TARGET PRELIMS 2023
BOOKLET-5
SCIENCE AND TECHNOLOGY-5
SPACE, ASTRONOMY AND ELECTROMAGNETIC WAVES

TABLE OF CONTENTS

1. Table of Contents 0

1. Some Basics About Satellite Orbits 1

1) Orbit: 1

2) Types of Orbits: 1. Circular (LEO, MEO, GSO) 2. Elliptical Orbits 1

A) Low Earth Orbit (Circular Orbit) 1
B) Medium Earth Orbit 3
C) Geosynchronous Orbit and Geostationary Orbit 3

3) Highly Elliptical Satellite Orbits 4

4) Transfer Orbits 5

a) Geostationary Transfer Orbit 5

5) Some other basics (Class Discussion) 6

2. Timeline: India in Space, through the Years 6

3. ISRO Launchers (Operational) 8

1) PSLV (Polar Satellite Launch Vehicle) 8

A) Solid Fuel Engine vs Liquid Fuel Engine (Extra Gyan) 9

2) PSLV C-54 (Nov 2022) 9

3) PSLV-C53 10

a) PSLV Orbital Platform Experiment Module (POEM) 11

4) GSLV (Geosynchronous Satellite Launch Vehicle) 12

A) Launch Vehicle Mark 3 (LMV3 or GSLV Mark 3) 12
B) GSLV MK-III – M2/ OneWeb India-1 Mission (Oct 2022) 13
C) India's Journey towards developing its own cryogenic engine 14
D) GSLV F-10: The Cryogenic Engine Problem and the future worries 15

5) Sounding Rockets 15

4. Other Engines and related projects in News 16

1) ISRO's Next-Gen Launch Vehicle (NGLV) may assume PSLV's Role 16
2) Semi-cryogenic Engine (Under development) 16
3) Differences between Cryogenic Engine and Semi-Cryogenic Engine 17
4) Reusable Rockets: Revolutionizing Access to Outer Space 18
5) Low-Cost Small Satellite Launcher (SSLV) 18
6) ISRO Tests Hybrid Propulsion System (Sep 2022) 19

5. ISRO Satellites 20

1) Basics 20
2) Communication Satellites 20
3) Communication satellites of India / ISRO 20
4) Recent ExAmples of Communication Satellites 21
   A) Recent Launches: CMS-01 21
   B) GSAT 7A (ANgry Bird) 21
   C) GSAT-11 21
5) Earth Observation Satellites (Photography, Imaging and Scientific Surveying) 21
   a) Earth Observation Satellite (EOS-06) / OCEANSAT-3 (Nov 2022) 22
   b) RISAT-2 23
6) Satellite Navigation (SAT – NAV) 23
   a) Global Positioning System (GPS) 23
   B) BeiDou 24
   C) NAVIC (Navigation using Indian Constellation) 24
7) Satellites to study the Sun: ADITYA and ADITYA L1 26

6. Other Important Projects of ISRO 27

1) Project NETRA 27
2) Mission Shakti 27
3) Gaganyaan 27
4) XPOSAT (X-RAY Polarimetry Satellite) 28
6) NASA-ISRO Synthetic APerture Radar (NISAR) Imaging Satellite 28

7. ISRO's Interplanetary Mission 29

1) Mars Orbiter Mission 29
2) Venus: Shukrayaan-1 29
3) Chandrayaan-1 30
4) Chandrayan-2 30
5) Chandrayaan 3.0 31
6) Lunar Probe Exploration Mission (LUPEX) 31

8. Other Important Projects of ISRO 32

1) India's Own Space Station: Plans 32

9. Important Telescopes in news recently 33

1) Various Telescopes at Devasthal 33

2) India's first Dark Sky Reserve (Sep 2022) 34

a) The Indian Astronomical Observatory (IAO) 35

3) SARAS Radio Telescope 36

10. Important Personalities 36

A) Dr Vikram Sarabhai (12th Aug 1919 – 30th Dec 1971) 37

B) S Somnath 37

1. Commercialization and Privatization in Space Sector 37

A) Prarambh Mission 37

B) Spacetech Innovation Network (SpIN) 38

1) New Institutions 39

A) New Space India Limited (NSIL) 39

B) In-Space (Indian National Space Promotion and Authorization Centre) 39

C) Indian Space Association (ISpA) 40

2) Civilian APplications of Space Technology 40

1) Science: Space: "Spatial Data Infrastructure Geoportal – 'Geo-Ladakh' for UT-Ladakh (Dec 2022 – Source: PIB) 40

12. International Efforts 41

1) Space Governance: GLobal Norms 41

2) International Space Station 42

3) Thirty Meter Telescope (TMT) 42

4) Space Based Internet 43

13. NASA Initiatives 44

1) Great Observatory Program 44

a) The Hubble Space Telescope (HST) 44

B) The Comptom Gamma Ray Observatory (CGRO) (not operating currently) 44

C) The Chandra X-ray observatory (CXO) 44

D) The Spitzer Space Telescope (SST) 45

2) James Webb Space Telescope 45

3) NASA's Artemis Accord 46

4) NASA's ARTEMIS Lunar PrograM 47

5) Artemis-1 mission 47

A) Orion Surpasses Apollo 13 Record DIstance from Earth (Nov 2022) 48

b) Artemis-2: 2024 48

c) Artemis-3: 2025 48

d) NASA's Gateway Lunar Orbit Outpost 48

e) Artemis may be last mission for Nasa Astronauts 49

f) NASA on Building a Nuclear Reactor in Space and What's Next 49

6) NASA's Mars 2020 Mission - Perseverance Rover 49

7) Parker Solar Probe 50

8) Lucy Mission 52

9) Dart Mission 53
14. European Space Agency 54
1) ESA's Mars Express 54
2) EXOMARS 2022 54
15. China 55
1) China's Space Station: TIangong 55
2) Chang'E-5 56
3) QIMINGXING-50 (or Morning Star – 50): China's Fully Solar Powered, semi-satellite Drone 57
16. Space Tourism 57
1) Sub-Orbital FLights and SPace Tourism 57
17. General Astronomy Topics 58
1) Space Debris 59
18. Sun 59
a) Basics About Sun 59
B) Sun's Structure – 3 Atmospheric LAYERS 59
C) Understanding Solar Winds 60
D) Solar Minimas: Researchers find what happens when the sun goes to sleep (Oct 2022: DTE) 61
E) Smiling Sun 62
1) Life Cycle of Stars: Stars – Dwarf Stars – Neutron Stars – Black Holes 63
A) Life Cycle of a Star 63
B) Medium Stars - > Red Giant -> White Dwarf -> Black Dwarf 63
C) Neutron Star 63
D) Black Hole 64
20. Electromagnetic Waves 66
1) Electromagnetic Spectrum 66
A) Radio waves: 67
B) Microwaves 67
F) Infrared Waves 68
G) Visible Rays 68
H) Ultraviolet Rays 68
I) X-Rays 69
J) Gamma Rays 69
2) Penetration of various EM waves in Earth's Atmosphere 69
3) WIRELESS CommunicatioN – Different Frequency Bands and THEIR Applications 69
A) Radio Waves (500 KHz – 1 G Hz) 69
B) MICROWAVES 71

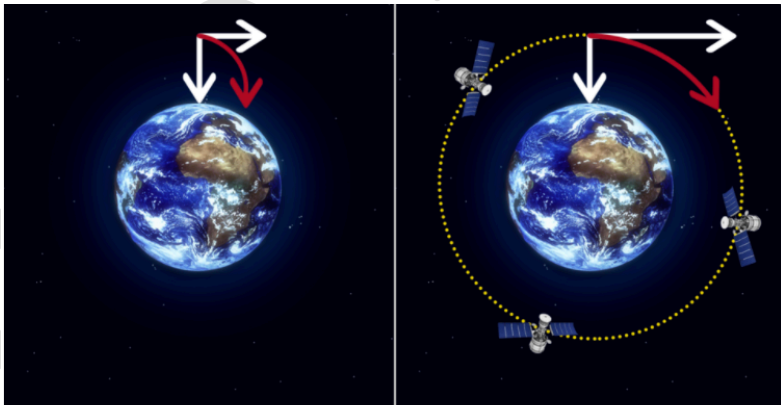
1. SOME BASICS ABOUT SATELLITE ORBITS

1) ORBIT:

- An orbit is the curved path that an object in space (such as a planet, moon, star etc.) takes around another object due to gravity.
  - Objects of similar mass orbit each other with neither object at the centre, whilst small objects orbit around large objects. In our Solar system, earth revolves around sun, Moon revolves around earth.
- **Satellite Orbits:** The path that satellite takes to revolve around a planet due to force of gravity is called satellite orbit.

