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Advancements in Earth Observation Satellites: A Case Study of ISRO's Missions

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Abstract

Earth observation satellites are an essential tool for monitoring and understanding the Earth's environment, weather patterns, and natural resources. The Indian Space Research Organisation (ISRO) has launched several earth observation satellites over the years, contributing significantly to this field. ISRO's earth observation satellites include the Resourcesat series, Oceansat, Cartosat, and ScatSat. These satellites are equipped with various sensors and instruments, such as multispectral cameras, microwave radiometers, and scatterometers, which provide high-resolution images and data of the Earth's surface. The Resourcesat series, launched in 2003, 2007, and 2011, are dedicated to resource monitoring and management. They provide high-resolution images of the Earth's surface, which are used for agricultural crop monitoring, soil moisture estimation, and natural resource management. Oceansat, launched in 2009, is designed to study the ocean-atmosphere interaction and the marine ecosystem. It provides data on sea surface temperature, ocean color, and wind speed, which are essential for weather forecasting, climate studies, and marine resource management. Cartosat, launched in 2005, 2007, 2011, and 2018, is a series of high-resolution imaging satellites. They provide high- resolution images of the Earth's surface, which are used for cartographic applications, urban planning, and infrastructure development. ScatSat, launched in 2016, is a scatterometer satellite that provides data on wind speed and direction over the ocean. It is used for weather forecasting, cyclone tracking, and oceanographic studies. ISRO's earth observation satellites have significantly contributed to the field of earth observation and remote sensing. They have provided valuable data and images for various applications, including weather forecasting, climate studies, natural resource management, and urban planning. The success of ISRO's earth observation satellites has established India as a significant player in the global space industry.

Keywords: Earth observation satellites, ISRO, Resourcesat, Oceansat, Cartosat, ScatSat, remote sensing, weather forecasting, climate studies, natural resource management, urban planning.

INTRODUCTION

The Indian Space Research Organization (ISRO), India's premier agency, has been a significant contributor to the global space industry, having a particular emphasis on Earth Observation Satellites (EOS) over the past five-year span. ISRO has been at the forefront of space technology, launching several EOS missions that have significantly advanced Earth observation capabilities, fostered scientific research, and served global communities through space-based solutions. These Earth Observation Satellites have been designed to monitor various aspects of the Earth's physical, chemical, and biological systems, with applications in cartography, oceanography, meteorology, natural resource management, space science, rural and

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urban management, forest cover and bio resources, weather monitoring and forecasting, river banks erosion and fresh water mapping, climate impact on biodiversity and wildlife and its migration pattern, monitoring and forecasting natural disasters, town/city planning, crop estimation, and disease detection, monitoring of fish shoals for fisheries, and mineralogy mapping.

Introduction to Earth Observation Satellites

Earth Observation Satellites, also known as Earth remote sensing satellites or Radar Imaging Satellites (RISAT), play a pivotal role in monitoring and understanding our planet from space. These satellites are instrumental in a wide array of applications, ranging from environmental monitoring and meteorology to cartography and disaster response. By harnessing advanced technology, Earth Observation Satellites provide crucial data on various aspects of our planet, including ocean salinity, crop health, and air quality.

Understanding the Types of Earth Observation Satellites

Earth Observation Satellites can be categorized into two main types based on how they capture imagery: passive and active satellites. Passive satellites detect radiation reflected from the Earth's surface, while active satellites transmit energy towards Earth and measure the returned signal. This distinction allows for a comprehensive view of the Earth's surface, with active satellites being able to penetrate cloud cover for uninterrupted data collection.

Data Collection Methods of Earth Observation Satellites

Earth Observation Satellites operate on diverse orbits, offering different perspectives of the Earth's surface. While these satellites do not continuously collect data due to power and memory constraints, they provide valuable insights into various environmental parameters. Data collected by these satellites is stored onboard until it can be transmitted to ground stations for further analysis. The availability of this data can vary from minutes to months, depending on the satellite's capabilities and operational protocols.

ISRO's Contribution to Earth Observation Satellites

The Indian Space Research Organisation (ISRO) has been at the forefront of Earth observation satellite technology, with a significant number of operational satellites in both sun-synchronous and geostationary orbits. These satellites play a crucial role in applications such as agriculture, water resource management, urban planning, disaster response, and more. ISRO's commitment to leveraging satellite technology for societal benefit underscores the importance of Earth Observation Satellites in addressing global challenges.

