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SIGNIFICANCE OF SATELLITE TECHNOLOGY IN AGRICULTURE, WEATHER FORECASTING AND ALLIED SUBJECTS

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Over the years, satellites have become essential tools, supporting a wide range of activities such as broadcasting, navigation, and the remote sensing of Earth. They fulfil various purposes, often categorized by their specific functions. Satellites orbit Earth in different ways, each orbit possessing unique characteristics suited for different missions. Regardless of their intended use, all satellite types contribute to expanding our understanding of Earth, bridging global communication gaps, aiding in disaster management, and advancing technological frontiers for humanity. An artificial satellite refers to any human-made object that has been launched into orbit using rockets. These spacecrafts are equipped with sensitive instruments and cameras designed for studying Earth, other planets, facilitating communication, and even observing distant parts of the universe. Their vantage point from space allows them to gather data more rapidly compared to ground-based sensors, thanks to their wide field of view and enhanced spatial resolution. Unlike observatories on Earth, satellites face no hindrance from atmospheric conditions like clouds and dust. Each spacecraft is deployed for specific tasks such as communication, scientific exploration, weather forecasting, or environmental monitoring. The purpose of a satellite dictates its size, orbit type, and overall design. Despite the variety of artificial satellites and their orbits, all operate within the confines of established physical laws and mathematical principles once deployed in space.

Types of Satellite According to Orbits

Typically, satellites are initially placed into specific orbits around Earth upon launch, although some may embark on journeys beyond Earth's orbit, navigating around the Sun until they reach their final destination.

Satellites are commonly categorized by their orbital altitude, which directly impacts their coverage and orbital speed around Earth. Developers selecting an orbit type must consider the satellite's intended mission, data acquisition capabilities, service provision, as well as cost, coverage area, and feasibility of different orbital configurations. The five primary types of satellite orbits are as follows:

1. Low Earth Orbit (LEO)
2. Medium Earth Orbit (MEO)
3. Geostationary Orbit (GEO)
4. Sun-synchronous Orbit (SSO)
5. Geostationary Transfer Orbit (GTO)

1. Low Earth Orbit (LEO) Satellites

Low Earth Orbit (LEO) satellites orbit at altitudes ranging from approximately 160 to 1,500 km above Earth's surface. They complete orbits quickly, typically every 90 to 120 minutes, allowing them to circle the planet up to 16 times daily. This orbital characteristic makes LEO satellites highly suitable for various applications such as remote sensing, high-resolution Earth observation, and scientific research, enabling rapid data acquisition and transmission.

LEO satellites can adjust their orbital plane relative to Earth's surface, offering flexibility in their path. This orbital type is widely used due to its accessibility, allowing spacecraft to cover a diverse range of trajectories. However, because they orbit closer to Earth, LEO satellites have a smaller coverage footprint compared to satellites in higher orbits. Often, clusters of LEO satellites, known as satellite constellations, are launched together to collectively cover extensive areas by coordinating their operations. EOS SAT, a prominent constellation of LEO satellites, holds significant promise for stakeholders in agriculture, including food producers, input suppliers, financial institutions, governments, and others engaged in the sector. These satellites provide essential remote sensing data crucial for enhancing sustainable practices and precision agriculture initiatives.

2. Medium Earth Orbit (MEO) Satellites

Medium Earth Orbit (MEO) satellites occupy a position between low Earth and geostationary orbits, typically situated at altitudes ranging from approximately 5,000 to 20,000 km above the Earth's surface. They are extensively utilized for positioning and navigation services such as GPS. Recently, there has been a deployment of high-throughput satellite (HTS) constellations in MEO, aimed at providing low-latency data communication services to service providers, commercial entities, and government organizations.

MEO satellites have longer orbital periods, usually between 2 and 12 hours, striking a balance between coverage area and data transmission rates. They require fewer satellites compared to those in low Earth orbit to achieve global coverage. However, MEO satellites experience longer signal delays and weaker signals compared to their counterparts in low Earth orbit.

3. Geostationary Orbit (GEO) Satellites

Satellites in geostationary Earth orbit (GEO) are positioned precisely 35,786 km above the Earth's surface, directly over the equator. Three satellites spaced evenly in GEO can offer nearly global coverage due to their expansive view of the Earth's surface.

