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GOVERNMENT OF INDIA
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MINISTRY OF DEFENCE
संयुक्त सेवा गाइड
JOINT SERVICES GUIDE

ON

**CLASSIFICATION
FRAMEWORK FOR SATELLITES**

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रक्षा उत्पादन विभाग
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0. FOREWORD

0.1 This guide has been prepared by the Defence Space Applications Standardisation Sub-Committee (DSASSC) on the authority of the Standardisation Committee, Ministry of Defence.

0.2 This is a new Joint Services Guide (**JSG**) and has been approved and notified by the Director, Directorate of Standardisation, Ministry of Defence (MoD) and is mandatory for use by the Defence Services.

0.3 Enquiries related to any technical matters may be referred to:

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0.4 Non-registered users can obtain the following on payment:

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1.0 SCOPE

1.1 This document intends to build a structured framework that classifies satellites using multiple criteria. It is a structured and comprehensive framework for the classification of satellites based on multiple technical, operational, and functional parameters. The scope encompasses a comprehensive classification of satellites based on application, Mass regime, orbital and ownership, and governance across various dimensions.

1.2 The document addresses classification based on application such as Anti-Satellite weapons or "Killer Satellites", Astronomical, Biosatellites communication, navigation, Reconnaissance, Remote Sensing, Earth observation, Weather, scientific research, Exploration, Military, Technology demonstration, reconnaissance, environmental and space situational awareness. It further includes emerging application domains such as environmental monitoring, terrain mapping, Tether, recovery satellites etc. The intent is to capture both traditional and next-generation use cases, ensuring relevance in a rapidly evolving space ecosystem.

1.3 The document also covers classification based on physical parameters such as satellite mass and size, including standardized categories like large satellites, mini, micro, nano, and pico satellites. Satellite weight is more accurately referred to as mass and is a critical engineering parameter. It directly influences the launch vehicle selection, propulsion architecture, structural design, power subsystem sizing, communication system capability, and operational lifespan. With the advent of miniaturization and the commercialization of space, the mass spectrum of satellites has broadened significantly, allowing a variety of mission types at multiple cost tiers. Classification of satellites based on Mass has been done to elaborate on this aspect.

1.4 Orbital based classification includes categorization based on altitude, eccentricity, inclination, and synchronicity. This enables clear differentiation of satellites based on their coverage patterns, latency characteristics, and operational constraints.

1.5 Satellites can be classified not only by their orbit or mission but also by ownership, operational control, and governance framework. Ownership and governance directly influence satellite mission priorities, data accessibility, security controls, and international legal obligations. With increasing commercialization and militarization of space, governance based classification has become increasingly important. This classification is crucial for understanding security implications, data access, liability, and international cooperation, especially in an era of increasing commercialization and strategic competition in outer space.

1.6 Military Satellites classification key attributes are reconnaissance, communication, navigation and Early warning systems. The broad categories covering all core and emerging military space capabilities internationally are ISR missions, Offensive Counterpace & EW missions, Early warning satellites (NCW & BMD applications), Targeting and support missions, Hybrid capability satellite missions.

1.7 The document further aims to provides a baseline for standardization bodies, regulatory authorities, defence organizations, and industry stakeholders to ensure consistency in terminology, system design, and operational planning.

1.8 However, this document does not delve into detailed design specifications, manufacturing processes, or mission-specific operational procedures of individual satellite systems. It is intended to serve as a high-level classification guideline rather than a technical design manual. Additionally, while indicative examples may be referenced for clarity, the document does not restrict innovation or emerging satellite architectures that may not strictly fall within existing classification boundaries.

1.9 In summary, this document establishes a unified and extensible classification framework for satellites, facilitating improved coordination, interoperability, and strategic planning across civil, commercial, and defence space domains.

2.0 INTRODUCTION

2.1 In 1957, a major event marked the beginning of a new era in Earth Observation and space exploration: the launch of the first artificial satellite, Sputnik 1, by the Soviet Union..The term “Satellite” refers to an object that is launched into space and moves around Earth or another celestial body. In astronomy, a natural satellite is understood as a celestial body orbiting around a planet or another celestial body (a moon). Artificial satellites are man-made objects orbiting around celestial bodies as shown in **Fig.1**.



Figure 1: A Glimpse of an Artificial Satellite

2.2 Thousands of artificial, or man-made, satellites orbit Earth. Some take pictures of the planet that help meteorologists predict weather and track hurricanes. Some take pictures of other planets, the sun, dark matter or faraway galaxies. These pictures help scientists better understand the solar system and universe. There are other satellites which are used mainly for communications, such as beaming TV signals and phone calls around the world. A group of more than 24 satellites make up the Global Positioning System, or GPS for global coverage. Militaries around the world have also been using satellites for various purposes.

3.0 OVERVIEW OF SATELLITE SYSTEM

3.1 The satellites give us bird’s-eye view that enables us to see large areas of Earth at one time. This ability means satellites can collect more data, more quickly, than instruments on the ground. Satellites also can see into space better than telescopes at Earth’s surface. TV signals travel in straight line and are thus obstructed by natural and manmade obstructions. To ensure large area coverage with TV signals a greater number of very high TV towers were installed. Phone calls to faraway places were also a problem. Setting up telephone wires over long distances or underwater is difficult and costs a lot. With satellites, TV signals and phone calls are sent upward to a satellite. Then, the satellite can send them back down to different locations on Earth.

3.2 Most satellites are launched into space on rockets. A satellite orbits Earth when its speed is balanced by the pull of Earth’s gravity. Without this balance, the satellite would fly in a straight line off into space or fall back to Earth. Satellites orbit Earth at different heights, different speeds, and along different paths. The orbit is the

path followed by any celestial body moving around a bigger celestial body. Most operational Earth satellites use near-circular orbits, though many missions intentionally use elliptical orbits. The two most common types of orbits are “**geostationary**” and “**polar**.” A geostationary satellite travels from west to east over the equator. It moves in the same direction and at the same rate Earth is spinning. From Earth, a geostationary satellite looks like it is standing still since it is always above the same location. Polar-orbiting satellites travel in a north-south direction from pole to pole. As Earth spins underneath, these satellites can scan the entire globe, one strip at a time.

3.3 Satellite orbits define the trajectory a satellite follows around the Earth and are determined by gravitational forces and the satellite’s velocity. The choice of orbit is a critical design decision, as it directly influences coverage area, signal latency, revisit time, and mission effectiveness. Satellite orbits are commonly classified based on altitude, inclination, shape, orbital period, and mission geometry. Low Earth Orbits enable high-resolution Earth observation and low-latency communication, while Medium and Geostationary Earth Orbits support navigation and continuous communication services respectively. Special orbits such as polar, sun-synchronous, and highly elliptical orbits are designed to meet specific mission needs like global coverage, consistent lighting conditions, or extended visibility over high-latitude regions. The appropriate selection and management of satellite orbits ensure reliable and efficient operation of space-based systems for civil, commercial, and military applications.

4.0 OVERVIEW OF SPACECRAFT SYSTEM

4.1 A spacecraft can be of various types and shapes. When considering spacecraft, it is convenient to subdivide them into functional elements or subsystems. But it is also important to recognize that the satellite itself is only an element within a larger system. There must be a supporting ground control system as shown in **Fig.2** that enables commands to be sent up to the vehicle and status and payload information to be returned to the ground. There must also be a launcher system that sets the vehicle on its way to its final orbit. Each of the elements of the overall system must interact with the other elements to achieve an overall optimum in which the mission objectives are realized efficiently. It is, for example, usual for the final orbit of a geostationary satellite to be achieved by a combination of a launch vehicle and the boost motor of the satellite itself. **Fig. 3** shows the breakdown of the elements needed to form a satellite mission. Each of these may be considered to perform functions that will have functional requirements associated with them. We can thus have an overriding set of mission requirements that will arise from the objectives of the mission itself. In the process of systems engineering, we are addressing the way in which these functional requirements can best be met, in a methodical manner.

4.2 The mission objectives are imposed on the system by the customer, or user of the data. They are statements of the aims of the mission, are qualitative in nature and should

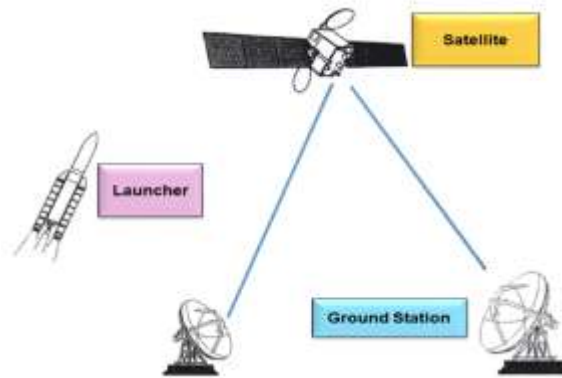


Figure 2: The total system—the combined space and ground segments

be general enough to remain virtually unchanged during the design process. It is these fundamental objectives that must be fulfilled as the design evolves. For example, the mission objectives might be to provide secure and robust three dimensional position and velocity determination to surface and airborne military users. The Global Positioning System (GPS) is a method adopted to meet these objectives. An illustration of the range of methods and the subsequent requirements that can stem from mission objectives is given by the large number of different concepts that have been proposed to meet the objective of providing a worldwide mobile communication system. They range from an extension of the existing Inmarsat spacecraft system to schemes using highly eccentric and tundra orbits to a variety of concepts based around a network of LEO satellites, such as The Globalstar or Iridium constellations. This example demonstrates an underlying principle of system engineering, that is, that there is never only one solution to meet the objectives. There will be a diverse range of solutions, some better and some worse, based on an objective discriminating parameter such as cost, mass or some measure of system performance. The problem for the system engineer is to balance all these disparate assessments into a single solution.

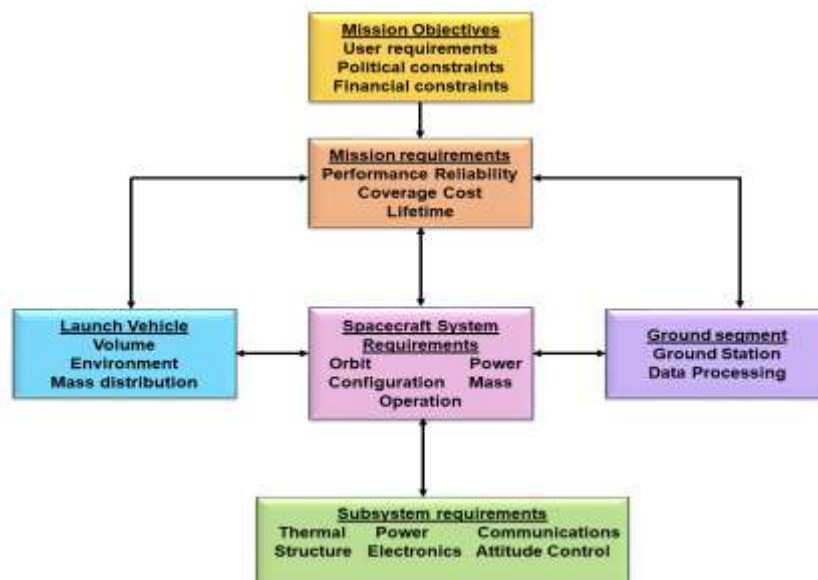


Figure 3: Objectives and requirements of a spacecraft mission

4.3 A spacecraft system is as shown in **Fig. 4**. It may be divided conveniently into two principal elements, the payload and the bus (or service module). It is of course the payload that is the motivation for the mission itself. In order that this may function it requires certain resources that will be provided by the bus. In particular, it is possible to identify the functional requirements, which include:

4.3.1 The payload must be pointed in the correct direction (1- Refer fig 4).

4.3.2 The payload must be operable (2- Refer fig 4).

4.3.3 The data from the payload must be communicated to the ground (3- Refer fig 4).

4.3.4 The desired orbit for the mission must be maintained (4- Refer fig 4).

4.3.5 The payload must be held together, and on to the platform on which it is mounted (5- Refer fig 4).

4.3.6 The payload must operate and be reliable over some specified period (6- Refer fig 4).

4.3.7 An energy source must be provided to enable the above functions to be performed (7- Refer fig 4).

4.4 These requirements lead on to the breakdown into subsystems, which are shown in **Fig. 4**. Inset in each of these is a number that relates it to the functions above.