- **Gravity and Speed of Satellite in an orbit**

- **How are satellites placed in Orbit – Circular vs Elliptical Orbit** - Detailed Class Discussion



- **Orbital Velocity – Circular vs Elliptical**
  - For a circular orbit, it is always the same.
  - However, in the case of an elliptical one this is not the case as the speed changes dependent upon the position in the orbit. It reaches the maximum when it is closest to the earth and it has to combat the greatest gravitational pull, and it is at its lowest speed when it is furthest away.

2) TYPES OF ORBITS: 1. CIRCULAR (LEO, MEO, GSO)

A) LOW EARTH ORBIT (CIRCULAR ORBIT)

- A low earth orbit is an orbit around earth with an altitude between 160 kilometers and 2000 Kilometers. Objects below approximately 160 Kilometers will experience very rapid orbit decay and altitude loss.

- It is **used for vast majority** of satellites.
  - **All human space flights** have taken place in LEO with the **exception of manned Lunar** flight of the Apollo program.

- **All manned space stations** to date, as well as the **majority of satellite have been in LEO**.

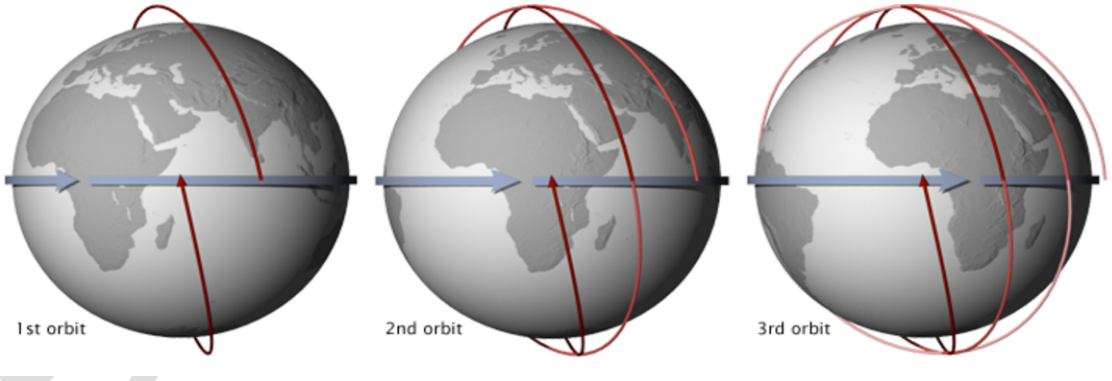
- **Main Characteristics**
  - **Low orbital period**
  - **User and satellites are closer** -> so better visibility of earth from satellites -> Earth Observation/ Remote Sensing.
  - Radiation levels are lower than what found at higher altitudes
  - **Easy placement:** Less energy is spent placing the satellite in LEO
  - **Lower Latency in communication:** The Round-Trip Time for radio signals is considerably less.

- **Applications**
  - **Earth Monitoring Satellites**
    - As they are able to see the surface of the earth more clearly
  - **Communication satellites**
    - Especially the satellite phones
  - **International Space Station** is at a height of 400 km.

SUN SYNCHRONOUS ORBIT (CIRCULAR OR ALMOST CIRCULAR) (POLAR ORBIT)

- **Satellites in Polar Orbit** usually travel past Earth from north to south rather than from west to east, passing roughly over Earth's pole. They don't have to pass the north pole or south pole precisely. Even a deviation within 20 to 30 degrees is still classed as polar orbit.

- **Sun Synchronous Orbit** is a kind of Polar Orbit. In this orbit, satellites are synchronized to always be in the same fixed position relative to the Sun. This means that the satellite always visits the same spot at the same local time. In this orbit, *whenever and wherever the satellite crosses the equator, the local solar time on the ground is always the same*.



  - A sun synchronous combines altitude and inclination in such a way that an object on that orbit will appear to orbit in the same position, from the perspective of the sun, during its orbit around the earth. In other words, it orbits in such a way that **it precesses once a year**. The surface illumination angle will nearly be same every time.

  - This is achieved by having the **osculating orbital plane precess (rotate) approximately one degree each day** with respect to celestial sphere, eastward, to keep pace with earth's movement around the sun.
  - Typical sun-synchronous orbits are about 600-800 Km in altitude, with periods in the 96-100-minute range, and inclination of around 98 degrees.
  - Possible only around **oblate planets like Earth, Mars etc**. The extra mass around the equator makes the precess possible. But Venus is too spherical to have a Sun Synchronous Satellite orbit.

□ **Significance of Sun-Synchronous Orbit**

- **Long term comparison of images**.

□ **Kinds of satellite put in Sun-Synchronous orbit**

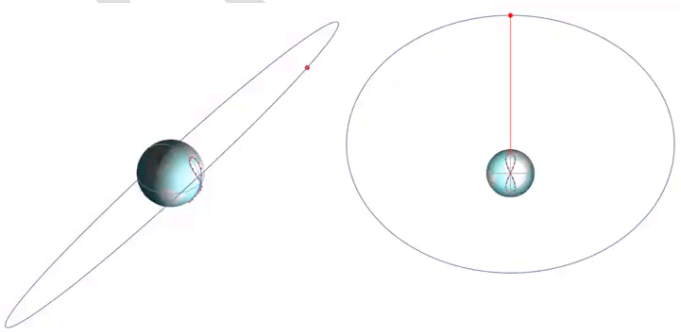
- Sun-synchronous orbit can place a satellite in constant sunlight and is useful for imaging, spy and weather satellites.
- E.g., Cartosat-2 series

B) MEDIUM EARTH ORBIT

- Height: 2000 km to 3,5786 kms
- Satellite speed is lower (compared to LEO)
- **Orbital Period** range from 2 to 24 hours
- **Most common use** of satellite in this orbit is for navigation, communication, and geodetic/space environment science.
- **Most common altitude** is approximately **20,200 km**, which yields an orbital period of 12 hours as used for examples by GPS.
- **E.g:**
  - GPS Satellites Fly in Medium earth orbit at an altitude of approximately 20,200 km.
  - Galileo (the satnav system of Europe) is also located in MEO

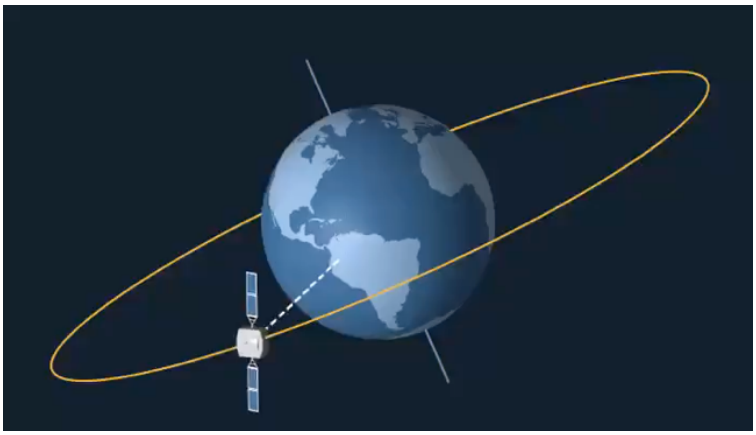
C) GEOSYNCHRONOUS ORBIT AND GEOSTATIONARY ORBIT

GEO-SYNCHRONOUS ORBIT



- It is a satellite orbit around the earth with an **orbital period that matches Earth's rotation period on its axis** (i.e., orbital period is **23 hours 56 minutes and 4 seconds**), irrespective of inclination.
  - » A person on a point on Earth, will see a satellite in this orbit in the same place in the sky at the same time of the day, every day.
  - » Over the course of a day, the object's position in the sky traces out a path, typically in a figure-8 form, whose precise characteristics depend on the orbit's inclination and eccentricity.

