placed in orbit.





### 1980

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

### 1981

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

### 1982

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

### 1983

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

### 1984

- Indo-Soviet manned space mission (April 1984)

### 1987

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

### 1988

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

### 1990

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

### 1992

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

### 1993

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





## 1994

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

## 1995

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

## 1996

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

## 1997

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

## 1998

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

## 1999

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

## 2000

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

## 2001

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

## 2002

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





## 2003

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

## 2004

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

## 2005

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

## 2006

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

## 2007

- PSLV-C7 successfully launches four satellites – India's Cartosat-2 and Space Capsule Recovery Experiment (SRE-1) as well as Indonesia's LAPAN-TUBSAT and Argentina's PEHUENSAT-1 (January 10, 2007)
- Successful recovery of SRE-1 after manoeuvring it to re-enter the earth's atmosphere and descend over the Bay of Bengal about 140 km East of Sriharikota (January 22, 2007)
- Successful launch of INSAT-4B by Ariane launch vehicle from Kourou, 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 38<sup>th</sup> 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 37<sup>th</sup> 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 42<sup>nd</sup> 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 fore-runner in the series of advanced communication satellites with multi-spot beam antenna coverage over Indian mainland and Islands. GSAT-11 will play a vital role in providing broadband services across the country. It will also provide a platform to demonstrate new generation applications.
- GSLV-F11 successfully launched GSAT-7A, ISRO's 39th communication satellite, on December 19, 2018 from the Second Launch Pad (SLP) of Satish Dhawan Space Centre SHAR, Sriharikota. GSAT-7A with a lift-off mass of 2250 kg, is a geostationary satellite carrying communication transponders in Ku-band. The Satellite is built to provide communication capability to the users over the Indian region.

## 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.
- 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.

## 2020

- On January 17, 2020, GSAT-30 was successfully launched from Kourou, French Guiana onboard Arianespace Ariane-5 VA-251 rocket.
- EOS-01 and nine customer satellites were successfully launched by PSLV-C49 on November 07, 2020 from Sriharikota.
- PSLV-C50 successfully launched CMS-01 on December 17, 2020 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
Aoi	Area of Interest
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
CMS	Communication & Data Relay Satellite
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
EOS	Earth Observation Satellite
ESA	European Space Agency
ESIC	Employees State Insurance Corporation
EUMETSAT	European Organisation for Exploitation of Meteorological Satellites
FCC	False Colour Composite
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
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	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
INSPACe	Indian National Space Promotion and Authorization Center
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
LCS	Lagrangian Coherent Structures
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
NDVI	Normalised Difference Vegetation Index
NEC	North Eastern Council
NEE	Net Ecosystem Carbon Exchange
NER	North Eastern Region
NE-SAC	North Eastern-Space Applications Centre
NGOs	Non-Government Organisations
NGPE	Non-Government Private Entity
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
SCORPIO	Satellite Based Cyclone Observation for Real-time Prediction over Indian Ocean
SDSC	Satish Dhawan Space Centre
SIS	Signal-In-Space
SITs	Satellite Interactive Terminals
SPADEX	Space Docking Experiment
SPPU	Savitribai Phule Pune University
SPROB	Solid Propellant Space Booster Plant
SPS	Standard Positioning Service
SSC	Swedish Space Centre





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