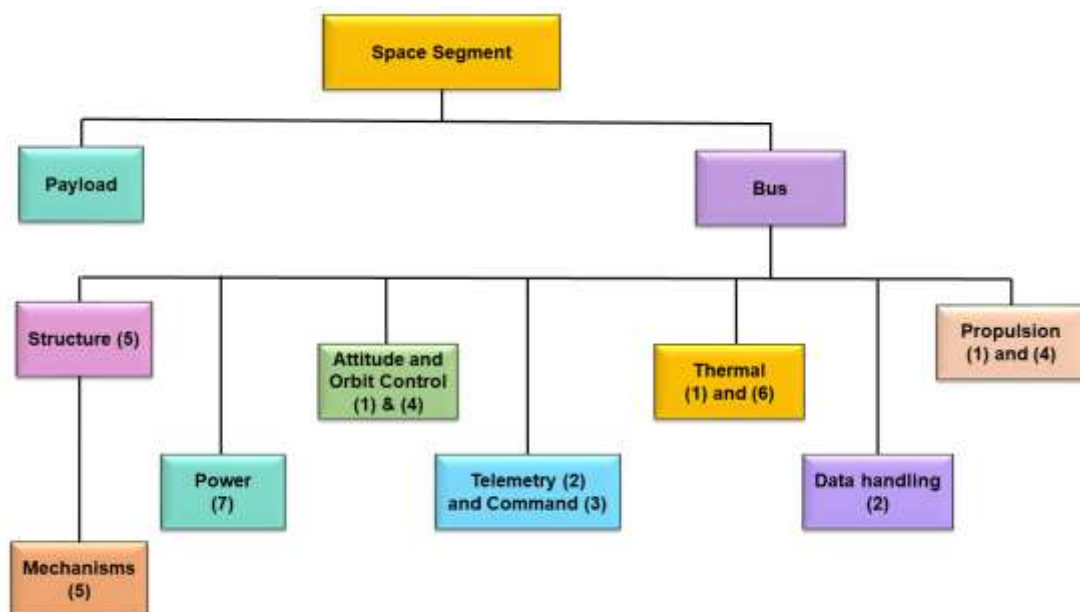


Figure 4: Spacecraft Subsystems

4.5 One facet of these subsystems is that the design of any one has impacts and resource implications on the others. A most important feature of spacecraft system design is to identify what aspects of the mission and what elements of the design provide the major influences on the type of satellite that may meet the specific mission requirements. This process is the identification of the ‘design drivers’. In some cases the drivers will affect major features of the spacecraft hardware. The varied mission requirements, coupled with the need to minimize mass and hence power, has thus led to a wide variety of individual design solutions being realized. However, the spacecraft industry is now evolving towards greater standardisation—in the shape of the specific buses that may be used to provide the resources for a variety of missions (e.g., the SPOT bus, the Eurostar bus, Mars/Venus Express, etc). It is not simply the nature of its payload that determines the design that is selected for a given mission, although this will have a considerable influence. Commercial and political influences are strongly felt in spacecraft engineering. Individual companies have specialist expertise; system engineering is dependent on the individual experience within this expertise. This was perhaps most notably demonstrated by the Hughes Company, which advanced the art of the spin-stabilized satellite through a series of Intelsat spacecraft. This leads to another major feature of spacecraft system design, namely, the impact of reliability. The majority of terrestrial systems may be maintained, and their reliability, while being important, is not generally critical to their survival. If a major component fails, the maintenance team can be called in. In space, this luxury is not afforded and while the Shuttle did provide in-orbit servicing for a limited number of satellites, this was an extremely expensive option. This requires that the system must be fault-tolerant, and when this tolerance is exceeded the system is no longer operable and the mission has ended.

4.6 There are two principal methods used to obtain high reliability. The first is to use a design that is well proven. This is true for both system and component selection. The requirement to validate the environmental compatibility of components leads to relatively old types being used in mature technology, especially in electronic components. This tends to lead to a greater demand for power than the terrestrial ‘state-of-the-art’ technology. At system level a ‘tried and tested’ solution will minimize development risk, reducing system cost while also achieving high reliability.

4.7 The second method of achieving high reliability is *via* de-rating. By reducing the power of the many electronic components, for example, a greater life expectancy can be obtained. This leads to an overall increase in mass. The net effect of designing for high reliability is that spacecraft design is conservative—‘if it has been done before then so much the better’. Much of satellite design is thus not state-of-the-art technology. Design teams evolve a particular design solution to meet varied missions—because it is a design they understand—and hence system design is an art as well as a science. In making the selection of subsystems for the spacecraft, the designer must have a good grasp of the way in which the subsystems work and the complex interactions between them, and they must recognize how the craft fits into the larger system. Further, the designer must be able to trade off advantages in one area with the disadvantages in another and achieve a balance in which the end result will work as a harmonious whole. While each subsystem will have its own performance criterion, its performance must nevertheless be subordinated to that of the system as a whole.

5.0 CLASSIFICATION OF SATELLITES

5.1 Satellites are integral assets within the global aerospace, defence, and commercial communication infrastructure. Their increasing diversity, offered through advancements in launch capabilities, miniaturized electronics, modular bus architectures, and constellation deployment strategies, has necessitated a more refined and technical classification framework. A comprehensive classification of satellites based on application, Mass regime, orbital and ownership, and governance is shown in **Fig.5**.

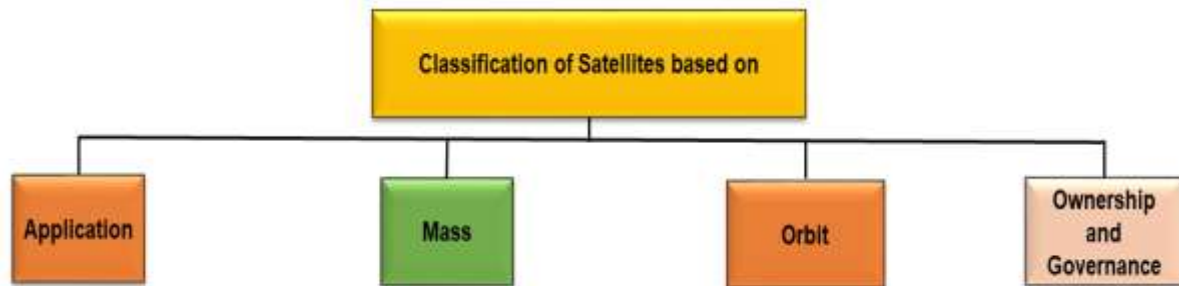


Figure 5: Classification of Satellites

6.0 CLASSIFICATION OF SATELLITES BASED ON APPLICATIONS. Based upon applications, satellites can be classified as shown in **Fig.6**.

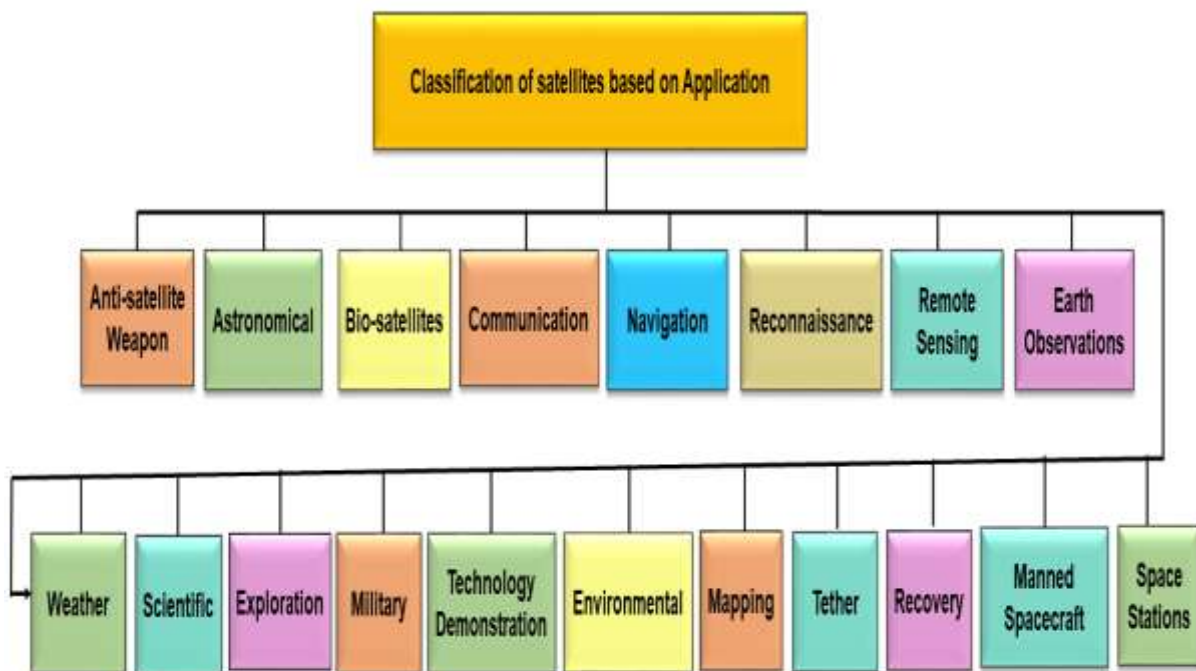


Figure 6: Classification of Satellites based on Applications

6.1 Anti-Satellite Weapons/"Killer Satellites". Anti-Satellite weapons are satellites that are designed to destroy enemy warheads, satellites, and other space assets. Kinetic-kill vehicles do not use warheads; destruction occurs via

hypervelocity impact. Currently only United States, Russia and China are known to have developed these weapons.

6.2 Astronomical Satellites

6.2.1 Astronomical satellites are satellites used for observation of distant planets, galaxies, and other outer space objects. A large number of observatories have been launched into orbit, and most of them have greatly enhanced our knowledge of the extra-terrestrial universe.

6.2.2 Performing astronomy from the Earth's surface is limited by the filtering and distortion of electromagnetic radiation (scintillation or twinkling) due to the atmosphere. Some terrestrial telescopes (such as the Very Large Telescope) can reduce atmospheric effects with adaptive optics. A telescope orbiting the Earth outside the atmosphere is subject neither to twinkling nor to light pollution from artificial light sources on the Earth.

6.2.3 Space-based astronomy is even more important for frequency ranges which are outside of the optical window and the radio window, the only two wavelength ranges of the electromagnetic spectrum that are not severely attenuated by the atmosphere. For example, X-ray astronomy is nearly impossible when done from the Earth, and has reached its current importance in astronomy only due to orbiting X-ray telescopes such as the Chandra observatory and the XMM-Newton observatory. Infrared and ultraviolet are also greatly blocked. ISRO had launched XpoSat India's first dedicated scientific mission to study various dynamics of bright astronomical X-ray sources in extreme conditions.

6.2.4 Space observatories can generally be divided into two classes: missions which map the entire sky (surveys), and observatories which make observations of chosen parts of the sky.

6.2.5 Many space observatories have already completed their missions, while others continue operating, and still others are planned for the future. Satellites have been launched and operated by ISRO, NASA, ESA, Japanese Space Agency and the Roscosmos.

6.3 Biosatellites. Biosatellites are satellites designed to carry living organisms, generally for scientific experimentation. The first satellite carrying an animal (a dog, Laika) was Sputnik 2 on November 3, 1957. On August 20, 1960 Sputnik 5 first time recovered animals (dogs) from orbit to earth.

6.4 Communications Satellites. Communications satellites are satellites stationed in space for the purpose of telecommunications. Modern communications satellites typically use geosynchronous orbits, Molniya orbits or Low Earth orbits.

6.4.1 Today's satellite communications can trace their origins all the way back to the Moon. A project named Communication Moon Relay was a telecommunication project carried out by the United States Navy. Its objective was to develop a secure and reliable method of wireless communication by using the Moon as a natural communications satellite.

6.4.2 The first artificial satellite used solely to further advances in global communications was a balloon named Echo 1, was the world's first artificial communications satellite capable of relaying signals to other points on Earth. It soared 1,000 miles (1,609 km) above the planet after its Aug. 12, 1960 launch, yet relied on humanity's oldest flight technology — ballooning. Launched by NASA, Echo 1 was a giant metallic balloon 100 feet (30 meters) across. The world's first inflatable satellite — or "satelloon," as they were informally known — helped lay the foundation of today's satellite communications. The idea behind a communications satellite is simple: Send data up into space and beam it back down to another spot on the globe. Echo 1 accomplished this by essentially serving as an enormous mirror 10 stories tall that could be used to bounce communications signals off of.

6.4.3 Communications Satellites are usually composed of the following subsystems:

- (a) Communication Payload, normally composed of transponders, antenna, and switching systems.
- (b) Engines used to bring the satellite to its desired orbit.
- (c) Station Keeping Tracking and stabilization subsystem used to keep the satellite in the right orbit, with its antennas pointed in the right direction, and its power system pointed towards the sun.
- (d) Power subsystem, used to power the Satellite systems, normally composed of solar cells, and batteries that maintain power during solar eclipse.
- (e) Command and Control subsystem, which maintains communications with ground control stations. The ground control earth stations monitor the satellite performance and control its functionality during various phases of its life-cycle.

6.4.4 The bandwidth available from a satellite depends upon the number of transponders provided by the satellite. Each service (TV, Voice, Internet, radio) requires a different amount of bandwidth for transmission. This is typically known as link budgeting and a network simulator can be used to arrive at the exact value.

6.4.5 State of the art Communication satellites includes relay signals for television broadcasting, radio services, direct-to-home entertainment, internet connectivity, maritime and aviation communications and military communication networks. Typical communication satellite payloads include transponders (C-band, Ku-band, Ka-band, Q/V-band), phased array antennas, regenerative processors and high-throughput digital modems. Most communication satellites operate in Geostationary Orbit (GEO) to provide fixed coverage. Some examples of communication satellites operating from GEO include the Intelsat, SiriusXM INSAT and GSAT series. However, modern broadband constellations Starlink, OneWeb, Kuiper use LEO mega-constellations for low-latency global internet.

6.5 Navigational Satellites

6.5.1 Navigational satellites are satellites which use radio time signals transmitted to enable mobile receivers on the ground to determine their exact location. The relatively clear line of sight between the satellites and receivers on the ground, combined with ever-improving electronics, allows satellite navigation systems to measure location to accuracies on the order of a few meters in real time.

6.5.2 A satellite navigation or SATNAV system is a constellation of satellites that provide autonomous geo-spatial positioning with global coverage. It allows small electronic receivers to determine their location (longitude, latitude, and altitude) to within a few metres using time signals transmitted along a line-of-sight by radio from satellites. Receivers calculate the precise time as well as position, which can be used as a reference for several applications. A satellite navigation system with global coverage may be termed a global navigation satellite system or GNSS.

6.5.3 As of date the following Navigation Satellite Systems are fully operational:

- (a) Global Navigation Satellite System (GNSS)
 - (i) NAVSTAR Global Positioning System (GPS) of United States of America
 - (ii) GLONASS of Russia
 - (iii) Beidou navigation system of China and
 - (iv) GALILEO of European Union
- (b) Regional Navigation Satellite System
 - (i) NavIC of India
 - (ii) QZSS of Japan

6.5.4 Global coverage for each system is generally achieved by a satellite constellation of 20–30 medium Earth orbit (MEO) satellites spread between several orbital planes. The actual systems vary, but use orbital inclinations of $>50^\circ$ and orbital periods of roughly twelve hours (at an altitude of about 20,000 kilometres (12,000 mi)).

6.5.5 State of the art Navigation satellites form global and regional PNT (Positioning, Navigation, and Timing) systems. They transmit time-stamped signals enabling receivers to derive geographic location using trilateration. Major global systems include GPS (USA), GLONASS (Russia), Galileo (European Union) and BeiDou (China). Regional systems include NavIC (India) and QZSS (Japan). Navigation satellites use atomic clocks, precise orbital determination, and inter-satellite communication links. Applications extend far beyond mapping, including aviation routing, maritime navigation,

military targeting systems, financial network synchronization, and scientific research.