- **Requirements:**
  - » **Circular Orbit** of **Height 35786 km**. At this height an orbital period of satellite is equal to earth's rotation period.
  - » **Direction of revolution** of satellite should be same as direction of rotation of earth.

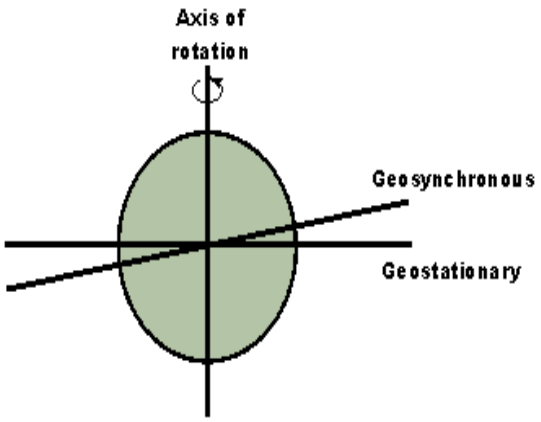


GEO-STATIONARY - A SPECIAL CASE OF GEOSYNCHRONOUS

- A Geostationary Orbit is a particular type of Geosynchronous orbit, the distinction being that while an object in Geosynchronous orbit returns to the

same point in the sky at the same time each day, an object in geostationary orbit never leaves that position.

- **Requirements for a satellite to be geostationary?**
  - Geosynchronous requirements
  - The equatorial plane of earth must be coplaner with the orbital plane of the satellite revolution (i.e., angle of inclination of orbit to equator is 0 degrees)
- Communication satellites and weather satellites are often placed in Geostationary orbits: **why?**

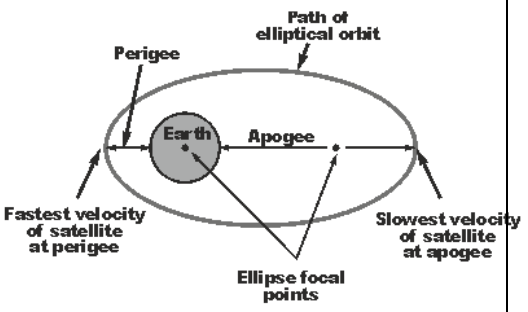


Geostationary orbit can only be over the Equator

- **Advantages**
  - Geo systems have significantly greater available bandwidth that the Low Earth Orbit - LEO and Medium Earth Orbit
  - Covers 1/3rd of Earth's surface
  - Less expenses on tracking activities
  - Higher life span of satellites
- **Limitations**
  - Would require line of sight communication paths between terrestrial antenna and the satellites.
  - Long path length, and hence losses when compared to LEO, or MEO.
    - Long path length introduces delays.
    - Satellite costlier to install in GEO in view of the greater altitude
    - Geostationary Orbit (GEO) can only be above equator and therefore poles can't be covered.

3) TYPES OF ORBITS: 2. HIGHLY ELLIPTICAL SATELLITE ORBITS

- Elliptical Orbits are often called Highly Elliptical orbits or HEO.
- Key Features
  - Follows the curve of an ellipse.
    - Moves much faster when it is near earth and slower when it is away from earth.
  - There are two focal points and one of the these is the geo-centre of the earth.
  - **Apogee**: Point where the satellite is furthest from Earth - gravitation pull is lowest - satellite moves the slowest
  - **Perigee**: Point where the satellite is nearest from earth - gravitation pull is highest - satellite moves the fastest
  - **How permanent coverage can be achieved?**
    - By placing a number of satellites in the same orbit, but equally spaced apart, permanent coverage can be achieved.



Highly elliptical satellite orbit, HEO

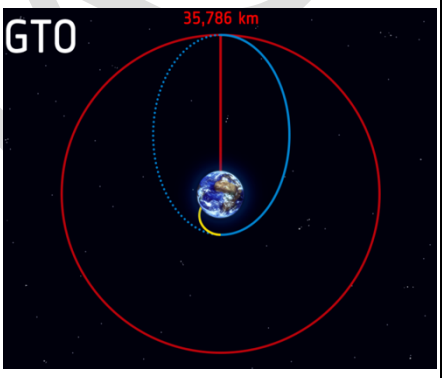
- **Applications**
  - Provide coverage at any point on the globe
    - It may provide high latitude and polar coverage.

- Countries such as Russia which needs coverage over polar and near polar areas make significant use of highly elliptical orbits.

4) TRANSFER ORBITS

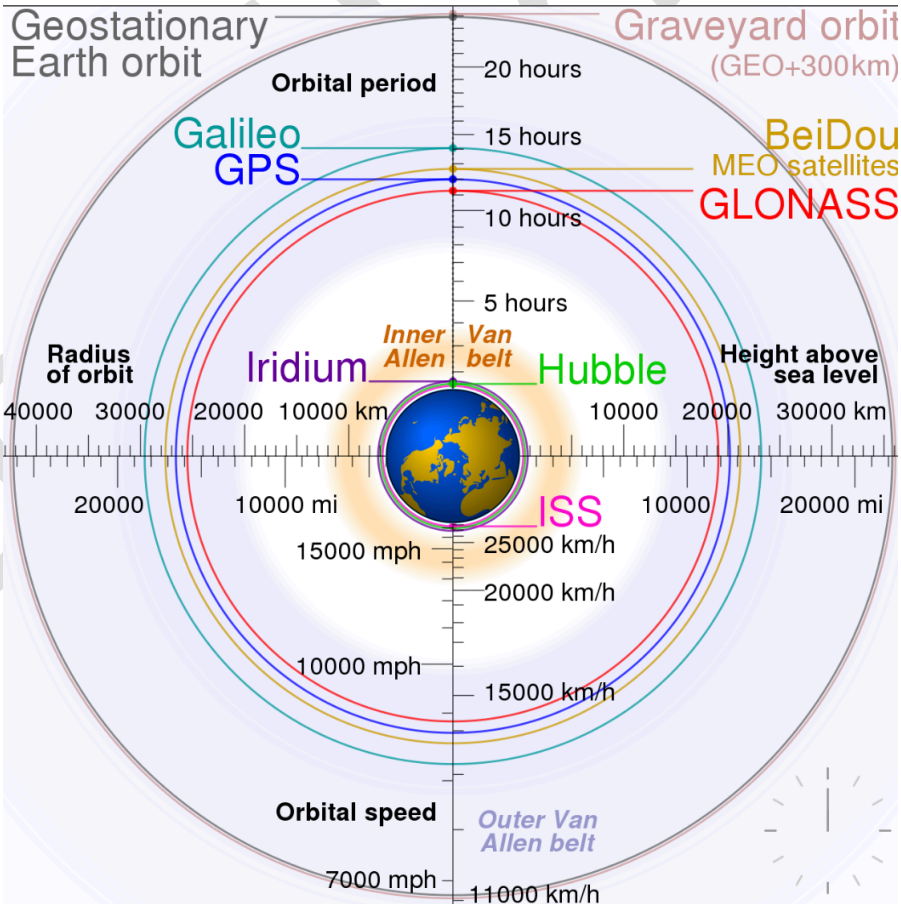
- These are special kind of orbits used to transfer satellites/spaceships from one orbit to another. These orbits are elliptical, with its perigee closer to earth. Satellites are taken to Perigee with the help of a rocket. After reaching this orbit, satellites by using relatively little energy from built in motors, can move to another larger orbit.
- This allows a satellite to reach a very high orbit, without needed the rocket to go to that height. **Geostationary Transfer Orbit (GTO)** is the most common type of transfer orbit.

