About ISRO and India’s National Space Programmes

1. Institutional Structure Related to Space Programme in India

- Space activities in the country were initiated with the setting up of the **Indian National Committee for Space Research (INCOSPAR) in 1962.**
- In the same year, work on Thumba Equatorial Rocket Launching Station (TERLS) near Thiruvananthapuram was also started.
- Indian Space Research Organisation (ISRO) was established in August 1969.
- The Government of India constituted the Space Commission and established the **Department of Space (DOS) in June 1972** and brought ISRO under DOS in September 1972.
- The Space Commission formulates the policies and oversees the implementation of the Indian space programme to promote the development and application of space science and technology for the socio-economic benefit of the country.
- DOS implements these programmes through, mainly, ISRO, Physical Research Laboratory (PRL), National Atmospheric Research Laboratory (NARL), North Eastern-Space Applications Centre (NE-SAC) and Semi-Conductor Laboratory (SCL).
- **Antrix Corporation, established in 1992** as a government owned company, markets the space products and services.
- Programme offices at ISRO headquarters coordinate the programmes like satellite communication, earth observation, launch vehicle, space science, disaster management support, international cooperation, system reliability, safety, etc.

2. Indian Space Research Organisation (ISRO)

2.1. Introduction

- ISRO is the space agency of India.
- The organization is involved in science, engineering and technology to harvest the benefits of outer space for India and mankind.
- ISRO was previously the **Indian National Committee for Space Research** (INCOSPAR), **set up in 1962**, as envisioned by Dr. Vikram Sarabhai.
- ISRO was formed on **August 15, 1969** and superseded INCOSPAR.

2.2. Objective

- The prime objective of ISRO/DOS is the development and application of space technology for various national needs.
- To fulfill this objective, ISRO has established a major space system for
    - communication, television broadcasting and meteorological services;
    - resources monitoring and management;
    - space-based navigation services.

- ISRO has developed satellite launch vehicles, PSLV and GSLV, to place the satellites in the required orbits.

2.3. Headquarters

- ISRO has its headquarters in **Bengaluru.**
- Launch Vehicles are built at Vikram Sarabhai Space Centre (VSSC), Thiruvananthapuram.
- Satellites are designed and developed at U R Rao Satellite Centre (URSC), Bangalore.
- Integration and launching of satellites and launch vehicles are carried out from Satish Dhawan Space Centre (SDSC), Sriharikota.

2.4. Execution of Indian Space Programme

DOS, through its agency ISRO, has evolved the following programmes with the objective of promoting and developing application of space science and space technology:

- **Launch Vehicle programme** having indigenous capability for launching satellites.
- **INSAT Programme** for telecommunications, broadcasting, meteorology, development of education etc.
- **Remote Sensing Programme** for application of satellite imagery for various developmental purposes.
- Research and Development in Space Sciences and Technology for serving the end of applying them for national development.

3. National Space Missions

3.1. Mangalyaan (Mars Orbiter Mission)

- Mars Orbiter Mission (MOM), popularly known as Mangalyaan, marks **India's first venture into interplanetary space.**
- The spacecraft launched on November 5, 2013, arrived safely into Mars orbit on September 24, 2014.
- ISRO has become the fourth space agency to reach Mars, after the Soviet space program, NASA, and the European Space Agency.
- As a result, India made history by becoming the **first-ever country to reach Mars on the first attempt** and it was done on a light budget.
- MOM was designed to explore and observe the Mars surface features, mineralogy and the Martian atmosphere.
- Further, it also performed a focused research in search of methane in the Martian atmosphere to enquire about the possibility or the past existence of life on the planet.

3.1.1. Equipment on board MOM

- **Lyman Alpha Photometer (LAP)** is an absorption cell photometer. It measures the relative abundance of Deuterium and Hydrogen from spectral studies of the Martian upper atmosphere (Exosphere and Exobase).
- **Methane Sensor for Mars (MSM)** was designed to measure methane in the Martian atmosphere with a particle-per-billion accuracy and also capacity to map the sources.
- **Mars Exospheric Neutral Composition Analyser (MENCA)** is a quadrupole mass spectrometer capable of analysing the neutral composition in the range of 1 to 300 amu, the range in which the bulk proportion of gases of the Martian atmosphere falls.