Objects in GEO appear stationary relative to the ground because they orbit the Earth at the same rate as the Earth's rotation—23 hrs, 56 min, and 4 sec. This unique characteristic allows ground-based antennas to maintain a constant connection with GEO satellites, making them ideal for continuous communication services such as television and telecommunications. Additionally, GEO satellites are utilized in meteorology to monitor specific regions' weather patterns and track the development of local weather phenomena. Despite their advantages for continuous communication and weather monitoring, GEO satellites suffer from longer signal delays due to their considerable distance from Earth. These satellites are crucial for observing cloud patterns, which are essential for calculating wind speeds and other meteorological data.

4. Sun-Synchronous Orbit (SSO) Satellites

Sun-synchronous orbit (SSO) satellites travel from north to south across the polar regions at an altitude ranging from 600 to 800 km above Earth. Their orbital parameters are carefully adjusted so that they consistently pass over any given location at the same local solar time. This synchronized timing ensures consistent lighting conditions for imaging, making SSO satellites highly effective for earth observation and environmental monitoring purposes.

The predictable timing of their passes also makes SSO satellites valuable for change detection through current and historical image comparisons. Scientists utilize these image sequences to study the evolution of weather patterns, predict cyclones, monitor and mitigate wildfires and floods, and gather data on long-term environmental issues such as deforestation and coastal changes.However, due to their lower orbital altitude, SSO satellites have a limited coverage area per pass and require more satellites to achieve continuous global coverage.

5. Geostationary Transfer Orbit (GTO) Satellites

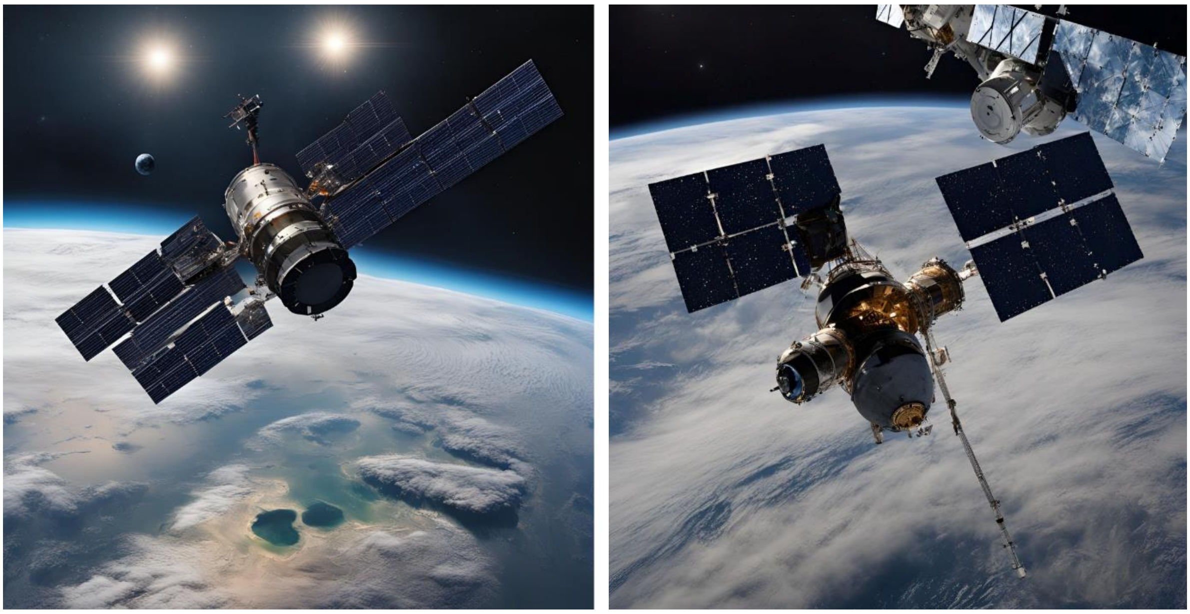
A commonly used satellite transfer orbit is the geostationary transfer orbit (GTO), which facilitates the journey from a launch vehicle's trajectory to a geostationary orbit (GEO). Satellites are typically not placed directly into their final orbits upon launch, such as those facilitated by rockets like Falcon 9. Instead, these rockets transport payloads to GTOs, which serve as intermediate stages on the path to their intended orbital positions (Davis.J,2014). From there, the satellite's engines are employed to maneuver into its designated orbit and adjust its inclination as needed. This approach enables satellites to reach geostationary orbits efficiently, conserving resources.