A) GEOSTATIONARY TRANSFER ORBIT



- It is a Hohmann transfer orbit used to reach, geosynchronous or geostationary orbit. It is highly elliptical earth orbit with an apogee of 42,164 km, or 35786 km above sea level. Perigee can be anywhere above atmosphere, but it is generally restricted to few hundred Kms above the earth's surface.

- **Hohmann transfer orbit:** It is an elliptical orbit used to transfer between two circular orbits of different radii in the same plane.



5) SOME OTHER BASICS (CLASS DISCUSSION)

Why are all satellites launched from east coast?

Why are satellites launched from near the equator?

2. TIMELINE: INDIA IN SPACE, THROUGH THE YEARS

1) **1962:** The Indian **National Committee for Space Research is formed** under the leadership of Vikram Sarabhai and physicist Kalpathi Ramkrishna Ramanathan
2) **21 Nov 1963:** India's space program takes off with **launch of a sounding rocket** from Thumba Equatorial Rocket Launching Station in Kerala. It was for probing upper atmosphere.
3) **Aug 15, 1969:** ISRO is formed
4) **Aug 19, 1975: Aryabhata** – India's first satellite is launched from a Soviet Kosmos-3M rocket from Kapustin Yar in then Soviet Union. It was designed and built in India
5) **1979: Bhaskara-1,** the **first experimental remote sensing** satellite built in India, is launched. Images taken by its camera were used in hydrology, forestry and oceanography.
6) **1980: Satellite Launch Vehicle (SLV)-3**, India's **first experimental satellite launch vehicle**, takes off with Rohini Satellite RS-D2. Camera had the ability to use data for classifying ground features like water, vegetation, bare land, clouds and snow.
7) **1982:** INSAT 1-A is launched. Abandoned in 1983 where its altitude control propellant was exhausted.
8) **1984:** Rakesh Sharma, former IAF pilot, becomes the first Indian in space. In a joint India-Soviet Union Mission, Sharma boards the Soyuz T-11 spacecraft to the Salyut 7 orbital station.
9) **2008:** Launch of Chandrayaan-1. It orbits the Moon but doesn't land. It performs high resolution remote sensing aiming, among various missions, to prepare a 3D atlas of both the near and far sides of the moon.

10) **2013:** Launch of Mangalyaan, the Mars Orbiter Mission. Orbiting and studying Mars since Sep 24, 2014.
11) **2016:** All 7 satellites of IRNSS system placed in Orbit
12) **2019:** Chandrayaan-2 launched using GSLV MK-III

3. ISRO LAUNCHERS (OPERATIONAL)

PSLV, GSLV, Sounding Rockets are three broad categories of rockets (launchers) that ISRO has developed over the years

- Both PSLV (Polar Satellite Launch Vehicle) and GSLV (Geosynchronous Satellite Launch Vehicle) are the satellite launch vehicles (rockets) developed by ISRO.

1) PSLV (POLAR SATELLITE LAUNCH VEHICLE)

- **Why in news?**
  - PSLV C-54 successfully places earth observation satellite (OCEANSAT-3, formally called EOS-6), 8 nano satellite in orbit (Nov 2022)

- The PSLV is the third-generation satellite launch vehicle of India. It is an expandable system and was the first Indian Launch Vehicle to be equipped with Liquid Stage.
  - **Note:** ISRO has over the years realized **5 generations of rockets** – SLV, ASLV, PSLV, GSLV, and GSLV-MK-III.

- **Where is PSLV used?**
  - It was developed to allow India to launch its Indian Remote Sensing (IRS) satellite into **Sun synchronous orbit**, a service that was, until the advent of the PSLV, commercially available only from Russia.
  - PSLV can also launch small size satellites into **Geostationary Transfer Orbit**.

- It is one of the world's most reliable launch vehicles.

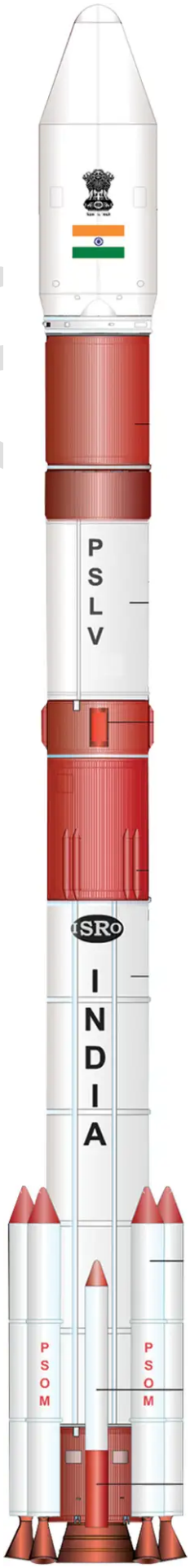
PSLV was developed for Low Earth Orbit satellites into Polar and Sun Synchronous Orbits, and GSLV for heavier INSAT class of Geosynchronous satellites into orbit.

	SLV-3	ASLV	PSLV-XL	GSLV MK-II	GSLV MK-III
Height	22.7 m	23.5 m	44 m	49 m	43.43 m
Liftoff weight	17 t	39 t	320 t	414 t	640 t
Propulsion	All solid	All solid	Solid and liquid	Solid, liquid, and cryogenic	Solid, liquid, and cryogenic
Payload mass	40 kg	150 kg	1860 kg	2200 kg	4000 kg
Orbit	Low Earth Orbit	Low Earth Orbit	475 km Sun Synchronous Polar Orbit*	Geosynchronous Transfer Orbit	Geosynchronous Transfer Orbit

- **Launches So Far**
  - Developed in early 1990s, its first launch in 1993 was a failure.
  - First successful launch of PSLV took place in 1994 and till Nov 2022 (i.e., PSLV C-54), PSLV has had 56 launches with only two failures.

Technical Specifications of PSLV

- **Capabilities**
  - Payload to SSPO (sun synchronous polar orbit): 1,860 Kg



- Payload to Sub GTO: 1,425 Kg
- **Key features of PSLV Engines**
  - PSLV has four stages using solid and liquid propulsion alternatively.
- **Expansion of capabilities: Strap on Motors**
  - PSLV uses 6 solid rocket strap-on motors to augment the thrust provided by the first stage in its PSLV-G (1678 kg in SSPO) and PSLV-XL (1750 kg to SSPO) variants. PSLV-DL, PSLV-QL versions use 2 and 4 straps on motors respectively. PSLV-CA (1100 kg in LEO) uses no strap on motors.

A) SOLID FUEL ENGINE VS LIQUID FUEL ENGINE (EXTRA GYAN)

» **A solid rocket fuel** has its fuel and oxidant mixed together as fine powders and then pressed into solid cake.

- **Key characteristics**
  - **Higher Thrust** -> Higher force to launch the vehicle.
  - **Less volume**
  - **One time burn** -> all fuel burns at the same time, i.e., once it has been lit it will carry on burning until it is used up.
  - **Produces a lot of smoke -> large particles** when fired

» **A liquid fuel engine** uses liquid fuel which can have following advantages

- **Controlling Thrust**
- **Engine can be shut down and restarted**
- **Higher energy density** (joules per kg of propellant) is higher.
- **Higher Specific Impulse** (impulse (in Newton second) per kg of propellent)
- E.g., a modern solid fuel rocket has specific impulse of around 2500 N s Kg^{-1}, while a good liquid fuel rocket produces an impulse of about 4500 N s Kg^{-1}.
- **Disadvantage: More complicated Engine requirements and thus more expensive and heavier engine** -> pumps, piping, separate storage for the fuel and oxidant means that extra mass has to be carried by the launch vehicle.