India's Satellite Fleet Overview

India boasts a robust satellite fleet, with a total of 53 operational satellites. Among these, 21 are dedicated to Earth observation, 21 serve communication purposes, eight are navigation satellites, and three are dedicated to scientific research. This comprehensive satellite network highlights India's commitment to leveraging space technology for a wide range of applications, from communication and navigation to environmental monitoring and disaster management.

LITERATURE REVIEW

The ISRO has launched several EOS missions, including EOS-07, EOS-06, EOS-04, EOS-03, and EOS-01, among others, each with specific objectives, technological advancements, and impacts. For instance, EOS-07 demonstrated the capabilities of the SSLV in Low Earth Orbit (LEO), while EOS-06 strengthened India’s remote sensing capabilities and contributed to disaster management, agriculture, and environmental monitoring. EOS-04 enhanced India’s geospatial data availability, supporting disaster response and resource management [1, 2]. EOS-03 laid the groundwork for future geosynchronous missions and gathered valuable data on Earth's surface and atmosphere. EOS-01 strengthened India’s emergency responses dealing with natural disasters.

In addition to these missions, ISRO also launched RISAT2BR1, CARTOSAT-3, and RISAT-2B, which exemplify ISRO's commitment to advancing Earth Observation technology, serving both civilian and military needs, and contributing to global scientific research. For example, RISAT2BR1 enhanced

India's observational capabilities and provided multi-spectral detailed images of Earth's surface in 2D/3D, assisting in surveillance and counter-terrorism efforts. CARTOSAT-3 provided very high-resolution imagery for cartographic applications, supporting urban planning, rural resource management, and disaster relief. RISAT-2B succeeded the older RISAT-2 spacecraft, providing military surveillance and civilian applications through X-band radar imagers for day/night, all-weather imaging.

This paper aims to study the advancements made by ISRO in the field of Earth Observation Satellites over the past five years and their implications. By examining the objectives, technological advancements, and impacts of these EOS missions, we can better understand the role of ISRO in advancing Earth Observation technology, fostering scientific research, and serving global communities through space-based solutions. This paper will provide a comprehensive overview of ISRO's contributions to Earth Observation technology and its applications, highlighting the significance of these advancements for the global space industry and the potential for future research and development.

EOS-07 MISSION

The EOS-07 [10] mission is a collaboration between ISRO and Singapore's ST Electronics (Satellite Systems) to launch the TeLEOS-2 satellite and can provide data at 1.m resolution. The mission is to monitor volcanic activity, track the impact of groundwater use, measure ice sheet melting, and track changes in vegetation around the world. The launch vehicle is ISRO's PSLV-CA with a mass of 120 tonnes and a height of 34 m. PSLV-CA has successfully launched 15 times without any problems.

The SSLV-D2 configuration includes three drive stages and a fast terminal module. EOS-07 (Figure-1) is a 156.3 kg satellite designed, built and operated by ISRO with new experimental features such as millimeter wave moisture detector and spectrum tracking payload. US-based ANTARIS's 10.2 kg satellite Janus-1 and the 8.7 kg AzaadiSAT-2 satellite built by 750 students across India are also part of this mission. SSLV-D2 is designed to launch satellites into a 450-kilometer orbit in 15 minutes. SSLV can launch satellites weighing up to 500 kilograms to low Earth on a "launch-on-demand" basis, providing low-cost space access with minimal requirements.

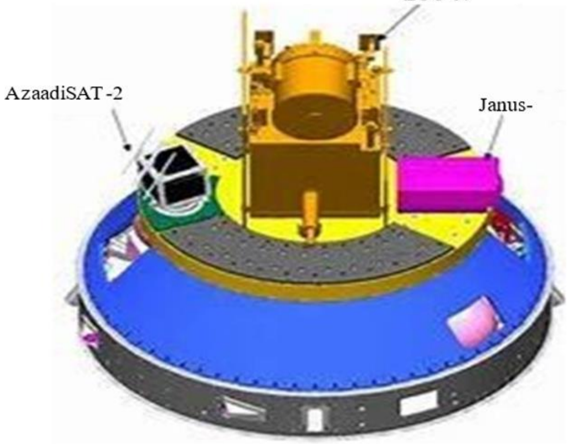

Figure 1. Placement of different components such as AzaadiSAT-2, EOS-07, and Janus within the SSLV-D2/EOS-07 Mission [10].

SSLV-D2 mission was successfully launched on 10 February 2023 at 09:18 from SDSC SHAR, Sriharikota. The structure is connected by upper and lower decks, 4-stage transverse beams and 4 closed vertical decks. The modules include a star sensor (mSS), a 4-day sensor (4 SS), a micro-inertial reference unit (mIRU), and a magnetometer. It features a non-volatile electronic system that includes optical components, multilayer technology, thermal interface materials, and more.