- **Mars Colour Camera (MCC)** images give useful inputs about the surface features and composition of the Martian surface and to monitor the dynamic events and weather of Mars.
- **Thermal Imaging Spectrometer (TIS)** is for surface and atmospheric exploration using thermal remote sensing and also detecting the sources of thermal radiation in the Martian environment.

3.1.2. Duration of Mars Mission

- Mangalyaan was planned for a mission life of six months. However, due to fuel-saving manoeuvres and accurate orbital injections and firings saved 20 Kg of fuel, making 40 Kg of fuel at the time of Mars's high elliptical orbit insertion.
- The functioning of instruments with no or less degradation even after six months of working under such harsh conditions is another great feat of the orbiter.
- ISRO utilized this opportunity to make use of the data and worked towards familiarizing the Martian conditions.
- The Control and Command Unit made necessary orbital corrections to further prolong the life of MOM to endure solar eclipse, bursts, flares and other mission unplanned phenomena.
- MOM instruments' prolonged functioning also helped to understand the response and health of the instrument to work in such harsh conditions.
- On October 02, 2022, it was reported that the orbiter had irrecoverably lost communications with Earth after entering a seven-hour eclipse period in April 2022 that it was not designed to survive.
- The following day, ISRO released a statement that all attempts to revive MOM had failed and officially declared it dead.

3.2. Chandrayaan I

- Chandrayaan I was India's first Moon mission.
- The mission had 11 payloads built by India, the United Kingdom, the United States of America, Germany, Bulgaria and Sweden.
- Chandrayaan mission, launched on a PSLV rocket on October 22, 2008 from Sriharikota, was designed to collect data about the topography of the Moon.
- The spacecraft was orbiting around the Moon at the height of 100 km from the lunar surface.

3.2.1. Significance of Chandrayaan I Mission

- It collected data on chemical, mineralogical and photo-geologic mapping of the Moon.
- The data from Chandrayaan I helped discover the presence of water on the Moon in September 2009.

3.3. Chandrayaan II

- Chandrayaan II is the second lunar exploration mission of the ISRO after Chandrayaan I.
- It consisted of an orbiter, a lander named Vikram and a rover named Pragyan.
- The spacecraft was launched from the second launch pad at the Satish Dhawan Space Centre in Andhra Pradesh on 22 July 2019 by GSLV MkIII-M1.
- The lander and the rover were scheduled to land on the near side of the Moon, in the south polar region on 6 September 2019.

- A successful soft landing would have made India the fourth country to land on the moon after the Soviet Union, United States and China.
- However, the lander crashed when it deviated from its intended trajectory while attempting to land.

3.3.1. Mission Objectives

- To develop and demonstrate the key technologies for end-to-end lunar mission capability, including soft-landing and roving on the lunar surface.

3.3.2. Science Objectives

- To expand the lunar scientific knowledge through detailed study of topography, mineralogy, surface chemical composition, thermo-physical characteristics and tenuous lunar atmosphere leading to a better understanding of the origin and evolution of the Moon.

3.3.3. Relevance of Chandrayaan II Mission

- Despite the failure, the mission's orbiter and other parts had functioned normally and gathered information.
- The information included the presence of water molecules on the moon, information about solar flares and discovery of minor elements.

3.4. Chandrayaan III

- Chandrayaan III is a follow-on mission to Chandrayaan II to demonstrate end-to-end capability in safe landing and roving on the lunar surface.
- It was **launched on 14 July 2023 by LVM3 M4** from the Satish Dhawan Space Center, and the lander and rover **landed near the lunar south pole region on 23 August 2023.**
- With this, **India has become the fourth country** – after Russia, the United States and China – to land on the moon and **also the first to land on the moon's South Pole.**

3.4.1. Mission objectives of Chandrayaan III

- To demonstrate Safe and Soft Landing on the Lunar Surface.
- To demonstrate Rover roving on the moon.
- To conduct in-situ scientific experiments.