Less common orbit types include highly elliptical orbits (HEO), polar orbits, and Lagrange points (L-points), each chosen based on the specific objectives and missions of the spacecraft. Consequently, careful consideration should be given to selecting the appropriate satellite orbit type based on its intended applications.

Types Of Satellites Based on Their Functions

Beyond their role in communication and television services, space-based technology serves a multitude of scientific purposes. In recent years, numerous types of satellites have been deployed for diverse applications such as Earth observation, meteorological research, navigation systems, studying the impacts of space travel on living organisms, and exploring the mysteries of the universe. Currently, the primary categories of satellites based on their applications include:

1. Communication Satellites
2. Earth observation Satellites
3. Navigation Satellites
4. Astronomical Satellites



(1) **(2)**

Fig 1 & 2: Geostationary Orbit (GEO) Satellites

1. Communication Satellites

A communication satellite, often positioned in geostationary orbit (GEO) and equipped with a transponder—a device that both receives and transmits radio signals—functions by receiving signals from Earth and retransmitting them back to the planet. This capability facilitates communication between distant regions that were previously hindered by vast distances or other obstacles. Various types of communication satellites support different forms of media transmission, including radio, television, telephone, and internet services.

Communication satellites can handle multiple signals simultaneously. Satellites dedicated to broadcasting and distributing TV signals to ground-based stations typically feature individual transponders for each signal carrier. However, in many cases, multiple carriers are transmitted through a single transponder. Their compatibility with mobile terminals makes these satellites particularly effective for long-range communication needs.

2. Earth Observation Satellites

Earth observation satellites are designed to observe and monitor our planet from space, providing continuous updates on any changes detected. This technology enables consistent environmental monitoring and swift analysis of events during emergencies such as natural disasters and conflicts.

The specific objectives of an Earth observation mission dictate the choice of satellite sensors used. Data collected varies depending on the sensor type and the range of frequencies utilized. For example, the EOS SAT constellation's satellite, EOS SAT-1, is currently orbiting Earth with a mission focused on enhancing agricultural and forestry management through advanced precision technology. It is equipped with eleven spectral bands tailored to monitor various aspects of agriculture and forestry, including the detection of crop diseases and assessment of soil moisture levels.

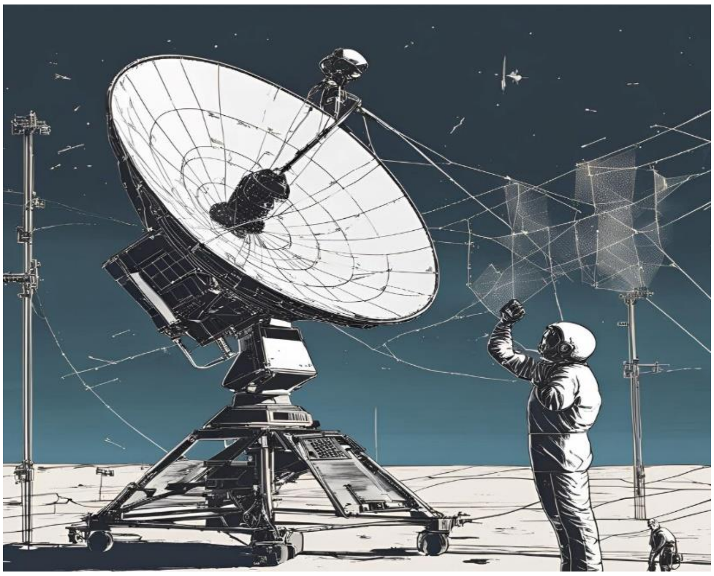


Fig. 3: Interception of data from satellite to radar

Earth Observation Spacecraft Can Be Categorized into Distinct Types

Weather satellites are utilized to monitor and forecast weather conditions, providing real-time weather data. Geostationary orbit (GEO) is particularly advantageous for weather satellites, offering a stable vantage point that allows scientists to observe cloud patterns and predict their movement accurately.