The altitude and orbit control system (AOCS) accuracy is ±0.1° (3°) and drift speed is ±7.5e-4°/s. It is equipped with a solar panel that can be used using Frangi bolt actuators to generate electricity. The panels produce 357 watts of electricity. It also comes with a lithium-ion battery with a capacity of 27.2 Ah. The onboard computer has a MIL STD 1553B protocol for interfacing with other subsystems. Data storage capacity is 32 GB. The RF system uses an S-band telemetry transmitter, an S-band remote control receiver, and a 12-channel SPS. It has accurate location within 15m, accuracy of 0.15m/s and X- band data transmission. MHS has 6 water vapor detectors rated at 50 rpm, weighing 26 kg and requiring 55 watts of power. SMP weighs 13 kilograms, requires 35W of power and has a data rate of 2Mbit/s.

EOS-06 MISSION

Oceansat-3 (Figure-2), also known as EOS-6 [9] (Earth Observation Satellite 6), is the third and latest satellite in the Oceansat series of the Indian Space Research Organization (ISRO). The satellite is a multi-role mission designed to provide ongoing service to Oceansat-2 data users and enhance existing capabilities in oceanography. Oceansat-3 data can be used for ocean colour, biology, climate and temperature. Oceansat-3 also carries the ARGOS-4 data collection as part of a collaboration with the French National Space Agency (CNES).

Oceansat-3 has four main goals: To provide continuous ocean color and wind vector data, to improve existing Oceansat products, to provide new Oceansat ocean data limit surface, and to develop and provide processes and data products to operate on big data. Also known as Advanced Data Acquisition System (ADCS-4). OSCAT-3 is a radar scatterometer designed to measure wind speed and sea level vectors; OCM-3 is a 13-channel medium-resolution spectroradiometer designed to collect ocean color data. SSTM is a multi-mode VIS/IR (visible/infrared) radio to be used in conjunction with the OCM-3 to identify potential fishing areas [11]. The width is 1440 km. As a radar scatterometer, it operates in the Ku band at a frequency of 13.515 GHz. The spatial resolution of OCM-3 is 360 m and the maximum grid area width is 1400 km.

OSCAT-3 operates in the visible (VIS) and near infrared (NIR) bands, in the wavelength range of 0.4 Âµm to 1.3 Âµm. The SSTM image is divided into two bands with a resolution of 1080 m and a field width of 1440 km. It can withstand seawater temperatures as low as 0.15 K (0.15 Â°C / 0.27 Â°F) and average temperatures up to 300 K (27 Â°C / 80 Â°F). Operating in a sun-synchronous orbit with an inclination of 98.28Â°, an orbital period of 99.31 minutes, and a falling node local solar time (LST) of 1200, Oceanat-3 used IRS- from previous ISRO missions such as IRS-1A. and -1B 1 (Indian Remote Sensing Satellite-1) bus. The bus weighs 1117 kg and is equipped with star sensors, ground sensors and gyroscopes for position measurement, as well as various systems for attitude control. Oceansat-3 is also equipped with the French National Science Center's (CNES) ARGOS-4 data acquisition system, also known as the Advanced Data Acquisition System (ADCS-4). ARGOS-4 receives and transmits data from remote sensing stations, or transponders, in the ocean and on land. It operates at 401.65 MHz, with a bandwidth of 110 kHz and data rates ranging from 400 to 4800 bits per second. Shown are busbars from previous ISRO missions like IRS-1C and -1D.

Oceansat-3 weighs 1,117 kg. Its structure consists of a main platform and a service platform using an aluminum honeycomb structure. The bus uses star sensors, ground sensors and gyroscopes for position sensing and is equipped with four wheels, two magnetic torques, 16 single-Newton hydrazine thrusters and one 11-Newton thruster for driving. It has a roll and pitch accuracy of Â±0.15Â°, a yaw accuracy of Â±0.2Â°, and a drift rate of 3.6 x 10-4Â°/s. The bus is also equipped with two 9.6-square-foot solar tracking solar panels providing 813 watts of power and two nickel-cadmium batteries with a capacity of 21 amp hours.

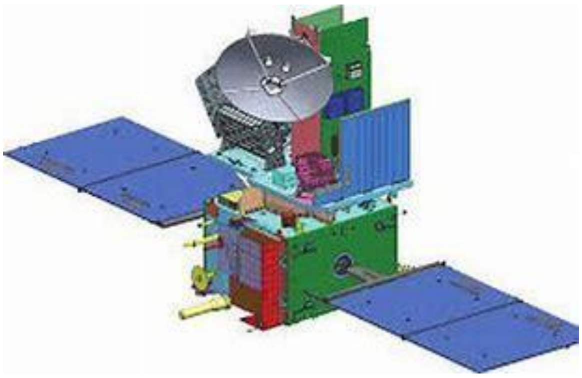

Figure 2. Oceansat 3, 3A (EOS 06) [9].