3.4.2. Components of Chandrayaan III

It consists of an **indigenous Lander module (LM), Propulsion module (PM) and a Rover.** The lander (Vikram) and rover payloads (Pragyan) of Chandrayaan III remain the same as the Chandrayaan II mission.

Propulsion module

- It is a box-like structure with one large solar panel mounted on one side and a large cylinder on top that acts as a mounting structure for the lander.
- It has one instrument called the **Spectropolarimetry of HAbitable Planet Earth** (SHAPE) to study Earth from lunar orbit.

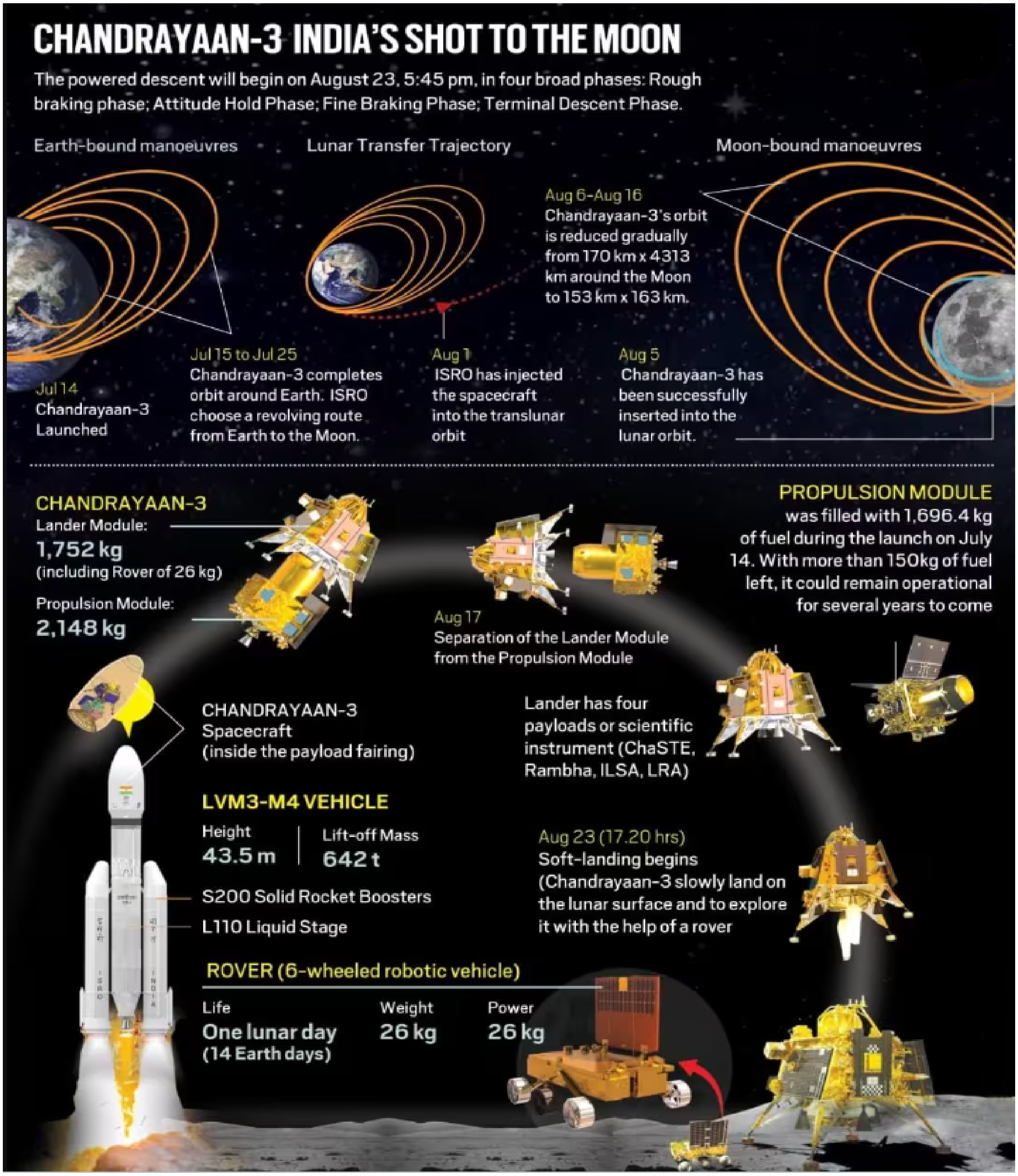
Vikram

- The Vikram lander is **responsible for the soft landing** on the Moon. It is box-shaped, with four landing legs and four landing thrusters capable of producing 800 newtons of thrust each.
- Payloads of Vikram lander are:

    - an instrument called **Chandra's Surface Thermophysical Experiment** (ChaSTE) to measure surface thermal properties,
    - the **Instrument for Lunar Seismic Activity** (ILSA) to measure seismicity around the landing site,
    - the **Radio Anatomy of Moon Bound Hypersensitive ionosphere and Atmosphere** (RAMBHA) to study the gas and plasma environment, and
    - a passive **laser retroreflector array** provided by NASA for lunar ranging studies.

Pragyan

- Pragyan rover has navigation cameras and a solar panel that can generate 50 W.
- It has two instruments to study the local surface elemental composition, an **Alpha Particle X-ray Spectromete**r (APXS) and **Laser Induced Breakdown Spectroscopy** (LIBS).



Infographic: How the Chandrayaan III Reached the Lunar Orbit

3.4.3. Changes and Improvements in Chandrayaan III

Simplified Payload

- Unlike Chandrayaan II, which comprised the Vikram lander, Pragyan rover, and an orbiter, Chandrayaan III is **equipped with a lander and a rover only.**
- While Chandrayaan II's orbiter carried nine in-situ instruments, Chandrayaan III's propulsion module housed a single instrument called SHAPE.

Enhanced Lander Capabilities

- Chandrayaan III incorporates "lander hazard detection & avoidance cameras" to assist in coordination with the orbiter and mission control during the lander's descent to the lunar surface.

Strengthened Legs

- The legs of the new Vikram lander have been strengthened to ensure that it can land safely up to a speed of 10.8 kilometres per hour.

Bigger Fuel Tank

- The Chandrayaan III mission carries more fuel than its predecessor to make sure that it can make last-minute changes if necessary.

More Solar Panels

- The new Vikram lander has solar panels on all four of its faces instead of just two, as seen with its predecessor.

Additional Instruments and Improved Software

- The Chandrayaan III mission has additional instruments and improvements to its software to aid the soft-landing effort.

3.4.4. Why Do Space Agencies Want to Explore the Moon's South Pole?

- All of the previous spacecraft to have landed on the Moon have landed in the region near the Moon's equator firstly because it is easier and safer there.
- The terrain and temperature are more conducive for a long and sustained operation of instruments.
- Sunlight is also present, offering a regular supply of energy to solar-powered instruments.
- The polar regions of the Moon, however, are different. Many parts lie in a completely dark region without sunlight, and temperatures can go below 230 degrees Celsius. This creates difficulty in the operation of instruments.
- In addition, there are large craters all over the place. As a result, the polar regions of the Moon have remained unexplored.
- Chandrayaan II also planned to land in that region in 2019, but it was not able to accomplish a soft landing and lost contact after it hit the surface.
- South pole of the Moon is of special interest to scientists because of the **occurrence of water ice in permanently shadowed areas** around it.
- The lunar south pole has **craters on its surface that contain a fossil record of hydrogen, water ice, and other volatiles** dating from the early Solar System.
- Considering these cold temperatures, the matter trapped in the southern lunar region would not have witnessed much change over the years and could thereby **hold clues to early life.**

3.5. Aditya L1 Mission

- ISRO launched the Aditya-L1 mission (Aditya in Sanskrit means the Sun), **India's first** dedicated scientific **mission to study the Sun,** on September 02, 2023.
- After the four months, the spacecraft will be placed at Lagrange Point 1 (L1) of the Sun-Earth system, which is about 1.5 million km from Earth. It is carrying 7 distinct payloads, all developed indigenously that will study the Sun.