6.6 Reconnaissance Satellites

6.6.1 Reconnaissance satellites are Earth observation satellite or communications satellite deployed for **military or intelligence applications**. Very little is known about the full power of these satellites, as governments who operate them usually keep information pertaining to their reconnaissance satellites classified.

6.6.2 A Reconnaissance satellite is an Earth observation satellite or communications satellite deployed for military or intelligence applications. These are essentially space telescopes that are pointed toward the Earth instead of toward the stars. The first generation type (i.e. Corona and Zenit) took photographs, then ejected canisters of photographic film, which would descend to earth.

6.6.3 Corona capsules were retrieved in mid-air as they floated down on parachutes. Later spacecraft had digital imaging systems and uploaded the images via encrypted radio links.

6.6.4 In the United States, most information available is on programs that existed up to 1972. Some information about programs prior to that time is still classified, and a small trickle of information is available on subsequent missions.

6.6.5 A few up-to-date reconnaissance satellite images have been declassified on occasion, or leaked, as in the case of KH-11 photographs which were sent to Jane's Defence Weekly in 1985.

6.6.6 On March 16, 1955, the United States Air Force officially ordered the development of an advanced reconnaissance satellite to provide continuous surveillance of 'pre selected areas of the earth' in order 'to determine the status of a potential enemy's war-making capability'.

6.6.7 Examples of reconnaissance satellite missions:

- (a) High resolution photography (**IMINT**)
- (b) Measurement and Signature Intelligence (**MASINT**)
- (c) Communications eavesdropping (**SIGINT**)
- (d) Covert communications
- (e) Monitoring of nuclear test ban compliance
- (f) Detection of missile launches

6.7 Remote Sensing Satellites. These satellites capture high-resolution images and spectral data for agriculture, urban planning, natural resource monitoring, disaster response, and environmental assessment. Instruments include multispectral cameras, hyper spectral imagers, optical telescopes, thermal sensors,

and radar systems (SAR). Eg. Sentinel, Landsat, Resourcesat, Cartosat, and RISAT. Earth observation satellites and Meteorological (Weather) Satellites are types of remote sensing satellites.

6.8 Earth Observation Satellites

6.8.1 Earth observation satellites are satellites specifically designed to observe Earth from orbit, similar to spy satellites but intended for non-military uses such as environmental monitoring, meteorology, map making etc.

6.8.2 Most Earth observation satellites carry instruments that should be operated at a relatively low altitude. Altitudes below 500-600 kilometers are in general avoided, for long-term missions, though, because of the significant air-drag at such low altitudes making frequent orbit raising manoeuvres necessary. The Earth observation satellites ERS-1, ERS-2 and Envisat of European Space Agency as well as the MetOp spacecraft of the European Organisation for the Exploitation of Meteorological Satellites are all operated at altitudes of about 800 km. The Proba-1, Proba-2 and SMOS spacecraft of European Space Agency are observing the Earth from an altitude of about 700 km.

6.8.3 To get a (close to) global coverage with such a relatively low orbit it has to be polar or at least close to polar. As such a rather low orbit will have an orbital period of roughly 100 minutes the Earth will rotate around its polar axis with about 25° between successive orbits with the result that the ground track is shifted towards west with these 25° in longitude.

6.8.4 For spacecraft carrying instruments for which an altitude of 36000 km is suitable the Geostationary orbit is sometimes the preferred choice. From such an orbit one gets uninterrupted coverage of more than 1/3 of the Earth. With 3 geostationary spacecraft positioned over the equator at longitudes separated with 120° the whole Earth is covered except the extreme Polar Regions. This type of orbit is mainly used for meteorological satellites.

6.9 Weather Satellites

6.9.1 A weather satellite is a type of satellite that is primarily used to monitor the weather and climate of the Earth. These meteorological satellites, however, see more than clouds and cloud systems. City lights, fires, effects of pollution, auroras, sand and dust storms, snow cover, ice mapping, boundaries of ocean currents, energy flows, etc., are other types of environmental information collected using weather satellites.

6.9.2 Weather satellite images helped in monitoring the volcanic ash cloud from Mount St. Helens and activity from other volcanoes such as Mount Etna. Smoke from fires in the western United States such as Colorado and Utah have also been monitored. The Antarctic ozone hole is mapped from weather satellite data. Collectively, weather satellites flown by the U.S., Europe, India, China, Russia, and Japan provide nearly continuous observations for a global weather watch, used via visible light and infrared rays of the electromagnetic spectrum.

6.10 Scientific Satellites. Scientific satellites support experiments in astrophysics, particle physics, solar observation, planetary science, Earth sciences and gravitational studies. Examples include Hubble Space Telescope, James Webb Space Telescope, Parker Solar Probe, ASTROSAT, Aditya-L1, Xposat and GRACE gravity satellites. These satellites often operate in special orbits such as Lagrange points, far beyond low Earth orbit.

6.11 Exploration Satellites. Exploration satellites investigate celestial bodies and deep space environments. They include planetary orbiters (Mars, Jupiter, Saturn), lunar orbiter, comet/asteroid probes and interstellar missions (Voyager 1&2). They employ long-range communication antennas, radiation protection, RTGs (radioisotope power systems), autonomous navigation software. Eg. Chandrayaan, Mars Orbiter Mission.

6.12 Military Satellites. Military satellites are built for secure communication, reconnaissance, signals intelligence (SIGINT), early-warning missile detection, navigation support, nuclear treaty verification. They feature encryption, anti-jamming, and manoeuvring capabilities for enhanced resilience.

6.13 Technology Demonstration Satellites. These satellites test new technologies such as miniaturized sensors, advanced thrusters, AI-based onboard processors, inter-satellite optical links and new communication bands. CubeSats frequently host experimental payloads for rapid prototyping.

6.14 Environmental satellites. Other environmental satellites can assist environmental monitoring by detecting changes in the Earth's vegetation, atmospheric trace gas content, sea state, ocean color, and ice fields. By monitoring vegetation changes over time, droughts can be monitored by comparing the current vegetation state to its long term average. For example, the 2002 oil spill off the northwest coast of Spain was watched carefully by the European ENVISAT, which, though not a weather satellite, flies an instrument (ASAR) which can see changes in the sea surface. Anthropogenic emissions can be monitored by evaluating data of tropospheric NO₂ and SO₂. These types of satellites are almost always in Sun synchronous and "frozen" orbits. The Sun synchronous orbit is in general sufficiently close to polar to get the desired global coverage while the relatively constant geometry to the Sun mostly is an advantage for the instruments. The "frozen" orbit is selected as this is the closest to a circular orbit that is possible in the gravitational field of the Earth.

6.15 Mapping. Terrain can be mapped from space with the use of satellites, such as RADARSAT-1 and TerraSAR-X.

6.16 Tether Satellites. Tether satellites are satellites which are connected to another satellite by a thin cable called a tether. Space tethers are cables, usually long and very strong, which can be used for propulsion, stabilization, or maintaining the formation of space systems by determining the trajectory of spacecraft and payloads. Depending on the mission objectives and altitude, spaceflight using this form of spacecraft propulsion may be significantly less expensive than spaceflight using rocket engines. Four main techniques for employing space tethers are in development.

6.16.1 Electrodynamic Tether. This is a conductive tether that carries a current that can generate thrust or drag from a planetary magnetic field, in much the same way as an electric motor.

6.16.2 Momentum Exchange Tether. This is a rotating tether that would grab a spacecraft and then release it at later time. Doing this can transfer momentum and energy from the tether to and from the spacecraft with very little loss; this can be used for orbital manoeuvring.

6.16.3 Tethered Formation Flying. This is typically a non-conductive tether that accurately maintains a set distance between space vehicles.

6.16.4 Electric Sail. A form of solar wind sail with electrically charged tethers that will be pushed by the momentum of solar wind ions. Many uses for space tethers have been proposed, including deployment as space elevators and for doing propellant-free orbital transfers.

6.17 Recovery Satellites. Recovery satellites are satellites that provide a recovery of reconnaissance, biological, space-production and other payloads from orbit to Earth.

6.18 Manned Spacecraft. Manned spacecraft are large satellites able to put humans into (and beyond) an orbit, and return them to Earth. Spacecraft including space planes of reusable systems have major propulsion or landing facilities. They can be used as transport to and from the orbital stations.

6.19 Space Stations. Space stations are man-made orbital structures that are designed for human beings to live on in outer space as shown in **Fig. 7**.

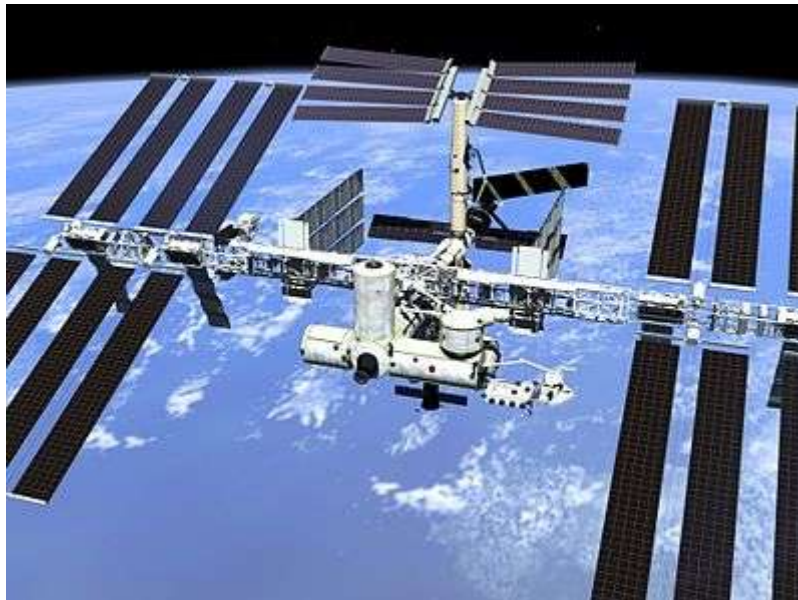


Figure 7: The International Space Station

6.19.1 A space station (or orbital station) shown in **Fig.7** is a spacecraft capable of supporting a crew which is designed to remain in space (most commonly in low Earth orbit) for an extended period of time, and to which

other spacecraft can dock. A space station is distinguished from other spacecraft used for human spaceflight by lack of major propulsion or landing systems. Instead other vehicles transport people and cargo to and from the station. As of now two space stations are in orbit: the International Space Station, and China's Tiangong Space Station. Previous stations include the Almaz and Salyut series, Skylab and most recently Mir.

6.19.2 Space stations are used to study the effects of long-term space flight on the human body as well as to provide platforms for greater number and length of scientific studies than available on other space vehicles. All space stations have been designed with the intention of rotating multiple crews, with each crew member staying aboard the station for weeks or months, but rarely more than a year. Since the ill-fated flight of Soyuz 11 to Salyut 1, all manned spaceflight duration records have been set aboard space stations. The duration record for a single spaceflight is 437.7 days, set by Valeriy Polyakov aboard Mir from 1994 to 1995. Three astronauts so far have completed single missions of over a year, all aboard Mir.

6.19.3 Space stations have been used for both military and civilian purposes. The last military-use space station was Salyut 5, which was used by the Almaz program of the Soviet Union in 1976 and 1977.

7.0 CLASSIFICATION OF SATELLITES BASED ON MASS. Based upon deployed mass, satellites can be classified as shown in **Fig. 8**.

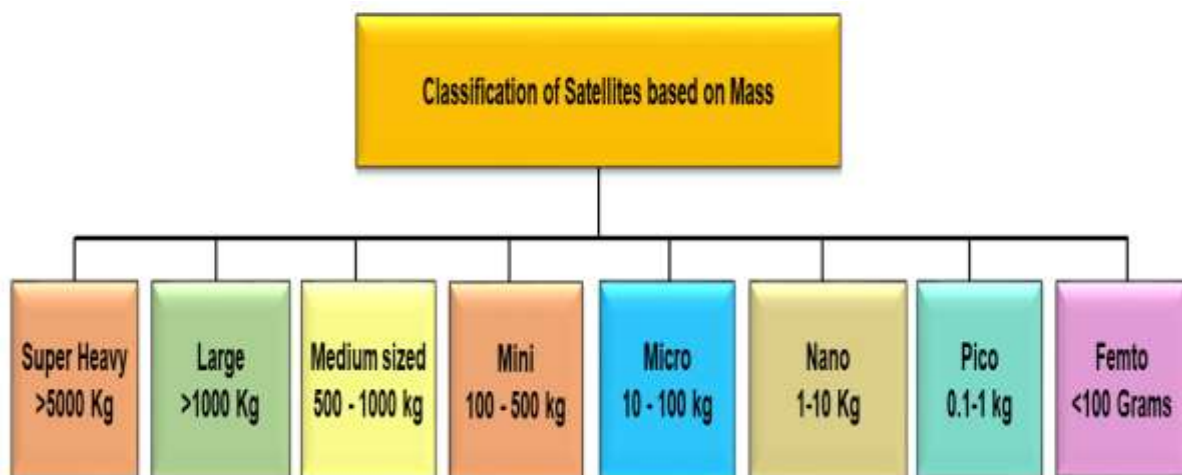


Figure 8: Classification of Satellites based on Mass

7.1 Super Heavy Satellites (5,000 kg and above). These are among the most complex spacecraft ever built. Designed for GEO operations, they support ultra-high throughput communications, advanced weather monitoring, military surveillance and interplanetary missions (e.g., large probes). The cost and complexity of super heavy satellites limit them to major space faring nations and large commercial corporations.

7.2 Large Satellites (1,000–5,000+ kg). Modern communication, meteorological, and military satellites typically fall in this category. Large satellites operate for 10–20+ years, host high-power transponders, provide broadband internet and television, support weather forecasting and are positioned in geostationary orbit (GEO). Their development requires extensive engineering, thermal control, redundancy systems, and radiation hardening.