Remote sensing satellites are predominantly used for environmental monitoring and geographical mapping. These satellites operate in one of three orbits: polar orbit, non-polar low Earth orbit (LEO), or geostationary orbit (GEO). Geographical information system (GIS) satellites, a subset of remote sensing spacecraft, specialize in capturing images suitable for GIS mapping and subsequent spatial analysis.

3. Navigation Satellites

Navigation system constellations orbit between 20,000 and 37,000 km above Earth's surface. These satellites emit signals containing information about their time, position in space, and operational status. There are two main categories of space-based navigation systems:

Fig 4: Navigation satellite

Global Navigation Satellite Systems (GNSS) transmit signals that receivers worldwide use for precise geolocation, offering comprehensive global coverage. Examples include Galileo in Europe, GPS in the United States, and China's BeiDou Navigation Satellite System (EUSPA,2021). Regional Navigation Satellite Systems (RNSS) operate as independent regional navigation systems, providing coverage over specific geographic areas. For instance, India's IRNSS project aims to deliver reliable location-based services to Indian users (www.isro.gov.in)

- **Indian Regional Navigation Satellite System (IRNSS) : NavIC**

IRNSS is an autonomous regional navigation satellite system developed by India. Its primary objective is to deliver precise positioning services to users within India and a surrounding region extending up to 1500 km beyond its borders. Additionally, it offers an Extended Service Area that stretches between the primary service area and an area defined by

Latitude 30 degrees South to 50 degrees North and Longitude 30 degrees East to 130 degrees East.

IRNSS offers two types of services: Standard Positioning Service (SPS), available to all users, and Restricted Service (RS), an encrypted service accessible exclusively to authorized users. The system aims to achieve a position accuracy better than 20 meters within its primary service area.

Some Important Applications of IRNSS Are as Follows

1. **Terrestrial, Aerial and Marine Navigation:** Provides accurate location information for navigation on land, in the air, and at sea.
2. **Disaster Management:** Facilitates coordination and response efforts during emergencies and natural disasters.
3. **Vehicle tracking and fleet management:** Enables real-time monitoring and management of vehicles and fleets.
4. **Integration with mobile phones:** Allows mobile devices to access navigation and positioning services seamlessly.
5. **Precise Timing:** Provides accurate time synchronization for various applications and systems.
6. **Mapping and Geodetic data capture**: Captures detailed geographical data for mapping and geodesic purposes.
7. **Terrestrial navigation aid for hikers and travellers**: Assists hikers and travellers with location-based guidance and information.
8. **Visual and voice navigation for drivers:** Offers visual and voice-guided directions to drivers for navigation and route planning.

4. Astronomical Satellites

Astronomical satellites essentially function as large telescopes stationed in orbit, enabling unobstructed observations without interference from Earth's atmosphere. Their infrared imaging technology operates effectively, unaffected by surface temperatures on Earth. These satellites offer vision capabilities up to ten times more powerful than the most advanced ground-based telescopes. Satellites designed for astronomy are specialized for studying various celestial bodies and phenomena in space. They capture detailed maps of stars and planetary surfaces, photograph planets within our solar system, and conduct research on phenomena like black holes. Climate research satellites equipped with specialized sensors enable scientists to collect comprehensive, multi-dimensional data on Earth's oceans, ice caps, land surfaces, biosphere, and atmosphere. Biosatellites facilitate space-based studies on cellular and structural aspects of plants and animals, supporting collaborative efforts among scientists globally and advancing fields such as medicine and biology.

While many satellites can perform multiple functions simultaneously, it is recommended for researchers to utilize diverse types of satellites to enhance the breadth and accuracy of their scientific investigations.

Conclusion

In conclusion, satellites have revolutionized numerous aspects of life on Earth, serving as invaluable tools across various domains. From enhancing global communications and weather forecasting to enabling precise navigation and monitoring environmental changes, satellites play a pivotal role in modern society. Their ability to provide real-time data and imagery facilitates disaster management, agricultural planning, and scientific research, fostering sustainable development and global connectivity. As technology advances, the future promises even more innovative uses for satellites, continuing to shape and improve our understanding and management of the world we inhabit.

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