- If it reaches Lagrange point L1 in space, ISRO will join the ranks of NASA and the European Space Agency as the **third space agency to station a solar observatory** there.
- From L1, which serves as a special vantage point for the Sun, Aditya-L1's four payloads will directly view the Sun and three payloads will carry out in-situ studies of particles and fields at the Lagrange Point L1, thus providing important scientific studies of the propagatory effect of solar dynamics in the interplanetary medium.
- The suits of Aditya L1 payloads are expected to provide the information to understand the problem of coronal heating, coronal mass ejection (CME), pre-flare and flare activities, dynamics of space weather, propagation of particles etc.

3.5.1. Launch Vehicle

- The solar probe was carried into space by the Polar Satellite Launch Vehicle (PSLV) in **'XL' configuration.**
    - Missions like Chandrayaan-1 in 2008 and Mangalyaan in 2013 were also launched using PSLV.
- The rocket is most powerful in the 'XL' configuration as it is equipped with six extended strap-on boosters — they are larger than the boosters of other configurations and, therefore, can carry heavier payloads.
- PSLV-XL can lift 1,750 kg of payloads to the sun-synchronous polar orbit. As **Aditya L-1 weighs 1,472 kg,** it was launched aboard PSLV.
- The PSLV will initially place the Aditya L-1 in a lower Earth orbit. Subsequently, the spacecraft's orbit around the Earth will be raised multiple times before it is put on a path to a halo orbit around the L1 Lagrange point.

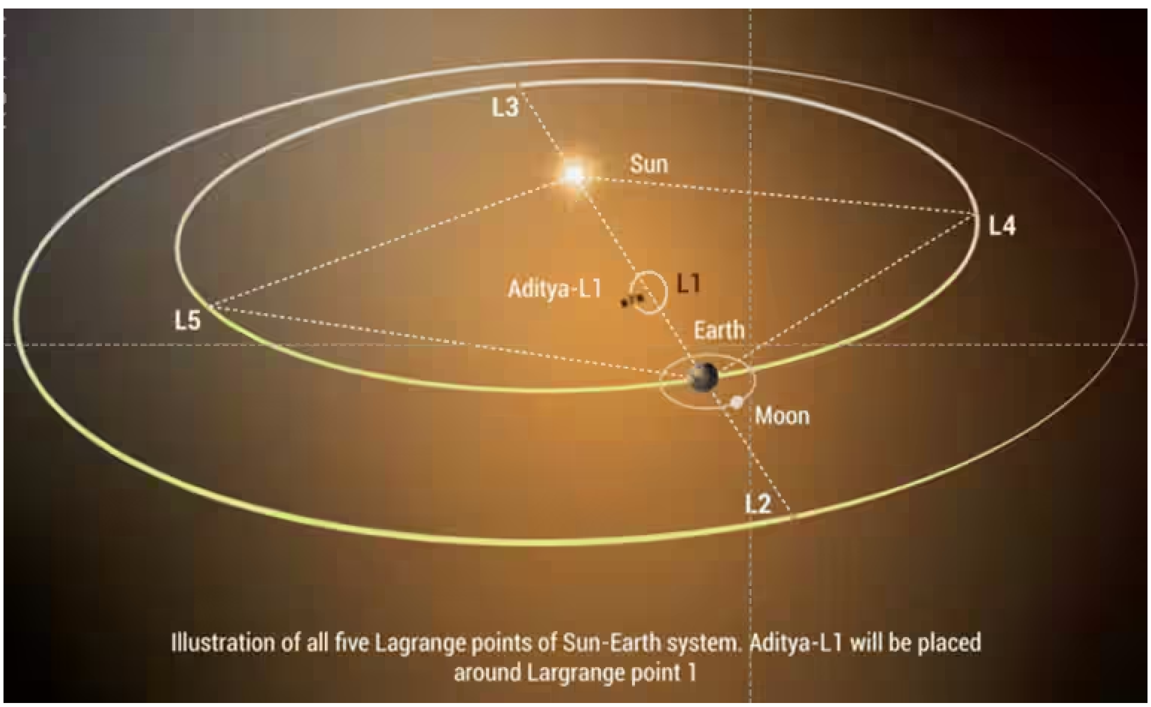


Figure.1. Aditya L1 and Lagrange Point 1

3.5.2. Major Objectives of Aditya-L1 mission

- Study of Solar upper atmospheric (chromosphere and corona) dynamics.