7.3 Medium Satellites (500–1000 kg). Medium-class satellites deliver greater mission complexity and high-bandwidth systems. They can support medium-resolution Earth observation, moderate-power communication payloads and navigation augmentation. They often serve governments and larger commercial operators with moderate budget profiles.

7.4 Small Satellites (Under 500 kg). The term “small satellites” generally encompasses femto-, pico-, nano-, micro-, and mini-satellites. This category has revolutionized the space industry by enabling large satellite constellations, rapid deployment cycles, commercial remote sensing and resilient networked space architectures. Companies like Space X, Planet Labs, and OneWeb rely heavily on small satellites for global broadband and imaging services.

7.5 Mini-Satellites (100–500 kg). Mini-satellites represent a transition between small lightweight satellites and heavier, fully-capable spacecraft. Their payload bay can support high-resolution imaging, scientific sensors, and small telecommunication payloads. They are commonly deployed in low Earth orbit (LEO) for applications such as detailed environmental monitoring, space weather observation, reconnaissance missions, and industrial research. Mini-satellites offer robust performance at a significantly lower cost than large monolithic satellites.

7.6 Micro-Satellites (10–100 kg) Micro-satellites have sufficient capacity to host more advanced payloads such as multispectral cameras, scientific instruments, radar sensors, and low-latency communication systems. This category is commonly used for low-cost Earth observation, commercial imaging start-ups, environmental monitoring, technology experiments, and interplanetary CubeSat missions. Micro-satellites strike a balance between affordability and capability, making them attractive for both government agencies and private firms.

7.7 Nano-Satellites (1–10 kg). Nano-satellites, particularly standardised CubeSats (1U = 10 × 10 × 10 cm), are one of the fastest-growing categories in modern space missions. They are widely used by universities, start-ups, and even major companies due to their affordability, short development cycles, modular structure and versatility in payload design. Missions powered by nano-satellites include Earth observation, in-orbit technology demonstrations, biological experiments, low-cost communication networks, and scientific data collection. Their small size and standardized volume make them easy to integrate as secondary payloads on commercial launches.

7.8 Pico-Satellites (0.1–1 kg). Pico-satellites weigh between 100 grams and 1 kilogram. This category includes many early university-level satellites and simple experimental systems. Typically configured as single-purpose platforms, pico-satellites can host basic imaging sensors, communication

beacons and radiation monitoring instruments. Their lightweight structure allows dozens to be launched at once, making them ideal for formation flying and swarm-based missions.

7.9 Femto-Satellites (Below 100 grams)

7.9.1 Femto-satellites, sometimes referred to as “chip satellites,” represent the smallest category. These highly miniaturized platforms typically weigh less than 100 grams and are mostly used for distributed sensor networks in space, student research missions, atmospheric measurements and technology miniaturization experiments. Their simplicity and low cost make them suitable for deployment in large swarms or as secondary payloads in space missions. Due to their extremely small mass, femto-satellites are limited in power, communication bandwidth, and payload capacity, but they play an increasing role in proof-of-concept missions and distributed scientific measurements.

7.9.2 The commercial space sector is typified by the Geostationary communications satellite, ranging in on-orbit mass from 1000 kg to well over 4000 kg. Current trends are for the in-orbit mass of these spacecraft to increase to 8000-12,000 kg. For many other applications, there have been trends towards smaller spacecraft, with particular emphasis on reducing cost and development time scales. For the purpose of these a mass below 500kg is considered a small satellite, however the mission development philosophy is also relevant, to distinguish the new generation of small satellites from the more traditional small satellites that typified the early exploration of space.

7.9.3 The spirit of the small satellite world has been encompassed by the slogan "Faster, Better, Smaller Cheaper", although various high profile failures of NASA spacecraft have made this phrase less popular. Nevertheless, small satellite projects are characterised by rapid development scales for experimental missions when compared with the conventional space industry, with kick-off to launch schedules ranging from just six to thirty-six months. Leading-edge or terrestrial COTS technology is routinely employed in order to provide innovative solutions and cheaper alternatives to the established methods and systems. As such they permit lighter satellite systems to be designed inside smaller volumes. Frequently, traditional procedures, with roots in the military and manned space programmes, can no longer be justified, and low cost solutions are favoured to match the reducing space budgets. So in many ways "Faster, Better, Smaller, Cheaper" is a philosophy and an objective in small satellite programmes.

7.9.4 Many terms are used to describe this rediscovered class of satellites, including SmallSat, Cheapsat, MicroSat, MiniSat, NanoSat and even PicoSat and FemtoSat! The US Defence Advanced Research Projects Agency refers to these as LightSats, the U.S. Naval Space Command as SPINSat's (Single Purpose Inexpensive Satellite Systems), and the U.S. Air Force as TACSat's (Tactical Satellites). Nevertheless, in recent years a general method of classifying satellites

in terms of deployed mass has been generally adopted. The boundaries of these classes are an indication of where launcher or cost tradeoffs are typically made. Within this classification, the term "Small Satellite" is used to cover all spacecraft with in-orbit mass of less than 500kg. The small satellites we are concerned with throughout are therefore satellites weighing approximately less than 500 kg.

7.9.5 Another definition proposed by the International Academy of Astronautics (IAA) for inexpensive small satellites is

- (a) The programme must have an unusual or unconventional approach.
- (b) The mission must fill a clear gap.
- (c) The programme must have a short lead time.

8.0 CLASSIFICATION OF SATELLITES BASED ON ORBIT. This classification as shown in **Fig. 9** depends on altitude, shape, inclination, orbital period and mission geometry which are governed by Kepler’s laws and Newtonian mechanics. Satellite classification by orbit provides a systematic way to understand how satellites are designed and deployed to meet specific mission objectives. By categorizing satellites according to the above mentioned characteristics it becomes easier to relate an orbit’s physical properties to its operational advantages and limitations. This classification helps engineers, scientists, and operators select suitable orbits for applications ranging from communication and navigation to Earth observation and scientific research, ensuring efficient coverage, optimal performance, and mission success. Orbital classification is fundamental for link budget design, revisit time optimization, radiation shielding requirements, and ground infrastructure planning.

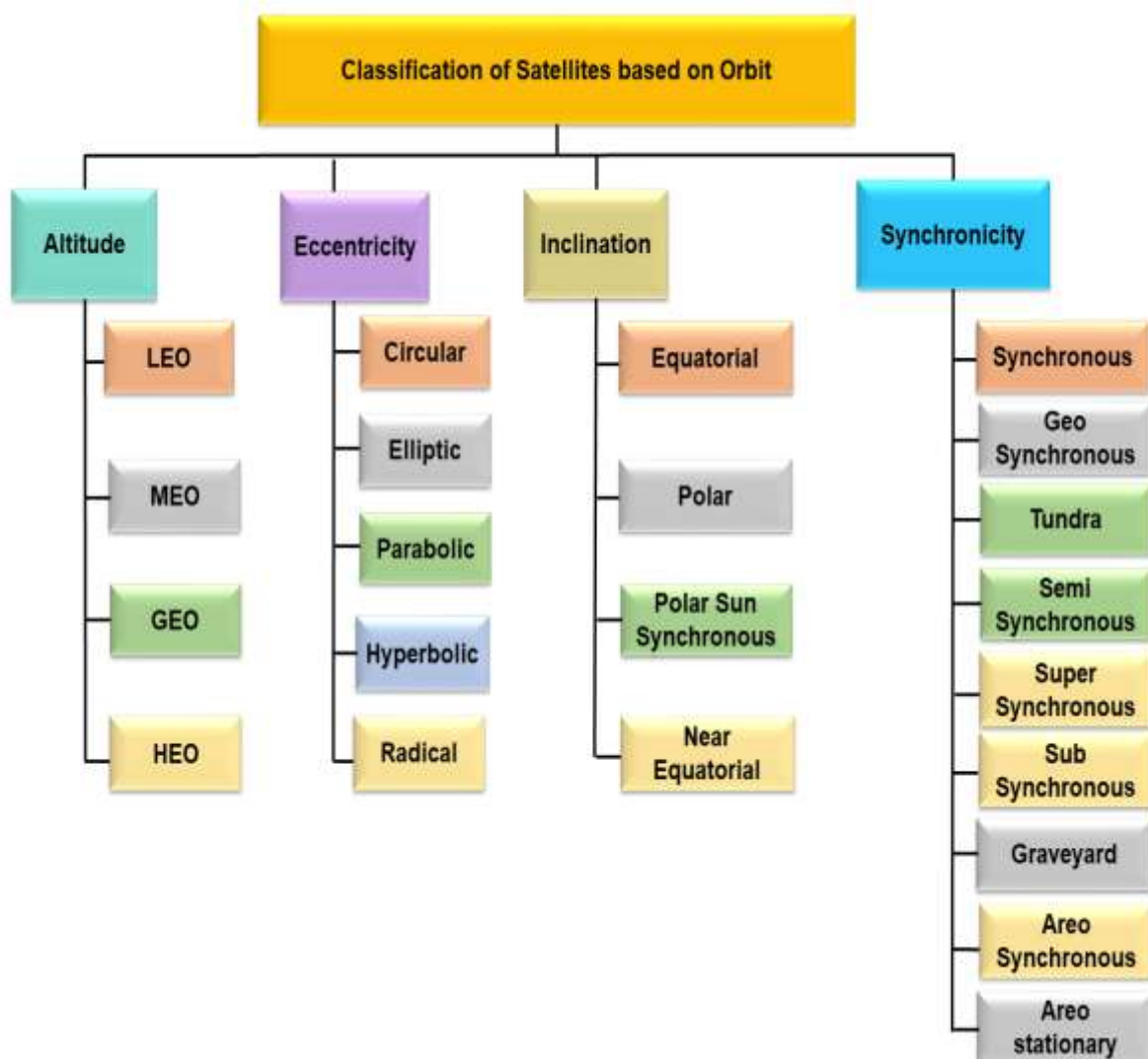


Figure 9: Classification of Satellites based on Orbit

8.1 Classification Based on Altitude. Satellites are classified by their altitude into Low Earth Orbit (LEO), Medium Earth Orbit (MEO), and Geostationary Earth Orbit (GEO). There are three main types of orbits satellites typically move around the earth as shown in **Fig.10**.

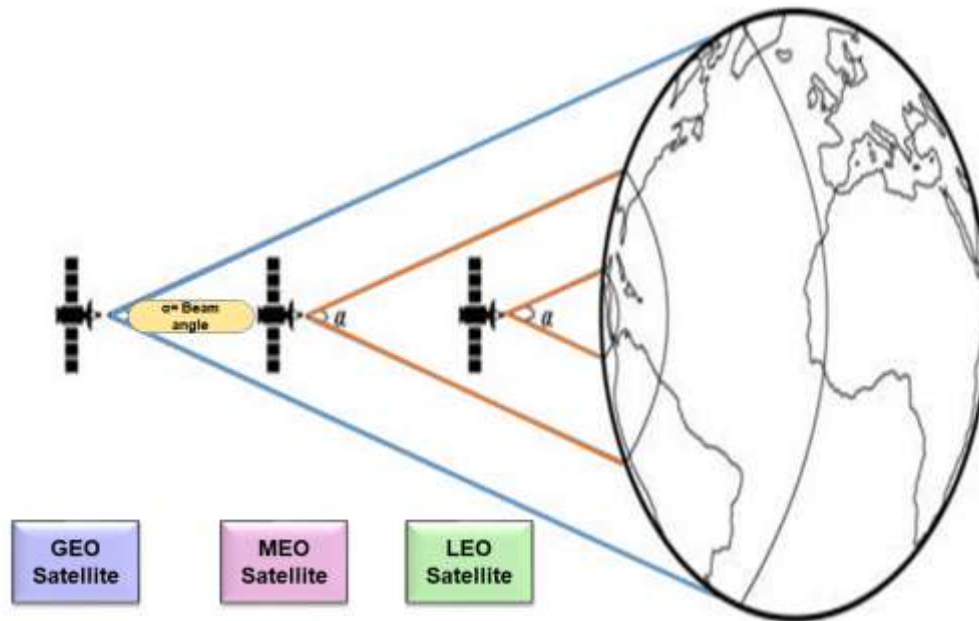


Figure10: Classification based on Altitude

8.1.1 Low Earth Orbit (LEO). It is located only a few hundred kilometres above earth, usually between 300 km to 2000 km. The lower orbit significantly reduces the delay that is created as the signal travels between Earth and the satellite and back to earth. This approach is particularly advantageous for global mobile telephone services in which signal delays during two-way communications can be disruptive and confusing. Low Earth orbit satellites do not remain in a fixed position in the sky relative to Earth. The low altitude also limits the area on the earth that the LEO satellite “sees” at a given time. As a result, a lot of satellites are needed to cover the globe to maintain a constant connection anywhere from a few hundred to a few thousand. Typical Applications include Earth observation, Remote sensing, Scientific missions and LEO communication constellations.

8.1.2 Medium Earth Orbit (MEO). It is located between 2,000 km and 36,000 km from earth. This is a good compromise between GEO and LEO as fewer satellites are required than LEO, typically less than 200, to maintain a constant connection. Typically, GPS satellites are located in this orbit. MEO satellites do have a unique challenge as they might pass through the Van Allen Radiation Belts and require extra protection.

8.1.3 Geostationary Orbit (GEO). Geostationary Orbit is located at about 36,000 kilometres from earth’s equator. The concept of geostationary satellite communications systems is generally credited to the futurist Arthur C. Clarke. Clarke wrote an article in 1945 stating that communications signals could be transmitted to and from Earth by a relay station (satellite) orbiting at that altitude (36,000 km), the satellite would travel at the same rotational rate as Earth and would appear to remain fixed over a location on the ground below, thereby providing a stationary platform for the continuous relay of communications signals.

Only one GEO satellite is needed to provide connection to a fixed spot on the earth, and three GEO satellites provide near global coverage excluding high-latitude polar regions. Applications include Communication, Weather monitoring and Broadcasting.