EOS-04 MISSION

EOS-04 [7] or Earth Observation Satellite-04 (previously known as RISAT-1A) is a radar imaging satellite of the Indian Space Research Organization designed to serve agriculture, forestry and plantation, soil and agriculture in various climates. Photograph as shown in Figure 3. The satellite built by ISRO is the sixth satellite in the RISAT satellite series.

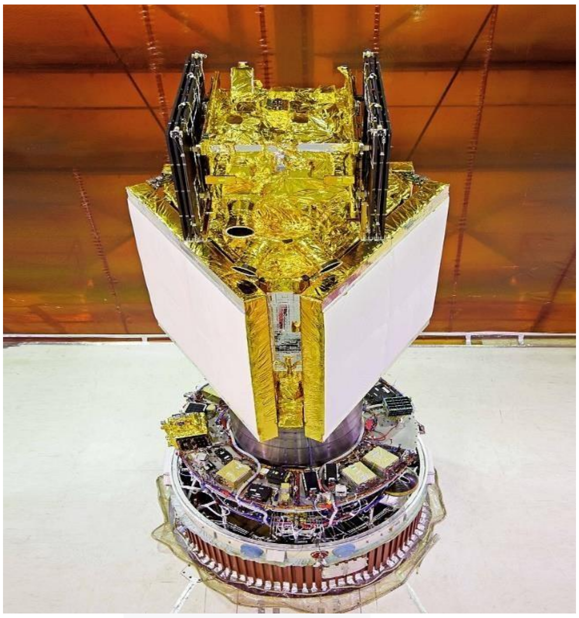

Figure 3. EOS-04 Satellite [7].

RISAT-1 is a device, RISAT-SAR, C-band High Resolution Radar Imager. RISAT-SAR monitors a variety of metrics related to vegetation, agriculture, forestry, soil moisture, geology, coastal and ocean monitoring, crop identification and flood monitoring. These goals are achieved through five types of studies: HRS (High Resolution Spotlight), FRS-1 (Fine Resolution Lane Map-1), FRS-2(Fine Resolution Lane Map-2), MRS (Medium Resolution ScanSAR), CRS (Coarse Resolution ScanSAR) and co-polarization and cross-polarization imaging.

The same RISAT-SAR instrument is also carried by RISAT-1A, also known as EOS-04 (Earth Observation Satellite 04), developed by ISRO, launched in February 2022. The frequency is 5.35 GHz and the field of view is 659 km. in all operating modes. The image models differ in resolution and width, with the same single and dual polarization capabilities, except for the FRS-2, which has four polarization capabilities. The resolution of the mode varies from 1 to 50 m and the lane width from 10 to 240 km. RISAT-SAR uses external observation equipment and can operate on both left and right. Its distance from the lowest point is 20° to 49°, and its angle of incidence is 12° to 55°.

In sun-synchronous orbit between 06:00 and 18:00 LTAN (ascending node local time). 4 years 11 months. This bus connects to eight 11N based AOCS (including 4 Sun Sensors, Magnetometer, IRU (Inertial Reference Unit), Star Sensor, Ground Sensor, DSS (Digital Solar Sensor) and SPSS (solar panel sun sensor). Attention and Adjustment System). inclined thrusters, a central 11N thruster and 4 field wheels. This results in an accuracy of 0.05°, a drift rate of 5.0 x 10-5°/s, and an attitude recognition of 0.02°.

EOS-03 MISSION

The EOS-03 [8] satellite mission is a major effort by the Indian Space Research Organization (ISRO) to develop a state-of-the-art agile Earth observation satellite into Geostationary Transfer Orbit (GTO) using the GSLV-F10 rocket. The mission is designed to provide close-up images of many countries and the ability to image the entire country four to five times per day. The satellite is part of a new generation of global observation satellites designed to assist in many areas such as agriculture, forest water, forestry and disaster warning. It is equipped with a large telescope that views the Indian subcontinent from a geostationary orbit more than 22,000 miles (36,000 kilometers) away. The satellite's Earth imaging telescope will take images of the entire Indian subcontinent every half hour and will have the ability to image a small area every five minutes. The satellite camera will be able to resolve features as small as 138 feet (42 meters) at the highest resolution. EOS-03's imaging system will capture images in the visible, near-infrared and shortwave infrared bandwidths to provide information on the growth and health of crops and forests, changes in water bodies, ice and snow cover, mineralogy and the evolution.