» **Why Hybrid Engines**

- Vastly reduce overall system weight and cost. It increases reliability (a smaller number of components which can fail)

2) PSLV C-54 (NOV 2022)

» PSLV C-54 successfully placed earth observation satellite (EOS-06) and 8 nano satellites in orbit

» The eight nanosatellites included ISRO Nano Satellite-2 for Bhutan (INS-2B), Anand, Astrocast (four satellites), and two Thybolt satellites.

» This is the 56th flight of the PSLV and the 24th of the PSLV-XL version with 6 PSOM-XLs.

» **ISRO Nano Satellite-2 for Bhutan (INS-2B)** is very important milestone in the history of joint collaboration of Indian scientists and Bhutanese scientists in building the satellites with two payloads.

- ISRO is also working with Bhutan to establish ground station in Thimphu, which will be commissioned shortly.

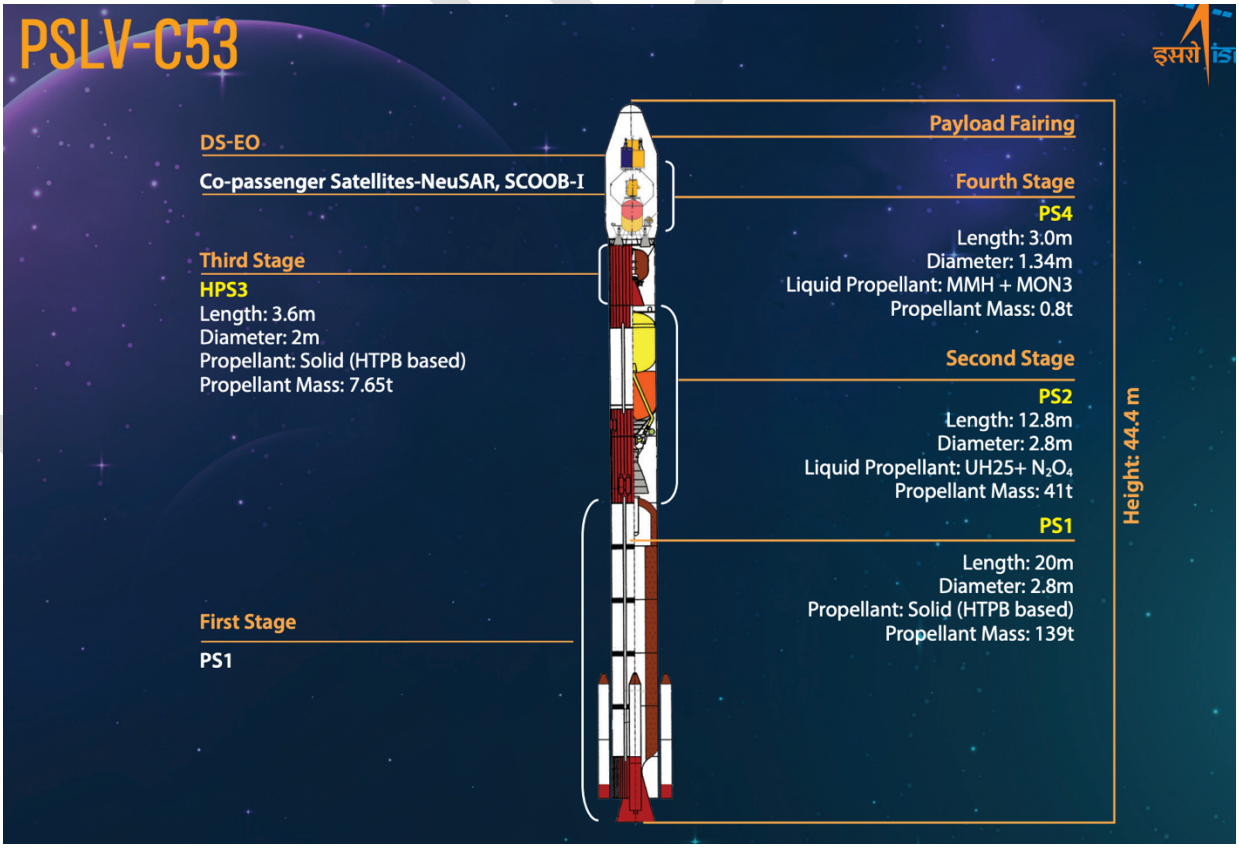
» **Multi-Orbit Mission:**

- The Primary satellite (EOS-6) was separated in Orbit-1.
- Subsequently, orbit was changed by using two orbit Change thrusters (OCTs) introduced in the Propulsion Bay Ring of the PSLV-C54 Vehicle.

- All the seven commercial satellites from NSIL were deployed successfully.
  - **Astrocast**, a 3U spacecraft with 4 satellites from Spaceflight Inc, US, wre separated.
  - Following this the 2 satellites of Thybolt were deployed.
  - The **Anand** three axis stabilized nano satellites, a technology demonstrator for miniaturized electro-optical payload and all other subsystems was also placed in orbit.
- Further, India-Bhutan Sat was successfully deployed. It has two payloads namely NanoMx, a multispectral optical imaging payload developed by space applications centre (SAC) and APRS-Digipeater, which is jointly developed by DITT Bhutan and URSC.

3) PSLV-C53

- **Why in news?**
  - » PSLV-C53/DS-EO Mission is successfully accomplished (June 2022)
- **PSLV-C53** was a dedicated commercial satellite mission of NewSpace India Limited (NSIL), a CPSE, under DoS, GoI.
- It launched **Singapore Satellites** – DS-EO, NeuSAR and SCOOB-1 to serve Singapore governmental, commercial & educational purposes.
- The mission was the 55th flight of PSLV and the 15th flight of its CA version.



A) PSLV ORBITAL PLATFORM EXPERIMENT MODULE (POEM)

- PSLV used spent PS-4 stage as an **orbital platform**, named as POEM.
- **The power of the platform** is derived from the solar panel mounted around the PS-4 and a Li Ion battery.
- **Payloads of POEM:**
  - » Software Defined Radio based Telemetry Multi-Media Transmitter (SDRT-MTx)
  - » UHF Transmitter
  - » Dhruva Space Satellite Orbital Deployer (DSOD)
  - » Space Radiation Monitoring

4) GSLV (GEOSYNCHRONOUS SATELLITE LAUNCH VEHICLE)

- **Why in news?**
  - GSLV-F10 failure: Key lessons (Aug 2021)
    - **What went wrong?** The third stage (i.e., the CUS) failed to ignite and the rocket along with the satellite (EOS-03) most likely fell off somewhere in the Andaman Sea.

- **Background of GSLV**
  - GSLV is an expandable launch system operated by ISRO.
  - First launch in 2001. First successful flight in 2003: successfully placed GSAT-2 in 2003.
  - **Main Purpose**: GSLV was primarily developed to launch INSAT class of satellites into Geosynchronous Transfer Orbits. GSLV is being used for launching GSAT series of satellites.
  - **Payload to GTO:** Presently GSLV can inject **2.5 ton** (GSLV Mk-2) of communication satellite into Geosynchronous Transfer Orbit.
  - **Payload to LEO:** GSLV's capability of placing up to **5 tonnes in LEO** broadens the scope of payloads from heavy satellite to multiple smaller satellites.

- **Three Stage Launcher (GSLV-Mk-2) (one solid motor stage (expandable with four liquid engine strap ons), one earth Storable Liquid stage, and one cryogenic stage)**

- **Third Stage: CUS**
  - Developed under Cryogenic Upper Stage Project (CUSP), the **CE7.5** is India's first cryogenic engine, developed by Liquid Propulsion Systems Centre in Mahendragarh, Tamil Nadu. CE-7.5 has a staged combustion operating cycle.
    - Fuel: LOX + LH_2 (Liquid Oxygen + Liquid Hydrogen)
    - Max Thrust: 75 KN

- **Variants**
  - **GSLV Mk 1(a,b,c)** - Not important
  - **GSLV Mk 2 (Operational)**
    - This variant uses an Indian cryogenic engine, the CE-7.5, and is capable of launching 2500 Kg into Geostationary transfer orbit. Previous GSLV vehicles (GSLV Mk1) have used Russian cryogenic engines.