8.1.4 High Earth Orbit. Orbits above the altitude of geosynchronous orbit > 36,000 km.

8.2 Classification based on Eccentricity. Satellite orbits are classified based on their eccentricity, which determines the orbit's shape. There are two types of orbits: closed (periodic) orbits, and open (escape) orbits. Circular and elliptical orbits are closed. Parabolic and hyperbolic orbits are open. Radial orbits can be either open or closed.

8.2.1 Circular Orbit. An orbit that has an eccentricity of 0 and whose path traces a circle and maintain a constant altitude and speed, providing uniform coverage, and are widely used in LEO, MEO, and GEO satellites.

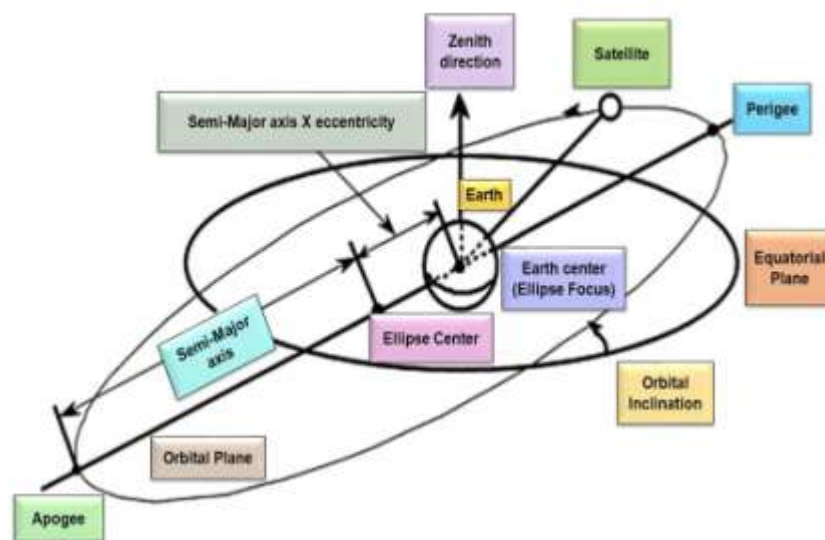


Figure11: Earth-orbiting Satellite Parameters

8.2.2 Elliptic Orbit. An orbit with an eccentricity greater than 0 and less than 1 whose orbit traces the path of an ellipse.

(a) **Geostationary or Geosynchronous transfer orbit.** An elliptic orbit where the perigee (as shown in Fig. 11) is at the altitude of a Low Earth Orbit (LEO) and the apogee at the altitude of a geostationary orbit.

(b) **Hohmann transfer orbit.** An orbital manoeuvre that moves a spacecraft from one circular orbit to another using two engine impulses. This maneuver was named after Walter Hohmann.

(c) **Coelliptic orbit.** Coelliptic orbits can be defined as two orbits that are coplanar and confocal. This is a relative reference

for two spacecraft or more generally, satellites in orbit in the same plane. A property of coelliptic orbits is that the difference in magnitude between aligned radius vectors is nearly the same, regardless of where within the orbits they are positioned. For this and other reasons, coelliptic orbits are useful.

8.2.3 Parabolic Orbit. An orbit with the eccentricity equal to 1. Such an orbit also has a velocity equal to the escape velocity and therefore will escape the gravitational pull of the planet. If the speed of a parabolic orbit is increased it will become a hyperbolic orbit.

(a) **Escape Orbit.** A parabolic orbit where the object has escape velocity and is moving directly away from the planet.

(b) **Capture Orbit.** A parabolic orbit where the object has escape velocity and is moving directly toward the planet.

8.2.4 Hyperbolic Orbit. An orbit with the eccentricity greater than 1. Such an orbit also has a velocity in excess of the escape velocity and as such, will escape the gravitational pull of the planet and continue to travel infinitely until it is acted upon by another body with sufficient gravitational force.

8.2.5 Radial Orbit. An orbit with zero angular momentum and eccentricity equal to 1. The two objects move directly towards or away from each other in a straight-line.

(a) **Radial elliptic orbit.** A closed elliptic orbit where the object is moving at less than the escape velocity. This is an elliptic orbit with semi-minor axis = 0 and eccentricity = 1. Although the eccentricity is 1, this is not a parabolic orbit.

(b) **Radial parabolic orbit.** An open parabolic orbit where the object is moving at the escape velocity.

(c) **Radial hyperbolic orbit.** An open hyperbolic orbit where the object is moving at greater than the escape velocity. This is a hyperbolic orbit with semi-minor axis = 0 and eccentricity = 1. Although the eccentricity is 1, this is not a parabolic orbit.

8.3 Classification based on Orbit Inclination. Satellites are also classified according to the angle of inclination of their orbit relative to Earth's equator (as shown in **Fig.12**).

8.3.1 Equatorial Orbits. have 0° inclination and remain over the equator, typically used by GEO communication satellites. Inclined orbits have intermediate angles and cover specific latitude ranges.

8.3.2 Polar Orbits. These are polar orbits with approximately 90° inclination, pass over the poles and allow complete Earth coverage over time, which is ideal for mapping, remote sensing, and Earth observation. Retrograde orbits, with inclination above 90° , move

opposite to Earth's rotation and are sometimes used for special reconnaissance missions or high-latitude coverage.

8.3.3 Polar Sun-Synchronous Orbit (SSO). A nearly polar orbit that passes the equator at the same local solar time on every pass. Useful for image-taking satellites because shadows will be the same on every pass.

8.3.4 Inclined Orbit. An orbit whose inclination with respect to equatorial plane is between 5 Deg and 80 deg. This orbit allows for coverage of specific region (often populated regions).

8.3.5 Near Equatorial Orbit. An orbit whose inclination with respect to the equatorial plane is nearly zero. This orbit allows for rapid revisit times (for a single orbiting spacecraft) of near equatorial ground sites.

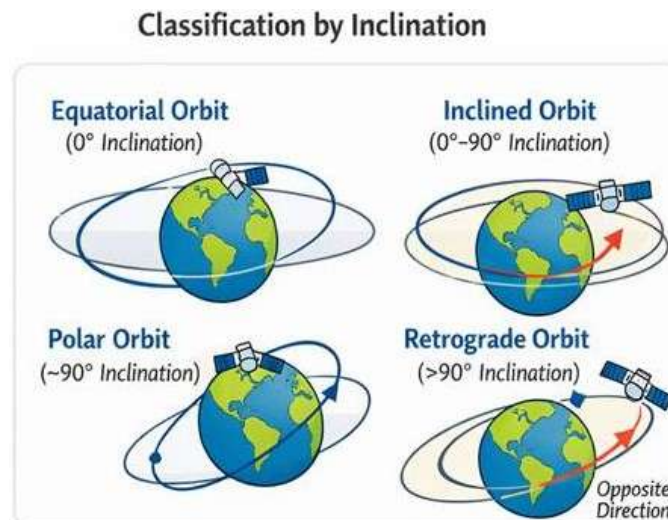


Figure12: Classification based on Inclination

8.4 Classification Based on Synchronicity

8.4.1 Synchronous Orbit. An orbit whose period is a rational multiple of the average rotational period of the body being orbited and in the same direction of rotation as that body. This means the track of the satellite, as seen from the central body, will repeat exactly after a fixed number of orbits. In practice, only 1:1 ratio (geosynchronous) and 1:2 ratios (semi-synchronous) are common.

8.4.2 Geosynchronous Orbit (GSO). An orbit around the Earth with a period equal to one sidereal day, which is Earth's average rotational period of 23 hours, 56 minutes, 4.091 seconds. For a nearly circular orbit, this implies an altitude of approximately 35,786 km (22,236 mi). The orbit's inclination and eccentricity may not necessarily be zero. If both the inclination and eccentricity are zero, then the satellite will appear stationary from the ground. If not, then each day the satellite traces out an analemma (i.e. a "figure-eight") in the sky, as seen from the ground. When the orbit is circular and the rotational period has zero inclination, the orbit is considered to also be geostationary. Also known as a Clarke orbit after the writer Arthur C. Clarke.

8.4.3 Geostationary Orbit (GEO). A circular geosynchronous orbit with an inclination of zero. To an observer on the ground this satellite appears as a fixed point in the sky. "All geostationary orbits must be geosynchronous, but not all geosynchronous orbits are geostationary."

8.4.4 Tundra Orbit. A synchronous but highly elliptic orbit with inclination of 63.4° and orbital period of one sidereal day (23 hours, 56 minutes for the Earth). Such a satellite spends most of its time over a designated area of the planet. The particular inclination keeps the perigee shift small.

8.4.5 Semi-Synchronous Orbit. An orbit with an orbital period equal to half of the average rotational period of the body being orbited and in the same direction of rotation as that body. For Earth this means a period of just under 12 hours at an altitude of approximately 20,200 km (12,544.2 miles) if the orbit is circular.

8.4.6 Molniya Orbit. A semi-synchronous variation of a Tundra orbit. For Earth this means an orbital period of just under 12 hours. Such a satellite spends most of its time over two designated areas of the planet. An inclination of 63.4° is normally used to keep the perigee shift small.

8.4.7 Supersynchronous Orbit. A disposal / storage orbit above GSO/GEO. Satellites will drift west. Also a synonym for Disposal orbit.

8.4.8 Subsynchronous Orbit. A drift orbit close to but below GSO/GEO. Satellites will drift east.

8.4.9 Graveyard Orbit. An orbit which is a few hundred kilometers above geosynchronous that satellites are moved into at the end of their operation.

(a) Disposal orbit: A synonym for graveyard orbit.

(b) Junk orbit: A synonym for graveyard orbit.

8.4.10 Aerosynchronous Orbit. A synchronous orbit around the planet Mars with an orbital period equal in length to Mars' sidereal day, 24.6229 hours.

8.4.11 Aerostationary Orbit (ASO). A circular aero synchronous orbit on the equatorial plane and about 17,000 km (10,557 miles) above the surface of Mars. To an observer on Mars this satellite would appear as a fixed point in the sky.

9.0 CLASSIFICATION OF SATELLITES BASED ON OWNERSHIP AND GOVERNANCE. Satellites can be classified not only by their orbit or mission but also by ownership, operational control, and governance framework as shown in **Fig.13**. This classification reflects who owns the satellite, who controls its use, and under what legal, political, or commercial rules it operates. Ownership and governance directly influence satellite mission priorities, data accessibility, security controls, and international legal obligations. With increasing commercialization and militarization of space, governance-based classification has become increasingly important. Classification of satellites based on ownership and governance highlights the evolving structure of space activities—from state-dominated systems to complex public–private, commercial, and multinational arrangements. This classification is crucial for understanding space law, security implications, data access, liability, and international cooperation, especially in an era of increasing commercialization and strategic competition in outer space.

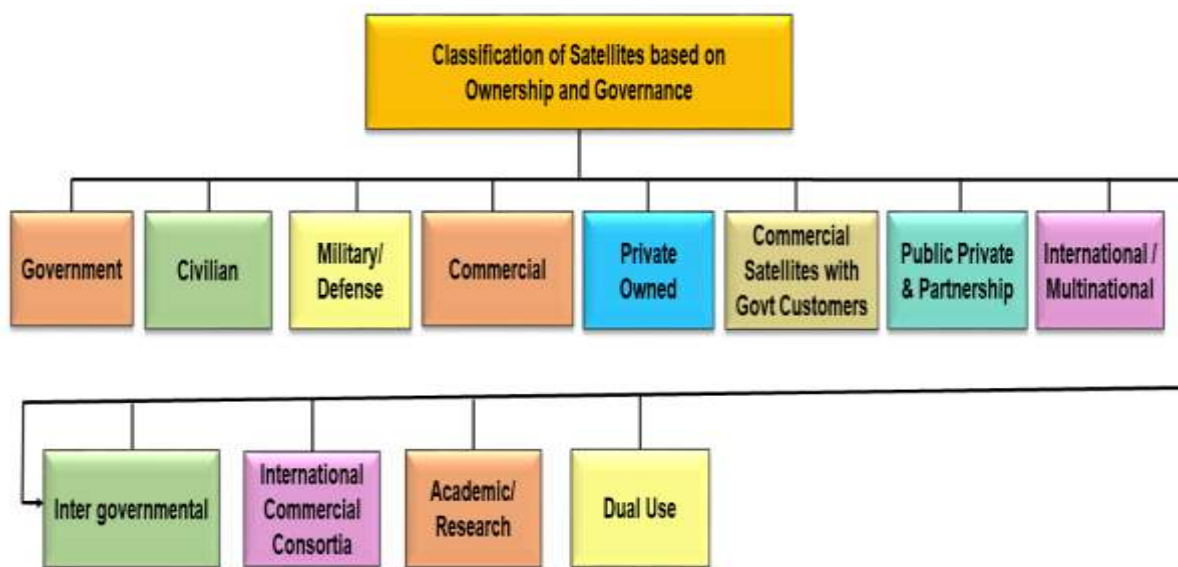


Figure13: Classification based on Ownership and Governance

9.1 Government (State-Owned) Satellites. Government satellites are owned, funded, and controlled by national governments. They operate under national space laws and international treaties such as the Outer Space Treaty (1967). These satellites are broadly divided into civil and military categories.

9.2 Civil Government Satellites These satellites are owned and operated by civilian space agencies (e.g., ISRO, NASA, ESA) or public institutions and are primarily intended for peaceful, developmental, and public-service missions. Some of the examples are INSAT / GSAT series Communication, broadcasting, meteorology satellites

9.3 Military / Defence Satellites. Military satellites are owned, controlled, and exclusively operated by defence organizations and are integral to modern military operations. These are Characterized by Classified or restricted access, Operated by armed forces or defence agencies, Governed by national security doctrines and Often integrated into weapon and command systems. Their Roles are Secure military communications, Intelligence,

Surveillance, and Reconnaissance (ISR), Missile early warning and tracking, Navigation and timing support and Electronic intelligence (ELINT). Examples are Reconnaissance and spy satellites and Navigation satellites with military signals (GPS, NavIC restricted services).