The launch of EOS-03 (Figure-4) was originally planned for August 12, 2021 but fell through due to a number of uncertainties. The GSLV-F10 rocket carrying the satellite malfunctioned five minutes after takeoff. Due to the anomaly, the upper cryogenic voltage does not occur and the mission cannot be completed as expected. The launch of GSLV-F10 on 12 August 2021 at 0543 IST went as planned with first and second phase operations. However, due to the anomaly, the upper cryogenic voltage does not occur, causing the mission to fail as expected.

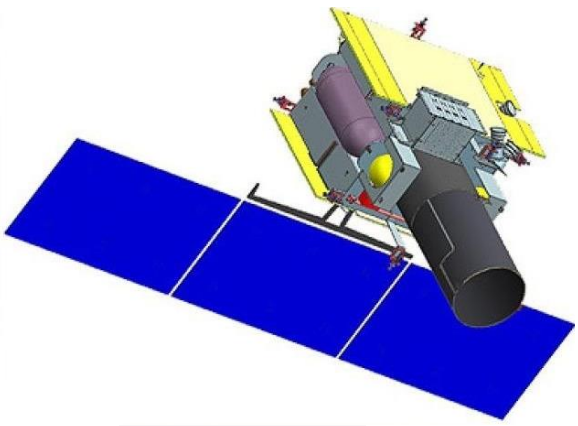

Figure 4. EOS-03 Satellite [8].

ISRO has several earth observation satellites in orbit and this is only the second satellite of ISRO to use the new terminology since November last year. The launch of EOS-03 is aimed at ending the stagnation in India's aerospace industry caused by the COVID-19 pandemic, with ISRO planning a launch within the coming months. At least four more deployments, including two global probes, are expected by the end of the year. The new launches will be tested in September and October this year using new rockets such as SSLV, so-called small satellite launch vehicles.

EOS-01 MISSION

The main device of the EOS-01 [6] is the X-band synthetic aperture radar (SAR), which can detect all weather conditions day and night. The X-band transmitter produces regular radio waves and the mobile receiver is a 3.6 m mesh antenna with a radial rib reflector. This information is used to support organizations working in the fields of agriculture, forestry and disaster management. Resolution imaging is always fixed beam scanning. While this orbital challenge is limited in international scope, it does make a return visit to Indian territory and nearby Pakistan for 90 minutes. RISAT-2B and RISAT-2BR1 are also in orbit, with each satellite spaced evenly 120° apart. The structure of the satellite BUS is similar to its predecessor RISAT-2, but it is slightly larger, weighing 628 kg. The busbar has a hexagonal structure and is equipped with an independent payload module. All satellites use 2 kW of power at peak operation, forest and disaster management.

It is part of India's RISAT series SAR imaging spacecraft and the RISAT-2B with 120° phase will be the third satellite in the series like RISAT-2BR1. EOS-01 (Figure-5) is an X-band SAR satellite with a weight of 628 kg and a design life of 5 years. It is part of ISRO's RISAT series of SAR satellites and was initially named RISAT-2BR2 but has been renamed EOS-1 under the new name. ISRO did not make a statement about the EOS-01 spacecraft and its cargo. On 7 November 2020 (09:11 UTC), ISRO launched the EOS-49 satellite on board the PSLV-C01 vehicle, marking the 9th worldwide since the first launch of SHAR at the Satish Dhawan Space Center (SDSC) in Sriharikota, India. customer satellites After this, nine commercial satellites were placed into orbit. Following separation, EOS-01's two solar arrays were deployed and ISRO's telemetry monitoring and command network in Bengaluru took control of the satellite. In the coming days, the satellite will enter its final operational configuration. Flat, altitude 575 km, slope 37°. The 37-degree inclined orbit chosen by the EOS-01 satellite does not provide global radar tracking, but it can regularly pass over Indian territory and neighboring Pakistan, India's long-term rival in the region.