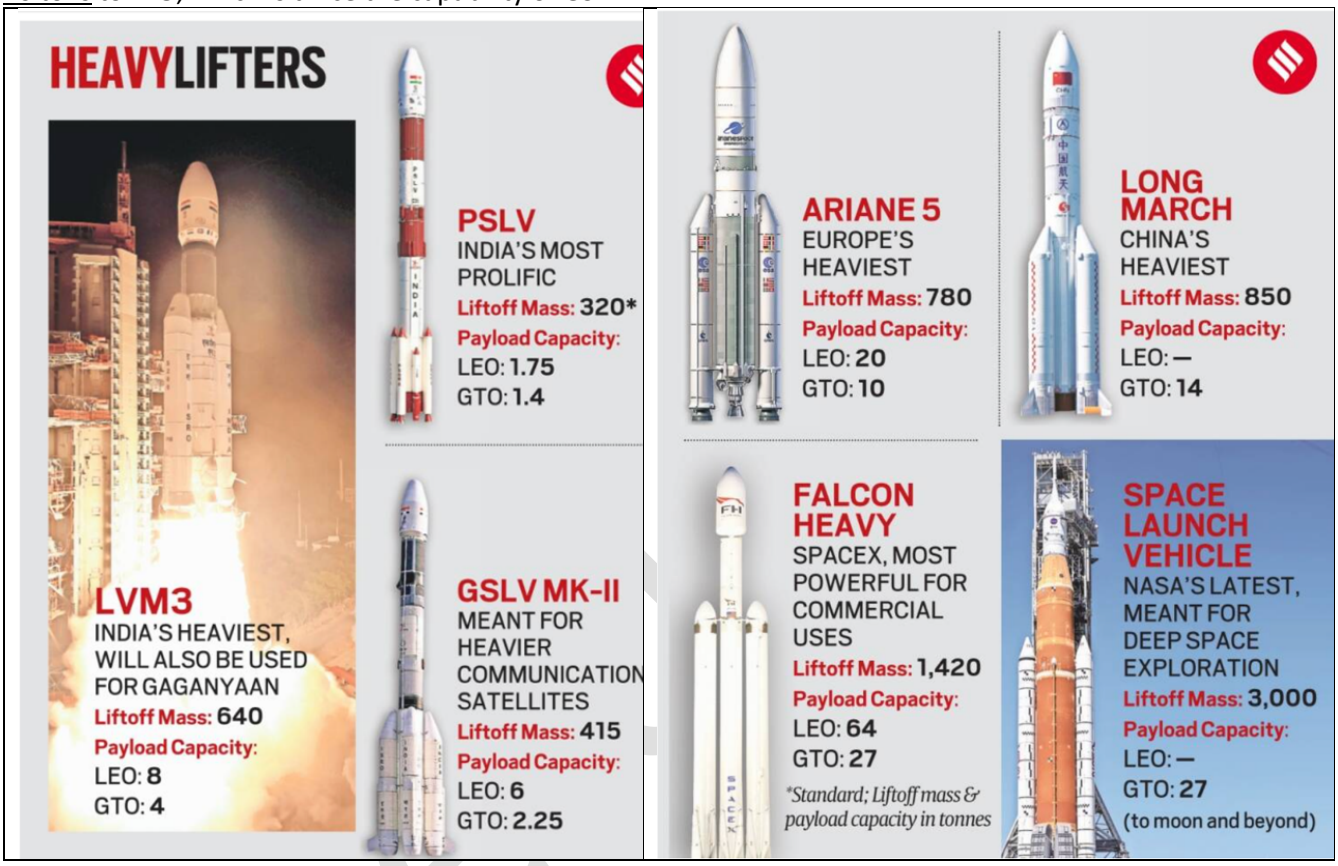
A) LAUNCH VEHICLE MARK 3 (LMV3 OR GSLV MARK 3)

- **Why in news?**
  - ISRO's heaviest rocket LVM3 has successfully orbited 36 satellites of UK-based OneWeb (Oct 2022)

- LVM3 is a **3-stage** heavy lift launch vehicle developed by ISRO.
  1) **Solid Rocket Boosters: S200 –** GSLV MK III uses two S200 solid rockets boosters to provide the huge amount of thrust required for lift off. Fuel: **HTPB**. The S200 was developed at **Vikram Sarabhai Space Centre**.
     - **The two strap-on motors of GSLV Mk III** are located on either side of its core liquid booster.
  2) **A liquid Propellant core stage (L110):** The L110 liquid stage is powered by 2 Vikas engines.

3) **A Cryogenic Stage (C25):** The C25 is an improvement on CE-20 Cryogenic engine, India's largest cryogenic engine, designed and developed by the Liquid Propulsion System Center
   a. Fuel: LOx + LH_2

- **Capability:** GSLV-Mk III can launch 4 tons class of satellites to Geosynchronous Transfer orbit (GTO) or about 8-10 tons to LEO, which is twice the capability of GSLV Mk II.



- **Flights so far:**

  - **First Experimental Flight in Dec 2014 (Dec 2014): LVM3/XCARE**
  - **First Developmental Flight- GSLV-Mk III-D1 (June 2017)**
    - It successfully placed GSAT-19 satellite to a Geosynchronous Transfer Orbit (GTO) on June 05, 2017 from SDSC SHAR, Shriharikota.

  - **2nd Developmental Flight – GSLV – MK -III – D2 (Nov 2018)**
    - Successful placement of GSAT-29, India's heaviest satellite in GTO.
    - **GSAT-29** is a multiband, multibeam communication satellite, intended to serve as test bed for new and critical technologies.

  - **GSLV MK-III – M1 / Chandrayaan 2 Mission** (July 2019)

B) GSLV MK-III – M2/ ONEWEB INDIA-1 MISSION (OCT 2022)

- It was only the second operational flight of LVM3 (after Chandryaan-2 mission). It was a dedicated commercial satellite mission of NewSpace India Limited (NSIL). This mission was undertaken as part of the commercial arrangement between NSIL and m/s Network Access Associates Limited (m/s OneWeb Ltd), a UK based company. A total of **36 OneWeb Gen-1** satellites of about 150 Kg each totaling about **5,796 Kg** were launched to a **circular LEO of about 601 km** with a 87.4 degree inclination.

- The separation of satellites involved a unique maneuver of the cryogenic stage to orientation and re-orientation covering 9 phases spanning 75 minutes.

- This was one of the biggest commercial orders executed by ISRO. With this launch, the LVM3 enters into global market in a grand manner.

- **Note: Some Unique features of the Mission**
  - First Commercial Mission of LVM3
  - First Multi-Satellite mission with 36 OneWeb Satellites onboard
  - First launch of LVM3 to LEO
  - First Indian rocket with six-ton payload
  - First NSIL Mission with LVM3
  - First OneWeb Mission with NSIL/DoS

OneWeb: OneWeb is a joint venture between India's Bharti Enterprises and the U.K. government.

LVM3-M2 launching 36 satellites was the 14th launch of OneWeb bringing the constellation to 462 satellites. Their plan is to launch a total of 648 LEO satellite fleet that will deliver high-speed, low-latency connectivity worldwide. With only four more launches to go, OneWeb remains on track to activate global coverage in 2023, while its connectivity solutions are already live in regions north of 50-degree latitudes.

This partnership with NSIL and ISRO demonstrates OneWeb's commitment to provide connectivity across the length and breadth of India by 2023.