9.4 Commercial (Privately Owned) Satellites. Commercial satellites are owned and operated by private companies and function under commercial contracts and national licensing frameworks, even though states remain internationally responsible for them.

9.5 Purely Commercial Satellites. These satellites are fully private, serving civilian and business markets. These are characterized as privately funded and operated, Services sold on a commercial basis, Governed by national regulators and commercial law and No direct government ownership. Its uses include television broadcasting, Satellite broadband & internet, Commercial Earth imaging and IoT and data relay services. Examples include Intelsat, SES, Eutelsat for Communication services and Planet Labs, Maxar – Commercial Earth observation satellites.

9.6 Commercial Satellites with Government Customers. In this model, satellites remain commercially owned, but governments or militaries act as customers rather than owners. In this arrangement Ownership remains with private entity and Governments lease capacity or data. This is widely used to reduce costs and deployment time. However, this Blurs line between civil and military use and Raises questions on neutrality and targeting during conflicts

9.7 Public–Private Partnership (PPP) Satellites. PPP satellites are jointly developed, funded, or operated by government and private entities, with responsibilities shared through formal agreements. Its advantages are reduced government expenditure, faster technology adoption and it encourages private sector growth.

9.8 International / Multinational Satellites. These satellites involve multiple nations or entities across borders, governed by treaties, international organizations, or multinational commercial agreements.

9.9 Intergovernmental Satellites. These are owned and governed by multiple governments through formal treaties or conventions. These are characterized by Multinational funding, Joint governance structures, Data sharing among member states and operate under international public law. Examples are INTELSAT (original intergovernmental structure) and EUMETSAT satellites – European meteorological services

9.10 International Commercial Consortia. These are owned by private entities from multiple countries, but governed by international commercial law rather than treaties. These are characterized by corporate governance, Multinational ownership and regulated by host-country laws.

9.11 Academic / Research Satellites. Academic satellites are owned and operated by universities or research institutions, often with government

funding but independent governance. These are **used** for Technology demonstration, Space science experiments and Capacity building & training.

9.12 Dual-Use Satellites (Governance-Based). Dual-use satellites serve both civilian and military purposes, depending on operational needs and governance conditions. These are owned by government or private entities and Operate under civil governance in peacetime. These can be integrated into defence systems during emergencies.

10.0 INTERRELATIONSHIP BETWEEN WEIGHT AND FUNCTIONALITY.

Weight and functionality are mutually reinforcing in satellite design. For example Large communication satellites require big antennas and powerful transponders thus have larger mass. High-resolution reconnaissance satellites require large optics thus they have increased payload mass. Deep-space missions require radiation shielding and large propulsion systems resulting in high mass. Conversely, Femto- and pico-satellites cannot host heavy sensors or high-bandwidth communication systems. Nano-satellites (CubeSats) must balance payload mass with bus limitations. Medium and large satellites accommodate complex multi-instrument payloads. Modern space architectures shift from single heavy satellites to networks of smaller satellites. Examples include Starlink's LEO satellites (low weight, high throughput), Planet Labs' Earth observation fleet (high revisit rates using small satellites). This distributed model enhances resiliency and reduces mission risk.

11.0 FUTURE TRENDS IN SATELLITE WEIGHT AND FUNCTIONAL DESIGN

11.1 Advances in electronics reduce component size, enabling more complex missions with smaller satellites. Future satellites may use plug-and-play payload modules to increase flexibility. Refuelling and repair missions may extend the life of large satellites. Autonomous fault detection and mission planning are becoming standard. Hundreds or thousands of small satellites will redefine global connectivity and Earth imaging.

11.2 The classification of satellites based on weight and functionality provides a core framework for understanding modern spacecraft design, mission planning, and space systems engineering. Weight classification—from femto- to super heavy satellites—reflects physical constraints, launch capabilities, cost structures, and technological maturity. Functional classification—from communication and navigation to scientific research and military applications—defines the operational purpose and mission objectives. Together, these classifications shape how satellites are designed, deployed, and utilized in both civilian and military contexts. As the space sector evolves through miniaturization, AI integration, constellations, reusable launch systems, and interplanetary exploration, satellite classification frameworks will continue to guide engineering choices, regulatory policies, and strategic priorities. The interplay of weight and functionality remains central to the advancement of global space infrastructure.

11.3 The classification of satellites is inherently multidimensional, reflecting the complex interplay between mission requirements, orbital dynamics, system architecture, regulatory frameworks, and technological innovation. For professionals across aerospace, defence, telecommunications, and policy

sectors, a thorough understanding of these classifications supports more efficient mission design, improved interoperability, optimized spectrum usage, and enhanced resilience against emerging threats such as space congestion and counter space capabilities. As space systems evolve toward larger-scale constellations, autonomous operations, and interplanetary networks, the ability to classify and understand satellites through a rigorous technical lens will become increasingly essential for ensuring responsible and effective utilization of the space domain.

12.0 MILITARY SATELLITE APPLICATIONS. This section provides detailed information on military satellite applications. Every country needs a strong presence in space to protect its security and support its armed forces. Space Technology now plays a very important role in modern military operations. From observing borders and seas, to guiding missiles, communicating with troops, detecting enemy missiles early, and protecting its satellites, all these tasks depend heavily on satellites applications. Military Satellite applications are categorised in five main areas, as shown in **Fig. 14** covering all core and emerging military space capabilities internationally. Together, these five categories show how countries are moving from application of satellite use to a complete military space strategy. The government (ISRO and DRDO) and private companies are working together to build more satellites, make systems stronger against attacks, and prepare for future challenges in space.

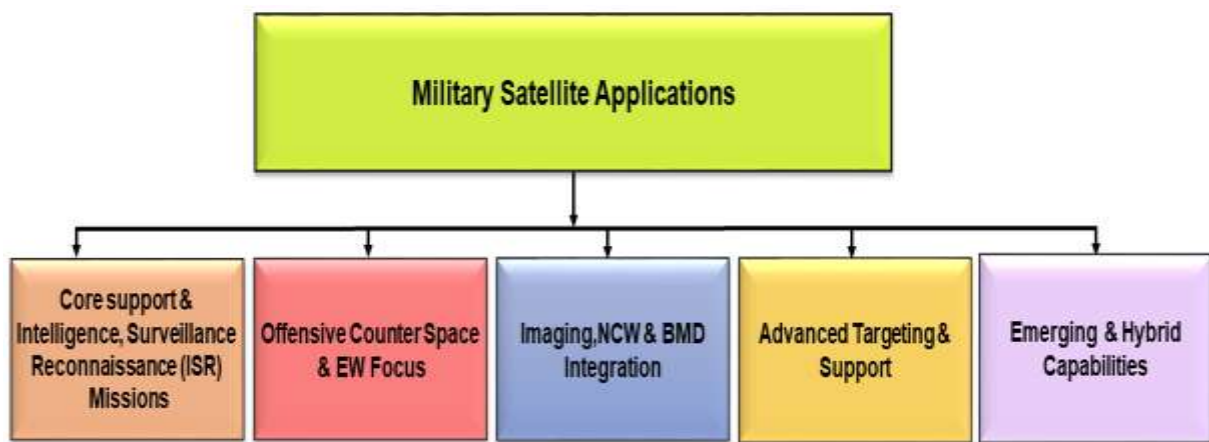


Figure14: Classification of Military Satellite applications

12.1 CORE SUPPORT & ISR MISSIONS. Core support & ISR missions can be classified as shown in **Fig.15**.

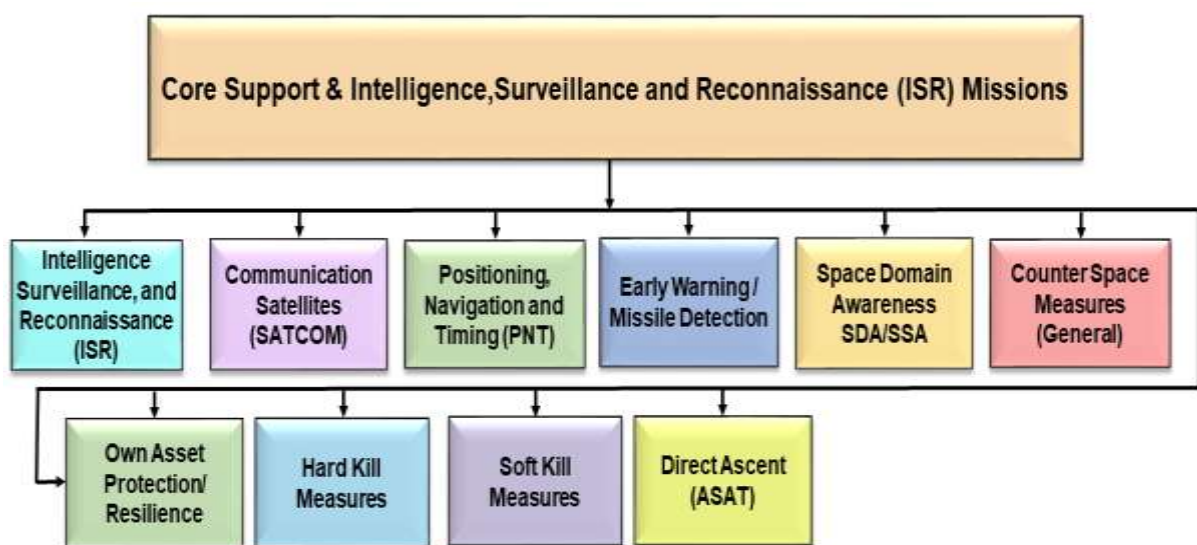


Figure15: Classification of Core Support & ISR Missions

12.1.1 Intelligence, Surveillance, and Reconnaissance (ISR). In the Indian military space ecosystem, ISR forms the foundational layer

for strategic and tactical awareness. It delivers persistent, multi-spectral monitoring of borders (particularly along the LAC and LOC), real-time tracking of troop deployments, vehicle movements, and infrastructure changes, maritime domain awareness across the Indian Ocean Region, battle damage assessment after engagements, and support for disaster response and humanitarian operations. The systems emphasize high-resolution imaging combined with all-weather, day-night capabilities through integration of electro-optical and synthetic aperture radar technologies. This enables rapid intelligence fusion for precision targeting, early warning of intrusions, and enhanced situational understanding for ground, air, and naval forces.

12.1.2 Communication Satellites (SATCOM). SATCOM provides the secure, reliable backbone for military command, control, and communications across all services. It supports encrypted voice, data, and video links for joint operations, beyond-line-of-sight connectivity in remote and high-altitude regions, tactical data exchange between drones, ships, aircraft, and ground units, and resilient backup during network disruptions or natural disasters. The emphasis is on jam-resistant, high-throughput channels capable of operating in contested electromagnetic environments. Ongoing developments aim to bridge capacity gaps and transition toward hybrid architectures that combine government-owned assets with emerging private-sector constellations for greater redundancy and scalability.

12.1.3 Positioning, Navigation, and Timing (PNT). PNT delivers precise location, velocity, and timing information essential for guided munitions, artillery fire control, naval and air navigation, synchronization of communication networks, and troop coordination in complex terrains. It is particularly vital in contested border areas where adversaries may attempt to degrade signals through jamming or spoofing. The indigenous regional system maintains seven operational satellites providing coverage over India and an extended 1,500 km radius, with military-grade signals designed for enhanced accuracy and anti-jam resilience. Continuous upgrades focus on improving robustness against electronic warfare threats, ensuring dependable performance for precision strike systems and time-sensitive operations.

12.1.4 Early Warning / Missile Detection. This capability focuses on rapid detection of ballistic and hypersonic missile launches, accurate trajectory estimation, and cueing of defensive systems. It serves as the first line of alert for both conventional and nuclear threats, enabling timely response and integration with layered missile defence architectures. Currently, India relies primarily on ground-based long-range tracking radars and phased BMD systems, but future enhancements plan to incorporate space-based infrared sensors for global early warning and improved discrimination of decoys from warheads. This evolution is driven by the need to address emerging hypersonic glide vehicles and multiple independently targetable re-entry vehicles deployed by regional adversaries.

12.1.5 Space Domain Awareness (SDA/SSA). SDA/SSA involves continuous monitoring of orbital objects, including debris, operational satellites, and potential threats from foreign systems passing over Indian territory. It supports collision avoidance, attribution of hostile manoeuvres, and overall space traffic management to protect national assets. Ground-based optical and radar networks form the current core, supplemented by planned orbital sensors to achieve persistent coverage, particularly in geosynchronous and low Earth orbits. This domain is increasingly critical as space becomes more congested and contested, requiring India to maintain situational awareness to safeguard its growing satellite infrastructure.

12.1.6 Counter Space Measures (General). Counter space operations aim to preserve Indian space superiority by denying, degrading, or destroying adversary space-enabled capabilities during conflict. This includes a spectrum of kinetic and non-kinetic tools, guided by a policy of responsible behaviour and minimum necessary action. Demonstrated capabilities and ongoing research reflect a balanced approach that combines deterrence with restraint to avoid unnecessary escalation or debris creation.

12.1.7 Own Asset Protection / Resilience. Protection strategies focus on making satellites harder to target and more survivable through hardening against electronic attacks, physical redundancy, rapid reconstitution, and distributed architectures. The shift toward proliferated low Earth orbit designs aims to reduce vulnerability to single-point failures or anti-satellite strikes, ensuring continuity of critical military functions even under sustained attack.

12.1.8 Hard Kill Measures. Hard kill involves physical destruction of adversary satellites using kinetic interceptors. India has demonstrated this capability at altitudes suitable for low Earth orbit engagements, though further testing has been paused under a voluntary moratorium to limit space debris risks. This option remains a credible deterrent within broader defence planning.

12.1.9 Soft Kill Measures. Soft kill methods achieve temporary or reversible disruption through electronic jamming, laser dazzling, high-power microwave effects, and cyber intrusions. These approaches offer lower escalation thresholds and are preferred in limited-conflict scenarios, relying heavily on ground-based systems with potential future orbital extensions.