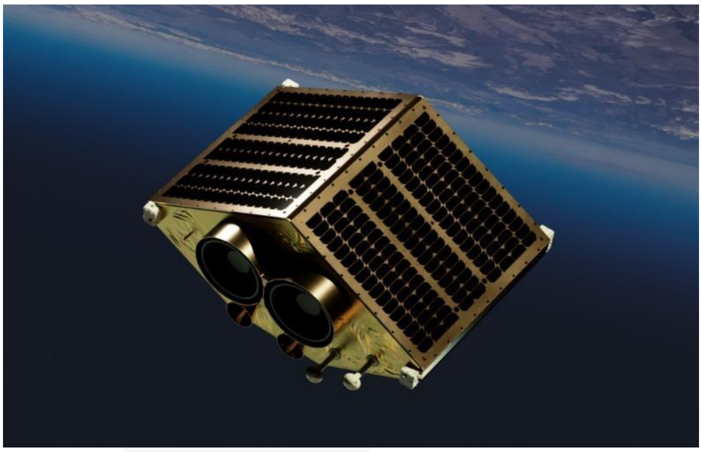

Figure 5. EOS-01 Satellite [6].

Nine customer satellites from Lithuania (1), Luxembourg (4) and the United States (4) were built under a commercial agreement with NewSpace India Limited (NSIL). R2 CubeSat (M6P 2, LacunaSat 2) is a demonstration system from Lithuanian NanoAvionics. M6P is a 6U CubeSat project developed by Lithuanian NanoAvionics as a mission finder for the M6P CubeSat platform. During operation, NanoAvionics will test the 6U (called M6P - Multi-Purpose 6U Platform) platform, which is based on the design and integration that allows packaging to be possible. Satellite plans to build a constellation of small satellites to monitor radio broadcasts around the world. The first four satellites were named Kleos research mission (KSM 1A, KSM 1B, KSM 1C, KSM 1D). Kleos Space S.A. is a radio frequency data as a service (DaaS) provider. 2) Kleos said its satellites will provide intelligence on ocean operations to governments and commercial customers by capturing radio frequency broadcasts and determining their geolocation. RF tracking data is particularly important for tracking ships that cannot be tracked using automatic markers or satellite imagery, Krios said. Kleos will launch and operate a constellation of up to 20 satellites to provide critical services for monitoring global events and critical locations. After the deployment is completed, the debugging phase begins. The team successfully established contact with all 4 satellites.

It has been confirmed that they are back to normal, the battery is as expected and the onboard monitors are working. KleosSpace S.A.-26, rue des Gaulois -L-1618 Luxembourg1 / 4MEDIA RELEASE The Kleos Space Exploration Mission satellite was successfully launched into a 37-degree inclined orbit3). Service provider with offices in the UK, USA and Australia. Kleos aims to protect borders, protect assets and save lives by providing intelligence and geolocation services on a global basis. The Kleos constellation will increase to up to 20 groups in order to improve and develop the products that Kleos can offer to its customers. Four Lemur-2 CubeSats were also built by San Francisco-based Spire Global, which operates small commercial satellites that monitor transportation and collect weather-data.

RISAT-2BR1 MISSION

The charge of the RISAT- 2BR1 (Figure-6) satellite is a major force of the Indian Space Research Organization (ISRO) working in the fields of husbandry, forestry and disaster operation. The charge is part of the RISAT series of SAR imaging satellites, of which RISAT- 2BR1 is the fourth satellite. It was launched on December 11, 2019, aboard the Polar Satellite Launch Vehicle (PSLV- C48) from the first launch pad at the Satish Dhawan Space Centre.

Figure 6. RISAT-2BR1 with its "Radial Rib Antenna" in deployed configuration [3].

The satellite has a mass of 628 kg and is equipped with an X-band SAR with a deployable radial caricature glass antenna with a periphery of3.6 measures. With a content range of 5 to 10 kilometers, it can operate in different modes, including an ultra-high resolution imaging mode with a resolution of 1 x0.5 cadence and 0.5 x0.3 cadence. Nine satellites importing 157.6 kilograms were launched together with the common marketable satellite trip. QPS-SAR 1, 1HOPSat TD, Pathfinder Risk Reduction, Lemur-2 108 to 111, Duchifat 3, and NANOVA are some of these satellites.

The satellite was separated from the PSLV fourth stage and fitted into a 576- kilometer route with an inclination of 37.0°. It packed its solar panels at 3- nanosecond intervals and its3.6- cadence antenna at 0830 UTC on December 12, 2019, and its main purpose is to use all- rainfall, day and night SAR monitoring capabilities for areas similar as husbandry. forestry, soil, geology, abysses, littoral surveillance, force and flood tide monitoring, as well as military surveillance.

The satellite's radar system is reportedly a prototype of Israel's TECSAR 1 system and has a continuance of over to five times. RISAT- 2BR1 was launched into a 536- kilometer sun-coetaneous route, passing the same point on the Earth's face at the same original sun time each day. Capabilities of Advanced Earth Observation Satellites. The satellite's X-band SAR device and capability to operate in a variety of modes make it useful in numerous operations, from husbandry and forestry to disaster operation and military surveillance.