C) INDIA'S JOURNEY TOWARDS DEVELOPING ITS OWN CRYOGENIC ENGINE

- **Why in news?**
  - ISRO's cryogenic engine, indigenously developed for LVM3 passes hot test (Nov 2022)

- **Basics about Cryogenic Engine**
  - **Cryogenic engine** is a rocket engine that uses cryogenic fuel or oxidizer, i.e. its fuel or oxidizer (or both) are gases liquified and stored at very low temperatures.
  - **Note:** All Cryogenic engines are also, liquid propellent rocket engines or hybrid rocket engines.
  - **Fuel:** Combination of Liquid hydrogen and Liquid Oxygen is the most commonly used propellant in cryogenic engine. The fuel provides **very high specific impulse**.

- **Difficulties in developing Cryogenic engine**
  - Technology is quite sophisticated
    - Burning a super cooled fuel at extremely high temperatures.
    - Developing material that can withstand high temperature and pressure during combustion.

- **Advantages**
  - More efficient and provides more thrust for every kg of propellant it burns.

- **Current status**
  - CE-7.5 being used in GSLV MK-II.
  - CE-20 is being used in GSLV MK-III. It is indigenously developed for LVM-3.

- **Further upgradation:**
  - In Nov 2022, **ISRO has successfully conducted a hot test of CE20 cryogenic engine**. This successful hot test was at an **uprated thrust level of 21.8 tonne** for the first time on Nov 9, at Mahendragiri in Tamil Nadu.
  - This will **enhance the LVM3 payload capability upto 450 Kg with additional propellant loading**. The major modification carried out on this test article compared to previous engines was introduction of Thrust Control valve (TCV) for thrust control.
  - In addition to the hot test, a 3D printed LOX and LH2 turbine exhaust casings were also inducted in the engine for the first time.

D) GSLV F-10: THE CRYOGENIC ENGINE PROBLEM AND THE FUTURE WORRIES.

- **why in news?**
  - » **GSLV-F10/EOS-03 mission** failed (Aug 2021)

- **what happened?**
  - » The launch took place in Aug 2021. The performance of first and the second stage was normal. However, **Cryogenic Upper Stage** ignition didn't happen due to technical anomaly. Thus, the mission couldn't be accomplished as intended.

5) SOUNDING ROCKETS

- **Why in news?**
  - » ISRO's RH-200 sounding rocket records 200th consecutive successful flight (Nov 2022)

- Sounding rockets are one or two stage solid propellant rockets used for probing the upper atmospheric regions and for space research.
- They also serve as easily affordable platforms to test or prove prototypes of new components or subsystems intended for use in launch vehicles and satellites.
  - With the establishment of the **Thumba Equatorial Rocket Launching Station (TERLS) in 1963** at Thumba, a location close to the magnetic equator, there was a quantum jump in the scope for aeronomy and atmospheric sciences in India.
    - The launch of **the first sounding rocket** from Thumba near Thiruvananthapuram, Kerala on 21 November **1963, marked the beginning of the Indian Space Programme**. The rocket was **US Nike Apache**.
  - **Operational Sounding Rockets**
    - **Currently 3 versions** are offered as operational sounding rockets, which cover a payload range of 8-100 Kg and an apogee range of 80-475 Km.

Vehicle	RH-200	RH-300-Mk-II	RH-560-MK-II
Payload (in kg)	10	60	100
Altitude (in km)	80	160	470
Purpose	Meteorology	Aeronomy	Aeronomy
Launch Pad	Thumba, Kerala	SDSC-SHAR	SDSC-SHAR

- **Rohini (Rocket Family)** is a series of sounding rockets developed by ISRO for meteorological and atmospheric study.

- **ISRO's RH-200 sounding rocket records 200th consecutive successful flight** (Nov 2022)
  - The small rocket lifted off from the launchedpad at the **Thumba Equatorial Rocket Launching Station (TERLS)** at the Vikram Sarabhai Space Centre (VSSC).

- **Example of Experiment: Air Breathing Propulsion Experiment** using RH-560 rocket fitted with a supersonic combustion (Scramjet) engine on Aug 28 from Sriharikota. (Aug 2016)

4. OTHER ENGINES AND RELATED PROJECTS IN NEWS

1) ISRO'S NEXT-GEN LAUNCH VEHICLE (NGLV) MAY ASSUME PSLV'S ROLE

- ISRO is developing a Next-Gen Launch Vehicle (NGLV), which will one day replace operational systems like PSLV
- In NGLV, ISRO is understood to be looking at a cost efficient, **three stage to orbit**, **reusable heavy lift vehicle** with a **payload capability of ten tonnes to GTO**.
- NGLV will feature semi-cryogenic propulsion (refined Kerosene as fuel with liquid oxygen as oxidizer) for the booster stages which is cheaper and efficient.
- It will have a simple robust design which will allow bulk manufacturing, modularity in systems, subsystems and stages and minimal turnaround time.
- Potential uses will be in the areas of launching communication satellites, deep space missions, future human spaceflight, and cargo missions.

2) SEMI-CRYOGENIC ENGINE (UNDER DEVELOPMENT)

- **Details**

  - Semi-Cryogenic Engine is an Indian Liquid fuel rocket engine using a combination of liquid oxygen (LOX) and refined kerosene (Isrosene) as propellants. It is being developed for future heavy lift launch vehicles and reusable launch vehicles.
  - It is being developed by Liquid Propulsion System Centre, a subsidiary of ISRO.

- Project Codename: SCE-200

- Where will it be used?
  - Immediate Application: One of the immediate applications will be to replace the liquid core (L110) engine of GSLV Mark-3 with the SCE-200 to boost the payload capacity of the rocket from 4 to six tonnes.

- Further plans
  - Power further heavy lift rockets
  - In reusable launch vehicles
  - In human spaceflight missions
  - Other plans for the future
    - A proposal to develop a bigger semi-cryogenic engine with a cluster of four or five engines that could generate a lift of eight to 10 tonnes.

- **SCE-200: Other Details**
  - Cost of project: 1800 crore (Cabinet cleared the project in 2008).
  - Currently, only US and Russia have this technology
  - In 2015, ISRO signed an MoU with Russian Space Agency to boost its plan for Semi-Cryogenic Launch Vehicle

3) DIFFERENCES BETWEEN CRYOGENIC ENGINE AND SEMI-CRYOGENIC ENGINE

	Cryogenic	**Semi-Cryogenic**
Fuel	Liquid Hydrogen + Liquid Oxygen	Isrosene + Liquid Oxygen
Temperature	Liquid hydrogen required to be stored at -253-degree celsius	Kerosene can be stored at normal temperatures
Weight	LH2 + LO2 is heavier than Kerosene and has to be stored at freezing temperature of -253 degree celsius.	Lighter than liquid fuel and can be stored at normal temperature. Therefore, **kerosene occupies less space, and more propellant can be packed** in the semi-cryogenic engine's fuel compartment.
Specific Impulse	Cryogenic engine offers higher specific impulse then SCE	
Thrust to weight Ratio		It offers better thrust to weight ratio upto 180. Higher density of the exhaust gas in case of the SCE contribute to high mass flow rates making it easier to develop high thrust engines.
Stage	Higher specific impulse is valuable for upper stage, where mass comes at a premium price. So Cryogenic is used at upper stage.	• SCE have been preferred in lower stages when high thrust is must-have over specific impulse.

4) REUSABLE ROCKETS: REVOLUTIONIZING ACCESS TO OUTER SPACE

- **Why in news?**
  - European Space Agency (ESA) has contracted with aerospace giant ArianeGroup to develop a reusable rocket. (Dec 2020)

- **Details**
  - Reusable launch system is a launch system that includes the recovery of some or all of the component stages and reuse of these components in another launch.
  - **Till now**, several fully reusable sub-orbital system and partially reusable orbital systems have been flown. During 21st century, the interest in reusable launch system has grown considerably, with several active launchers.
    - **SpaceX's Falcon 9** rocket has a reusable first stage and expendable second stage. Plans for the second stage of the Falcon 9 to be made reusable, creating a fully reusable system, have been cancelled, with the SpaceX starship being planned as a fully reusable launch vehicle.
  - If ISRO is able to develop this technology, it will reduce the cost of launch by 70-80% and increase the competitiveness of ISRO in satellite launch market.