12.1.10 Direct Ascent ASAT. Direct ascent anti-satellite weapons enable rapid, ground-launched interception of satellites in low to medium orbits. Integrated with missile defence programs, this capability provides a swift response option for neutralizing high-value orbital threats, though its use is constrained by international norms and debris concerns.

12.2 Offensive Counterspace & EW Focus. Offensive Counterspace & EW Focus is shown in **Fig.16**.

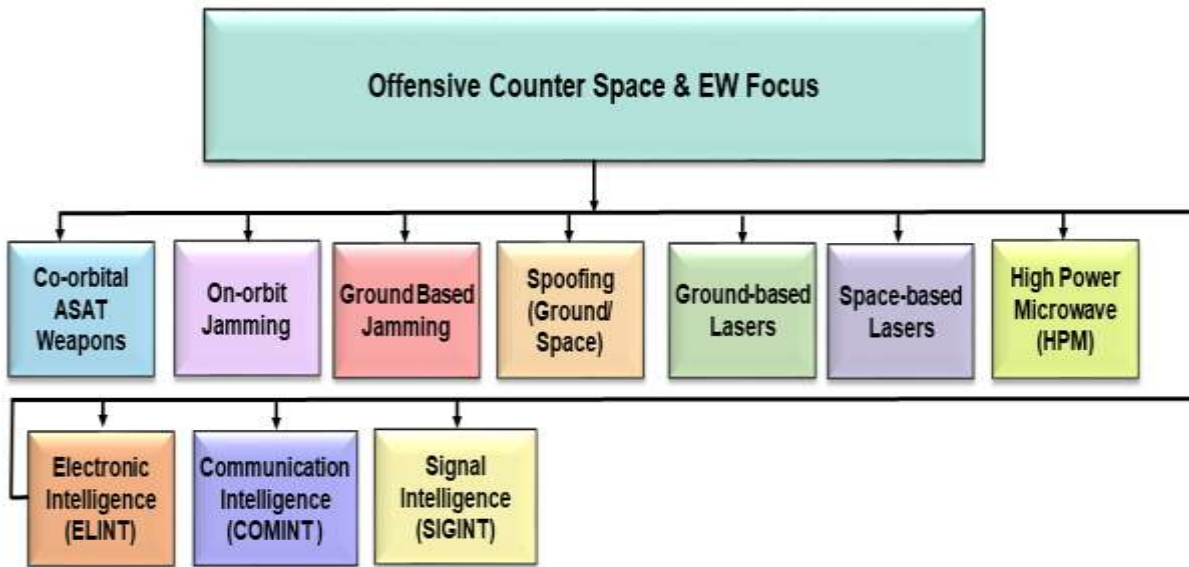


Figure16: Offensive Counter Space & EW Focus

12.2.1 Co-orbital ASAT Weapons. Co-orbital anti-satellite weapons represent a sophisticated, hard-to-attribute form of counterspace capability, allowing a satellite to manoeuvre into close proximity with a target and then disable or destroy it through mechanisms such as kinetic impact, robotic grappling, explosive charges, or embedded jamming devices. In the Indian context, this approach remains largely conceptual and in early research stages, with no publicly demonstrated or operational systems. The focus is on understanding dual-use technologies like rendezvous and proximity operations, which could support both servicing of friendly assets and potential offensive actions. Development in this area would provide India with a stealthier, reversible or permanent denial option in high-escalation space conflicts, particularly against adversary satellites operating in similar orbits, while minimizing immediate debris signatures compared to direct-ascent methods.

12.2.2 On-orbit Jamming. On-orbit jamming involves deploying space-based platforms to emit interfering radio-frequency signals that disrupt adversary satellite communications, navigation broadcasts, or data downlinks. This capability offers persistent, orbital-position-specific denial without physical destruction, making it suitable for controlled escalation scenarios. In India's current position, no dedicated on-orbit jamming satellites exist, and the concept remains undeveloped in the public domain. Any future pursuit would likely build on existing electronic warfare expertise, aiming to complement ground-based systems by providing coverage over regions where terrestrial jammers have line-of-sight limitations.

12.2.3 Ground-based Jamming. Ground-based jamming is the most mature and operationally deployed form of soft-kill counterspace in India. Mobile or fixed electronic warfare units transmit powerful

signals to overwhelm or block satellite uplinks, downlinks, GPS receivers, or SATCOM terminals used by adversary forces. This technique is particularly effective in border regions for denying real-time navigation, drone control, and battlefield communications during limited conflicts. DRDO-developed systems provide tactical flexibility, rapid deployment, and integration with existing army and air force electronic warfare units, offering a low-cost, reversible means to degrade space-enabled capabilities without crossing into kinetic thresholds.

12.2.4 Spoofing (Ground/Space). Spoofing creates false navigation or timing signals to mislead receivers, causing positional errors, timing desynchronization, or false command acceptance in adversary systems. In the Indian scenario, ground-based spoofing capabilities are part of electronic warfare toolkits used in exercises to simulate contested environments and test countermeasures. Space-based spoofing remains conceptual. This method is valuable for deception operations, disrupting precision-guided munitions or coordinated movements without physical engagement, and aligns with India's emphasis on non-escalatory responses in hybrid conflict settings.

12.2.5 Ground-based Lasers. Ground-based directed-energy lasers target satellite optical sensors, solar arrays, or communication antennas to dazzle (temporary blinding), blind (permanent sensor damage), or thermally degrade components. DRDO is advancing high-energy laser research primarily for counter-drone and missile defence roles, with potential crossover applications to low-orbit satellites. These systems offer speed-of-light engagement, reusable effects, and lower collateral risks than kinetic weapons, making them attractive for graduated responses against reconnaissance or communication satellites passing over sensitive areas.

12.2.6 Space-based Lasers. Space-based lasers would place directed-energy weapons in orbit for precise, line-of-sight dazzling, blinding, or thermal damage against adversary satellites. This capability remains purely conceptual in India, with no known development programs or prototypes. If pursued in the future, it would provide persistent, global-reach denial options, though technical challenges (power generation, thermal management, targeting accuracy) and international treaty implications would pose significant hurdles.

12.2.7 High Power Microwave (HPM). High-power microwave weapons generate intense electromagnetic pulses that can overload and disable satellite electronics, ground terminals, or onboard systems without kinetic impact. DRDO has developed ground-based HPM prototypes, primarily for counter-electronics roles against drones and missiles, with latent applicability to space targets at closer ranges. HPM offers wide-area, non-kinetic effects suitable for area denial or temporary neutralization, complementing jamming and laser approaches in a layered counter space strategy.

12.2.8 Electronic Intelligence (ELINT). ELINT collects and analyses non-communications electromagnetic emissions (primarily radar signals) to characterize adversary emitters, locate platforms, and build electronic order-of-battle databases. In India, this supports border threat assessment, air defence cueing, and targeting of enemy radar networks. Dedicated payloads provide passive, long-range collection, feeding into multi-intelligence fusion centers for real-time decision support.

12.2.9 Communications Intelligence (COMINT). COMINT intercepts and exploits adversary voice, text, and data communications to reveal command intent, force dispositions, and operational plans. India utilizes dual-use satellite payloads and ground stations to gather COMINT, particularly from regional actors, contributing to strategic warning and operational planning. The capability enhances understanding of enemy C2 structures and supports information operations.

12.2.10 Signals Intelligence (SIGINT). SIGINT combines ELINT and COMINT (along with other signals types) into comprehensive intelligence products that reveal adversary capabilities, intentions, and vulnerabilities. India is expanding SIGINT through dedicated payloads on military satellites and planned constellations, enabling broader coverage and faster processing. This fused intelligence directly informs force posture, targeting, and diplomatic signalling in contested domains.

12.3 Imaging, NCW & BMD integration. Imaging, NCW & BMD integration can be classified as shown in Fig.17.

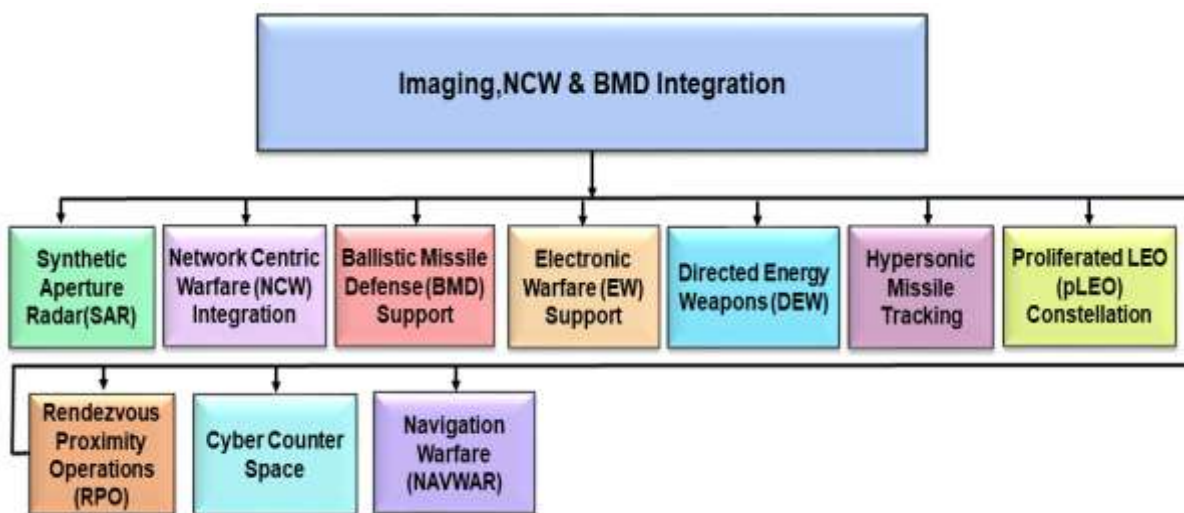


Figure17: Classification of Imaging, NCW & BMD Integration

12.3.1 Synthetic Aperture Radar (SAR). Synthetic Aperture Radar provides high-resolution, all-weather; day-and-night imaging that penetrates clouds, fog, and darkness, making it indispensable for continuous border and maritime surveillance in India's diverse climatic

conditions. It excels in terrain mapping, detecting camouflaged targets, identifying ship movements in the Indian Ocean Region, monitoring infrastructure changes along disputed boundaries, and supporting precision strike planning. SAR's ability to generate detailed imagery regardless of environmental factors ensures persistent reconnaissance over remote or contested areas, feeding directly into command centers for rapid decision-making and operational planning.

12.3.2 Network Centric Warfare (NCW) Integration. Network Centric Warfare leverages space-based assets to create a shared, real-time information environment across the Army, Navy, and Air Force. It integrates ISR feeds, SATCOM links, and PNT data to deliver common operational pictures, accelerate the observe-orient-decide-act loop, enhance coordination between services, and improve combat effectiveness through synchronized manoeuvres and fires. In the Indian context, this manifests in evolving tri-service networks that fuse satellite-derived intelligence with ground sensors, enabling faster response to border incursions, joint air-land operations, and maritime domain control.

12.3.3 Ballistic Missile Defence (BMD) Support. BMD support from space involves early detection, precise tracking, and signalling of interceptors to counter ballistic and emerging hypersonic threats. Orbital sensors would provide wide-area coverage, discriminate warheads from decoys, and deliver critical handover data to ground and sea-based systems. India's phased BMD program currently relies heavily on terrestrial radars, but future incorporation of space-based elements aims to strengthen layered defence against regional missile arsenals, ensuring higher intercept probabilities and reduced warning times.

12.3.4 Electronic Warfare (EW) Support. EW support from space coordinates the electromagnetic spectrum to disrupt, deceive, or deny adversary use of communications, radar, and navigation systems. It includes jamming uplinks/downlinks, spoofing signals, and collecting emissions for targeting. In India, this bridges ground-based EW units with orbital payloads to create multi-domain effects, particularly useful for suppressing enemy C2 in border conflicts or protecting friendly forces from space-enabled threats.

12.3.5 Directed Energy Weapons (DEW). Directed energy weapons, including high-energy lasers and high-power microwaves, offer speed-of-light, precision effects for counter space, missile defence, and counter-drone roles. They can dazzle or damage satellite sensors, disrupt electronics, or intercept projectiles with minimal collateral. India's DRDO programs are progressing toward operational prototypes, primarily ground-based, with potential future orbital or airborne extensions to provide non-kinetic, reusable denial options against space and aerial threats.

12.3.6 Hypersonic Missile Tracking. Hypersonic missile tracking requires persistent, high-cadence sensing to detect, characterize, and follow low-altitude, manoeuvring glide vehicles that evade traditional radar coverage. Space-based infrared and radiofrequency sensors would provide early warning, trajectory prediction, and handover to interceptors. This capability addresses a growing priority in India due to regional adversaries' hypersonic developments, with planned integration into next-generation surveillance constellations to close detection gaps.

12.3.7 Proliferated LEO (PLEO) Constellations. Proliferated Low Earth Orbit constellations distribute functions across numerous small satellites to achieve resilience against jamming, physical attack, or single-point failures. They deliver low-latency communications, frequent revisit ISR, and redundant PNT, ensuring continuity even if portions are degraded. India's emerging strategy emphasizes small satellite swarms for cost-effective, survivable architectures, blending government and private-sector contributions to rapidly scale capacity and reduce vulnerability.

12.3.8 Rendezvous and Proximity Operations (RPO). Rendezvous and Proximity Operations enable satellites to approach, inspect, service, or potentially interact with other objects in orbit. Applications include on-orbit refuelling, repair, debris inspection, and defensive manoeuvring. In India, this domain is in early development, with technology demonstrations focusing on docking and relative navigation, offering dual-use potential for asset life extension and future counterspace roles.

12.3.9 Cyber Counterspace. Cyber counterspace protects Indian satellites and ground stations from intrusion while exploring options to exploit or disrupt adversary space systems through software vulnerabilities, command-link interference, or supply-chain attacks. Emphasis remains on defensive hardening, anomaly detection, and secure architectures, with DRDO cyber units leading efforts to safeguard critical military space infrastructure in an increasingly digitized battlespace.