CARTOSAT-3 MISSION

The Indian Space Research Organisation (ISRO) has developed Cartosat-3 [4], an upgraded Earth observation satellite that will replace the Indian Remote Sensing Satellite (IRS) series. With a high-quality resolution of 1 meter and a panchromatic resolution of 0.25 meters, it is one of the imaging satellites with the best resolution in the world at the time of launch. Compared to the earlier payloads in the Cartosat series, this is a major advance. Weather mapping, defense or cartography, and strategic applications are among the possible uses.

The resolution of Cartosat-3 (Figure-7) is 25 cm (10"). Compared to Cartosat-2, it employs 1.2 m optics with 60% weight removal. The utilization of acousto optical devices, wide area, low weight mirrors, MEMs for in-orbit focusing, adaptive optics, and sophisticated sensing with high quality resolution are further features. Its five-year mission life is scheduled. Cartosat-3's approved cost is ₹351.16 crore, or US$44 million. With a spectral bandwidth of 0.45 - 0.9 μm, it can record panchromatic and multispectral images encompassing visible blue (0.45 - 0.52 μm), visible green (0.52 - 0.59 μm), visible red (0.62 - 0.68 μm), and near infrared (0.77 - 0.86 μm). The third generation of ISRO's high-resolution imaging satellites is called Cartosat-3. It was created in response to the growing need for imaging services to meet the demands of infrastructure development, rural resource management, and urban planning.

Figure 7. Render of Cartosat-3 satellite [4].

Using the XL version of the Polar Satellite Launch Vehicle, PSLV-C47 carrying Cartosat-3 was launched on November 27, 2019, at 03:58 UTC from the Second Launch Pad (SLP) at the Satish Dhawan Space Centre into a 450-kilometer Sun-synchronous orbit. Using the same launch vehicle, thirteen commercial ride-sharing 3U Cubesats were also launched into orbit: twelve Super Doves (Flock-4p) by Planet Labs and one Meshbed by Analytical Space of the United States. Spaceflight Industries, ISI Launch, and NewSpace India Limited partnered for commercial ride-sharing.

Furthermore, the satellite makes a substantial contribution to India's security infrastructure with its topographical and geographical data as well as its detailed mapping capabilities. Cartosat-3 assists land resource management, urban planning, coastal research, and numerous surveys vital for national security and defense planning by offering comprehensive maps and detailed spatial information. Essentially, because Cartosat-3 can supply high-resolution imagery for strategic analysis, sensitive area monitoring, and defense-related decision-making, it plays a critical role in augmenting India's national security and surveillance capabilities. India's surveillance capabilities are enhanced by the satellite's cutting-edge imaging technology, which also makes it possible to make more strategic decisions and be more prepared and responsive in the area of national security.

Risat-2B Mission

The Indian Space Research Organization (ISRO) created the powerful radar imaging satellite RISAT-2B as a member of the RISAT family of earth observation spacecraft. India's capabilities in remote sensing have advanced significantly with the launch of RISAT-2B [5] on May 22, 2019, especially in the area of day and night, all-weather imaging.

RISAT-2B (Figure-8) differs from other optical imaging satellites in that its main payload is a sophisticated X-band Synthetic Aperture Radar (SAR) equipment. Regardless of the weather or the time of day, the SAR system can produce high-resolution photos of the Earth's surface. One important aspect that increases the satellite's usefulness for a variety of applications is its capacity to image in any weather conditions, day or night.

Figure 8. RISAT-2B Satellite [5].

The ability of the SAR instrument on RISAT-2B to function in many imaging modes, such as the Very High Resolution (VHR) mode, which may attain a resolution of up to 0.5 x 0.3 meters, is one of its primary features. The satellite is useful for applications including infrastructure monitoring, urban planning, and defense-related activities because of its level of detail, which enables the accurate identification and monitoring of small-scale structures on the ground. RISAT-2B, weighing 615 kg, is intended to function in a sun-synchronous orbit at a height of 557 kilometers with a 37-degree inclination. The satellite's orbital arrangement facilitates many revisits of the same area of interest, thereby supplying an uninterrupted flow of data for diverse applications.

As the 71st flight of the Polar Satellite Launch Vehicle (PSLV) and the 36th flight of the PSLV-QL configuration (with four strap-on motors), the launch of RISAT-2B represented a major milestone for ISRO. The satellite's successful launch and deployment proved ISRO's prowess in creating and launching cutting-edge earth observation satellites. The RISAT-2B mission's support for India's endeavors in forestry, agriculture, and disaster management is one of its main goals. High-resolution SAR imagery from the satellite can be used to track deforestation, evaluate crop health, and help detect and respond to natural disasters like earthquakes, landslides, and floods.