- Study of chromospheric and coronal heating, physics of the partially ionized plasma, initiation of the coronal mass ejections, and flares.
- Observe the in-situ particle and plasma environment providing data for the study of particle dynamics from the Sun.
- Physics of solar corona and its heating mechanism.
- Diagnostics of the coronal and coronal loops plasma: Temperature, velocity and density.
- Development, dynamics and origin of coronal mass ejections.
- Identify the sequence of processes that occur at multiple layers (chromosphere, base and extended corona) which eventually leads to solar eruptive events.
- Magnetic field topology and magnetic field measurements in the solar corona.
- Drivers for space weather (origin, composition and dynamics of solar wind.

3.5.3. Payloads

Remote Sensing Payloads

- **Visible Emission Line Coronagraph (VLEC):** the prime payload designed as a reflective coronagraph with a multi-slit spectrograph. The payload will send 1,440 images of the Sun every day to the ground station on Earth for analysis and research of the intended orbit.
- **Solar Ultraviolet Imaging Telescope (SUIT):** to picture the solar disk in the near ultraviolet wavelength range.
- **Solar Low Energy X-ray Spectrometer (SoLEXS):** to measure the solar soft X-ray flux to study solar flares.
- **High Energy L1 Orbiting X-ray Spectrometer (HEL1OS):** to observe the Sun and study solar flares in the high-energy X-rays.

In-Situ Payloads

- **Aditya Solar Wind Particle Experiment (ASPEX):** it consists of two subsystems – Solar Wind Ion Spectrometer (SWIS) and Suprathermal and Energetic Particle Spectrometer (STEPS).
    - SWIS is a low-energy spectrometer that will measure the proton and particles of the solar wind and STEPS is a high-energy version of it tasked with measuring high-energy ions of the solar wind.
- **Plasma Analyser Package For Aditya (PAPA):** the instrument will help scientists understand the solar winds and their composition. It will also carry out mass analysis of solar wind ions.
- **Advanced Triaxial High-Resolution Digital Magnetometers:** it will measure the low intensity interplanetary magnetic field in space.

3.5.4. Why Study the Sun From Space?

- The Sun emits radiation/light in nearly all wavelengths along with various energetic particles and magnetic fields.
- The atmosphere of the Earth as well as its magnetic field acts as a protective shield and blocks a number of harmful wavelength radiations including particles and fields.
- This means studying the Sun from Earth can't provide a complete picture and it becomes crucial to observations from outside the planet's atmosphere i.e., from space.

Space Weather Conditions

- Space weather refers to changing environmental conditions in space. It is mainly influenced by activity on the Sun's surface. In other words, the solar wind, magnetic field, as well as solar events like CME affect the nature of space.
- During such events, the nature of the magnetic field and charged particle environment near to the planet change.
- In the case of the Earth, the interaction of the Earth's magnetic field with the field carried by CME can trigger a magnetic disturbance near the Earth. Such events can affect the functioning of space assets.
- The mission hopes to generate user-friendly information that can help safeguard a range of satellite-dependent operations such as telecommunications, mobile-based Internet services, navigation, power grids, etc.

3.6. Gaganyaan

- The Gaganyaan Mission is an **indigenous mission** that would **take Indian astronauts to space** for the first time.
- The abort mission demonstration for Gaganyaan is expected around the last week of October of 2023.
- So far, **Wing Commander Rakesh Sharma** is the only Indian to have gone to space. In 1984, he went to space as part of an India-Soviet Union joint mission and spent eight days aboard the Salyut 7 Space Station.
- The project envisages demonstration of human spaceflight capability by launching a crew of three members to an orbit of 400km for a three-day mission and bringing them back safely to earth, by landing in Indian sea waters.
- The prerequisites for Gaganyaan mission include
    - development of many critical technologies including human rated launch vehicle for carrying crew safely to space,
    - life support system to provide an earth like environment to crew in space, crew emergency escape provision and
    - evolving crew management aspects for training, recovery and rehabilitation of crew.