12.3.10 Navigation Warfare (NAVWAR). Navigation Warfare encompasses protecting indigenous PNT signals from interference while denying or degrading adversary navigation capabilities. It includes anti-jam technologies, frequency-hopping, authentication mechanisms, and offensive jamming/spoofing. India's approach prioritizes robust military-grade signals and countermeasures to maintain precision in contested environments, ensuring reliable guidance for weapons and forces during electronic conflict.

12.4 Advanced Targeting & Support. Advanced Targeting & Support can be classified as shown in Fig.18.



Figure18: Classification of Advanced Targeting & Support

12.4.1 Space-Based Targeting. Space-Based Targeting shortens the sensor-to-shooter timeline by enabling direct, near-real-time signalling from orbital sensors to ground, air, naval, or missile platforms. In the Indian context, this capability is vital for time-sensitive targeting of mobile launchers, terrorist camps, naval task forces, or cross-border infrastructure during rapid-escalation scenarios. It relies on high-revisit-rate ISR constellations feeding geolocated coordinates and target metadata directly into fire-control networks (e.g., BrahMos command posts, artillery digital systems, fighter aircraft targeting pods). Challenges include secure, low-latency data relay in contested environments and integration across tri-service networks. When mature, this will significantly enhance India's conventional deterrence by compressing the observe-orient-decide-act cycle against time-critical threats.

12.4.2 Meteorology / Environmental Support. Meteorological and environmental satellites deliver actionable weather intelligence that directly influences mission success across all domains. For the Indian military, this includes forecasting monsoon cloud cover affecting air operations, predicting dust storms impacting western border visibility, assessing sea-state conditions for amphibious or carrier operations, and providing atmospheric data for ballistic trajectory corrections and sensor performance modelling. Dual-use satellites supply visible, infrared, and microwave imagery that supports not only operational planning but also environmental reconnaissance (e.g., assessing camouflage effectiveness or river-crossing feasibility). The data also feeds into disaster-response planning, allowing rapid redeployment of forces during cyclones or floods. India maintains a small but reliable constellation of meteorological satellites with ongoing efforts to improve temporal resolution and integration with numerical weather prediction models used by the three services.

12.4.3 Ocean Surveillance. Ocean Surveillance provides wide-area, persistent monitoring of surface and near-surface activity in the Indian Ocean Region, critical for maritime domain awareness, anti-submarine warfare support, counter-piracy, EEZ enforcement, and

protection of sea lines of communication. It combines radar signatures, optical identification, AIS correlation, and signals intelligence to track merchant vessels, naval combatants, fishing fleets, and anomalous behaviour (dark ships, loitering patterns). For India, this capability supports the Navy's carrier battle group operations, submarine deployment planning, and response to adversaries.

12.4.4 Geosynchronous SSA. Geosynchronous Space Situational Awareness delivers continuous, high-altitude monitoring of assets and activities in the GEO belt, where India stations critical communication and potential early-warning satellites. It detects station-keeping anomalies, proximity operations, unusual manoeuvres, and potential threats from inspector or co-orbital vehicles. Given the strategic importance of GEO slots over the Indian subcontinent, persistent coverage is essential for early warning of interference attempts. India currently relies on ground-based telescopes and limited orbital sensors, but future spy constellations will incorporate dedicated GEO-facing payloads to build a robust high-orbit picture, supporting both defensive repositioning and attribution in crisis scenarios.

12.4.5 Anti-Jam SATCOM. Anti-Jam SATCOM ensures reliable, secure communications in electronically contested environments through protected waveforms, spread-spectrum techniques, adaptive nulling antennas, and frequency-hopping. For Indian forces operating along contested borders or in maritime standoffs, this capability maintains C2 continuity when adversaries deploy mobile jammers or spoofers. Military-specific transponders on dedicated satellites already incorporate anti-jam features, with future systems planned to include advanced beam-forming and on-board processing to dynamically counter interference.

12.4.6 On-Orbit Servicing / Refuelling. On-orbit servicing and refuelling extend the operational life of high-value satellites by replenishing propellant, replacing failed components, upgrading payloads, or performing inspections. This directly enhances resilience by delaying costly replacements and enabling defensive orbital adjustments. India has successfully demonstrated key technologies (docking, fluid transfer, relative navigation), positioning the country among a small group of nations capable of mature servicing operations. Future applications will focus on military communication and ISR satellites, reducing vulnerability windows during replenishment and supporting sustained presence in contested orbits.

12.4.7 Electromagnetic Spectrum Dominance. Electromagnetic Spectrum Dominance integrates sensing, electronic attack, protection, and management to control the usable spectrum across all warfighting domains. For India, this means denying adversary use of radar, communications, and navigation while preserving friendly access in dense electromagnetic environments along borders and sea lanes. It combines ground EW units, satellite payloads, and cyber tools into a cohesive framework that supports both offensive disruption and

defensive hardening, essential for maintaining information superiority in modern conflict.

12.4.8 Informatized Warfare Support. Informatized Warfare Support exploits the fusion of space-derived data (ISR, SATCOM, PNT, weather etc) with AI, machine learning, and big-data analytics to generate predictive insights, automated target recognition, and decision superiority. In the Indian context, this enables commanders to anticipate adversary moves, optimize resource allocation, and conduct multi-domain operations with reduced uncertainty. The tri-services are progressively building joint fusion centers that integrate satellite feeds, creating a foundation for network-centric, knowledge-based warfare.

12.4.9 Nuclear Detonation Effects Mitigation Nuclear Detonation Effects Mitigation designs satellites to survive the electromagnetic pulse (EMP), ionizing radiation, thermal flash, and prompt gamma-ray effects of a high-altitude nuclear burst. Hardened electronics, shielding, redundant systems, and nuclear-survivable waveforms ensure continuity of strategic command, early warning, and communication links in nuclear conflict scenarios. India incorporates these protections in key military satellites to maintain nuclear command authority and retaliatory options even under nuclear attack conditions.

12.4.10 Orbital Warfare / Manoeuvre. Orbital Warfare involves the offensive and defensive use of orbital dynamics rapid repositioning, evasion trajectories, altitude changes, and plane changes to gain positional advantage or deny adversary access. Advanced electric propulsion, autonomous guidance, and rapid manoeuvre planning enable satellites to respond to threats dynamically. For India, this emerging capability will support defensive dispersion, offensive repositioning to cover new theatres, and resilience against co-orbital or direct-ascent threats.

12.5 Emerging & Hybrid Capabilities. Emerging & Hybrid Capabilities can be classified as shown in Fig.19.

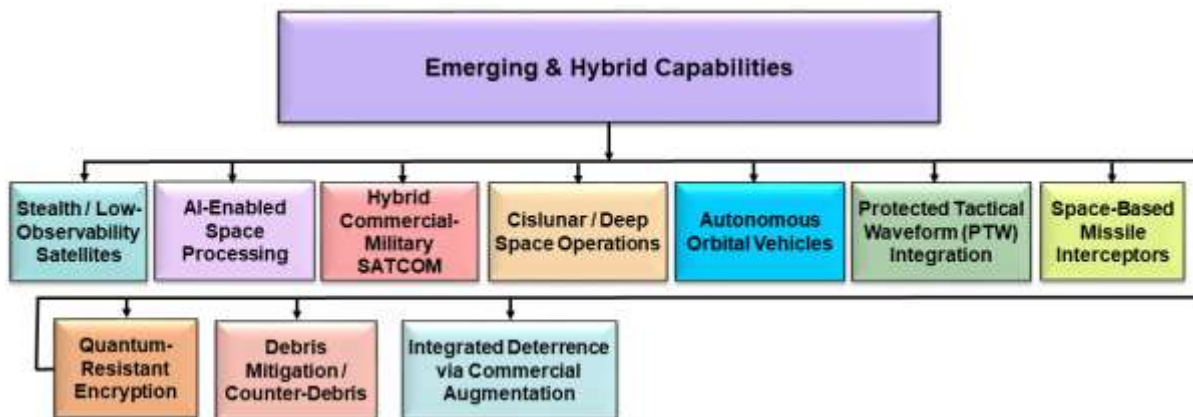


Figure 19: Classification of Emerging & Hybrid Capabilities

12.5.1 Stealth / Low-Observability Satellites. Stealth or low-observability satellites minimize radar cross-section, optical reflectivity, thermal signature, and RF emissions to evade ground- and space-based tracking networks. This reduces the probability of detection and targeting by adversary SSA systems. While India has not yet fielded dedicated stealth satellites, research into low-signature materials, shapes, and emission control is underway, particularly for future high-value reconnaissance or counterspace platforms operating in contested orbits.

12.5.2 AI-Enabled Space Processing. AI-Enabled Space Processing moves computation onboard satellites to perform real-time image analysis, target detection, change detection, anomaly identification, and autonomous tasking. This drastically reduces downlink bandwidth requirements, latency, and dependence on ground stations. In India's context, AI payloads on future constellations will enable persistent monitoring with automated alerts for border intrusions, ship movements, or missile launches, significantly enhancing responsiveness and reducing operator workload.

12.5.3 Hybrid Commercial-Military SATCOM. Hybrid Commercial-Military SATCOM combines protected government satellites with high-capacity commercial constellations to provide surge bandwidth, rapid replenishment, and diversified pathways. This approach increases resilience against targeted attacks on military-only assets and leverages private-sector innovation for cost-effective expansion. India is actively pursuing partnerships that allow military users to access commercial capacity during crises while maintaining secure fallback to dedicated systems.

12.5.4 Cislunar / Deep Space Operations. Cislunar and Deep Space Operations extend military-relevant domain awareness and presence beyond geosynchronous orbit to lunar distances and interplanetary trajectories. This includes tracking adversary lunar missions, securing future resource nodes, and supporting deep-space communication relays. India's ongoing lunar program provides foundational experience, with future military applications likely focused on SSA, navigation beacons, and potential defensive positioning in cislunar space.

12.5.5 Autonomous Orbital Vehicles. Autonomous Orbital Vehicles operate with minimal ground control, performing inspection, characterization, proximity operations, and response tasks independently. They increase operational tempo, reduce uplink vulnerabilities, and enable persistent presence in key orbits. India's technology demonstrations in relative navigation and docking lay the groundwork for future autonomous platforms that could support servicing, reconnaissance, or counterspace missions.

12.5.6 Protected Tactical Waveform (PTW) Integration. Protected Tactical Waveform Integration delivers high-data-rate, low-probability-of-intercept communications optimized for tactical users in electronically contested environments. It combines anti-jam techniques, encryption, and waveform agility to ensure voice, video, and data reach forward-deployed units despite jamming. Future Indian military SATCOM will incorporate PTW-like capabilities to maintain tactical connectivity during high-intensity conflict.

12.5.7 Space-Based Missile Interceptors. Space-Based Missile Interceptors conceptualize placing kinetic kill vehicles or directed-energy weapons in orbit for global, layered ballistic and hypersonic missile defence. This would provide boost-phase or mid-course intercept opportunities with minimal reaction time. While still theoretical in India, the concept aligns with long-term aspirations for comprehensive missile defence against regional threats.

12.5.8 Quantum-Resistant Encryption. Quantum - Resistant Encryption replaces vulnerable algorithms with post-quantum cryptography to protect SATCOM, PNT signals, and command links against future quantum computers capable of breaking current standards. India is incorporating lattice-based, hash-based, and multivariate schemes into next-generation military satellite designs to future-proof strategic communications.

12.5.9 Debris Mitigation / Counter-Debris. Debris Mitigation and Counter-Debris strategies minimize the creation of long-lived orbital debris through design guidelines (passivation, de-orbit plans) and explore active removal techniques. For India, responsible operations are essential to protect the growing constellation from cascading collision risks, particularly after ASAT demonstrations. Private-sector innovations are expected to play a key role in developing affordable de-orbit and capture technologies.

12.5.10 Integrated Deterrence via Commercial Augmentation. Integrated Deterrence via Commercial Augmentation harnesses the private space sector's speed, innovation, and scalability to augment government capabilities, creating a resilient, whole-of-nation space ecosystems. Through public-private partnerships, India leverages startups for rapid prototyping, proliferated constellations, and surge capacity, ensuring that commercial assets can be mobilized as a reserve force multiplier in crisis or conflict, thereby strengthening deterrence by denial and raising the cost of any attempt to degrade Indian space power.

13.0 CONCLUSION

13.1 Satellites have evolved from passive reconnaissance tools to integral components of global military power. They enable strategic decision-making, ensure resilient communication, guide precision weapons, and support real-time operational awareness across every domain of conflict. As technological innovation accelerates and geopolitical tensions heighten, satellites will continue shaping the course of warfare, diplomacy, deterrence, and national security. The integration of military doctrine with engineering and standards development is not only necessary but inevitable. Defence forces must understand both the strategic necessity and the technical fragility of space systems. Space is no longer a silent or distant arena—it is the beating heart of modern war fighting capability. The future of military power on Earth now depends, to an unprecedented degree, on what is built and protected in orbit.

13.2 India's military space journey has reached a strong and balanced stage. Reliable ISR, SATCOM, and NavIC systems already give real-time advantage on borders and seas. The futuristic satellite program and BMD integration mark a major leap in persistent coverage and defence. Counterspace tools, electronic warfare, and directed-energy efforts provide credible protection. Emerging capabilities like onboard AI, satellite servicing, and proliferated orbits show clear foresight.

13.3 Private companies are bringing speed, innovation, and affordable scale to the ecosystem. Resilience against jamming, ASAT attacks, and cyber threats remains the top priority. This multi-layered approach guarantees space support stays available in any scenario. India is no longer just using space; it is shaping it for national security. A self-reliant, future-proof military space foundation is now taking solid shape.

13.4 This JSG covers the classification of satellites based on application, Mass regime, orbit, ownership and governance. This also covers various applications of Military Satellites in detail. This JSG will serve as a standard for all concerned.

14.0 SUGGESTIONS FOR IMPROVEMENT

Any suggestions for improvement in this document may be forwarded to:

The Director,
Directorate of Standardisation,
Ministry of Defence
6th Floor, 'A' Block,
Defence Offices Complex,
K G Marg, New Delhi-110001.