RISAT-2B includes military surveillance capabilities in addition to its civilian uses, which are essential for India's national security. The satellite is a useful tool for monitoring border regions and identifying possible threats because of its all-weather, day-and-night imaging capabilities. As of right now, the RISAT-2B satellite has been in operation for more than 4 years, exceeding its intended 5-year lifespan. During that time, it has provided an abundance of data and imagery that have been used by a variety of government agencies, academic institutions, and commercial enterprises to address a wide range of opportunities and challenges.

FINDINGS

Many Earth Observation Satellite (EOS) missions have been launched by the Indian Space Research Organization (ISRO), each with distinct goals and cutting-edge technology. EOS-07, EOS-06, EOS-04, EOS-03, EOS-01, RISAT-2B, RISAT-2BR1, and Cartosat-3 are some of these missions.

Launched in 2023 and 2022, respectively, the EOS-07 and EOS-06 missions signify the most recent iteration of ISRO's earth observation satellites. These satellites can monitor land, ocean, and atmospheric conditions in great detail since they are fitted with high-resolution optical and multispectral sensors. A wide range of applications, including forestry, urban planning, disaster management, and agriculture, are anticipated to be supported by the data from these missions.

Prior to these most recent launches, ISRO had the EOS-04 and EOS-03 satellites successfully deployed in 2022 and 2021. While EOS-03 is a high-resolution optical imaging satellite intended for uses such as land and water resource management, EOS-04 is a radar imaging satellite capable of capturing images day or night and in all weather conditions.

Part of ISRO's RISAT family of Synthetic Aperture Radar (SAR) imaging satellites, the EOS-01 satellite was launched in 2020. High-resolution radar imaging can be obtained by EOS-01, formerly known as RISAT-2BR2, for a range of uses, such as forestry, disaster relief, and agriculture.

India's radar imaging capabilities have been enhanced by the 2019 launch of the RISAT-2B and RISAT- 2BR1 satellites. These satellites can take precise, all-weather photos of the Earth's surface because they are outfitted with cutting-edge X-band SAR equipment. Special recognition has been given to the RISAT-2BR1, which has improved India's national security and surveillance capabilities by supplying military-grade imagery.

To enhance the capabilities of these radar imaging satellites, ISRO has launched the Cartosat-3 satellite, a noteworthy development in high-resolution optical imaging. Launched in 2019, Cartosat-3 is one of the world's highest-resolution earth observation satellites, capable of capturing photos with a resolution as high as 0.25 meters. Applications like infrastructure monitoring, urban planning, and defense-related tasks require this degree of information.

DISCUSSIONS

Through its wide range of EOS missions, ISRO has made important contributions to the fields of earth observation and space research, as evidenced by the search results. These missions have used a range of technologies to support a wide range of applications, such as sophisticated radar imaging systems and high-resolution optical and multispectral sensors.

ISRO's dedication to using space technology for the benefit of society and the country is demonstrated by the diverse goals of the EOS missions, which cover everything from disaster relief and national security to forestry and agriculture. India's capacity to monitor crops, track deforestation, and respond to disasters has improved because to these satellites' ability to gather precise, all-weather imagery, which has aided in the nation's sustainable development.

Furthermore, the fact that satellites like RISAT-2BR1 have military-grade imaging capabilities shows how hard ISRO is working to improve India's surveillance and security capabilities. This technical breakthrough could reduce India's need on foreign partners for vital information needed for defence-related activities.

The recent EOS-07 and EOS-06 satellite launches, and successful missions' operation demonstrate ISRO's expanding proficiency and capability in earth observation. These accomplishments not only advance science and technology in India but also establish the nation as a major force in the international space industry, one that can cooperate and share its knowledge with other nations.

CONCLUSION

In conclusion, India's expanding space technology capabilities have been firmly established by ISRO's varied range of Earth Observation Satellite (EOS) missions launched over the past five years. In addition to pushing the limits of imaging and radar technologies, these missions—which include cutting- edge spacecraft like RISAT-2BR1, Cartosat-3, and the most recent EOS-07 and EOS-06—have also shown that ISRO can create and deploying satellites that serve a broad range of purposes. Beyond just advancing science, these EOS missions have a direct positive social impact by enhancing national security, resource planning, and catastrophe management. India is now positioned to be a major player in the international space industry, with the ability to cooperate and share its expertise for the benefit of humankind as a result of its outstanding success.

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