- **Steps taken by ISRO to develop RLV**
  - In May 2016, ISRO successfully test fired its first indigenous winged reusable satellite launch vehicle.
    - In this experimental mission, the HS9 solid rocket booster carrying RLV-TD lifted off form the First Launch Pad at Satish Dhawan Centre, Sriharikota.
    - The RLV-TD re-entered the earth after reaching a height of 70 km.
    - It was a baby step towards developing reusable launch vehicle.
    - Critical technologies validated
      - Autonomous navigation
      - Guidance and control
      - Reusable thermal protection system
      - Re-entry mission management
    - **Ultimate Aim**: Ultimate aim of the project is to put satellite into orbit around earth and then reenter the atmosphere.
  - **The final version would take another 10-15 years to get ready**.

5) LOW-COST SMALL SATELLITE LAUNCHER (SSLV)

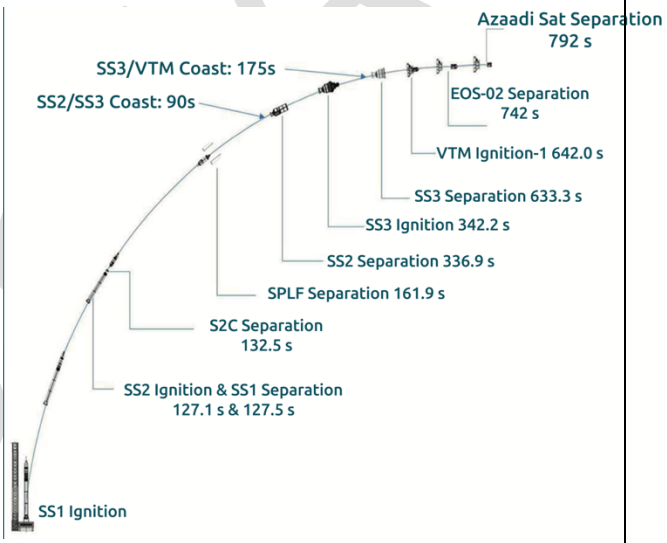
- **Why in news?**
  - ISRO SSLV Maiden Flight (SSLV-D1) only a partial success (Aug 2022)

- **Introduction**
  - The Indian SSLV (Small Satellite Launch Vehicle) is a small launch vehicle which will serve small satellite launches.
  - It is the **smallest vehicle** at 110-ton mass at ISRO.
  - **Low turnaround time**: It will take only 72 hours to assemble (unlike around 70 days needed for PSLV).
  - **Low Human Resource requirement**: Only 6 people will be required to do assembly (unlike 60 people for the PSLV).
  - **Cost Effective:** The overall cost of building the SSLV will only be Rs 30 crores.

- **Capability:** Payload capacity of 500 Kg to 500 km planar orbit or 300 kg to SSPO. Using PSLV for these small satellites was an overkill.
- It uses **three solid fuel-based stages** and a liquid fuel-based **velocity trimming module (VTM**) to place the satellite in orbit.
- It is ideal for on-demand, quick turn-around launch of small satellites.
- **Major technologies** developed as part of SSLV are flexible nozzle control with electro-mechanical actuators for all stages, miniaturized avionics, and a velocity trimming module in the upper stage for precise satellite injections.

- **Need**
  - The **global demand** for launch of small satellite is increasing. It is being demanded by businesses, government agencies, universities, and various research labs.

- **First Developmental Flight**
  - The maiden flight of SSLV in Aug 2022 can be considered a partial success.
    - The three solid fuel-based propulsion stages functioned normally.
    - However, when it came to the stage when the satellite had to be set in orbit, there was a glitch which resulted in the satellite being lost forever. ISRO announced that there was a malfunction of a sensor which resulted in placing the satellites in an elliptical orbit, rather than a circular orbit.
      - It placed the satellites into 356 km X 76 km elliptical orbit instead of 356 km circular orbit.



    - **What next:** A committee would study this failure and with the implementation of recommendations, ISRO will come back soon with SSLV-D2.
    - **What satellites was SSLV-D1 carrying?**
      - It was carrying EOS-02 weighing 145 kg and AzaadiSat, made by 750 schoolgirls to celebrate 75 years of independence under SpaceKids India, weighing 8 Kg.

6) ISRO TESTS HYBRID PROPULSION SYSTEM (SEP 2022)

- This hybrid propulsion system uses solid fuel (HTPB) and liquid oxidizer (LOX). The test was conducted for 15 seconds on a 300 – mm sounding rocket motor.
  - **Advantages:** It is more efficient, 'greener' and safer to handle and paves the way for new propulsion technologies for future mission. Hybrid technology would allow restarting and throttling capabilities on the motor. The use of liquids facilitates throttling and control over the flow rate of LOX.

» The test paves the way for hybrid propulsion-based sounding rockets and an exciting platform for vertical landing experiments for spent-stage recovery.

- The test was conducted by Vikram Sarabhai Space Center at ISRO Propulsion Complex, Mahendragiri.

5. ISRO SATELLITES

1) BASICS

- **What is a satellite?**
  - Satellite means a smaller, space-based object moving in a loop (an orbit) around a larger object.
    - The Moon is a natural satellite of earth because gravity locks it in orbit around our planet.
  - **Types of Artificial Satellites**
    - Artificial satellites are grouped according to the jobs they do or the orbit they follow.

2) COMMUNICATION SATELLITES

- **Introduction**
  - A communication satellite is an artificial satellite that is placed in earth's orbit for the purpose of sending and receiving communication data between a source and destination. They are basically "**space mirrors**" that can help us bounce radio, TV, Internet data, and other kinds of information from one side of earth to another.
  - It is used to provide **data communication and relaying services** for televisions, radio, telecommunication, weather and internet.
  - Communication satellites essentially overcome the problem of sending radio waves, which travel in straight lines, around our curved planet.
  - They commonly move in geo-stationary orbit.
    - Why?
    - Communication satellites can also move in highly elliptical orbit.

- **Two types of Communication Satellites – Passive and Active**

3) COMMUNICATION SATELLITES OF INDIA / ISRO

- **The Indian National Satellite System (INSAT) System** is one of the largest domestic communication satellite system in Asia-Pacific region.
  - It was established in 1983 with the launch of INSAT 1B, it initiated a major revolution in India's communications sector and sustained the same later.

- The system presently consists of the constellation of INSAT system consisting of around 20 operational satellites, namely INSAT-3A, 3C, 4A, 4B, 4CR, GSAT 6,7,8,9,10, 12, 14, 15, 16, 18, 19, 17, 6A, 29, **11** (largest 5850 Kg, Dec 2018), 7A (Mostly for serving air force, Dec 2018) and 31 (Feb 2019).

- INSAT system with more than 200 transponders in the C, extended C and Ku-bands provides services to telecommunication, television broadcasting, satellite newsgathering, societal application, weather forecasting, disaster warning and search and rescue operations.

4) RECENT EXAMPLES OF COMMUNICATION SATELLITES

A) RECENT LAUNCHES: CMS-01

- CMS-01 is a communication satellite envisaged for providing services in Extended-C Band and frequency spectrum. It is the 42nd communication satellite of India.
- The extended C-band coverage will include Indian Mainland, Andaman-Nicobar & Lakshadweep Islands.
  - It was launched in Dec 2020 with the help of PSLV C-50 rockets. It is located in GSO orbit.

B) GSAT 7A (ANGRY BIRD)

This is the first satellite built primarily for Air Force (around 70%). It will also support aerial activities for Army and Navy wherever required.

C) GSAT-11

- It is the biggest and most advanced communication satellite built by ISRO till date (Dec 2018). The satellite weighs **5854 kg** and was launched on Dec 5, 2018 using Ariane 5 ECA – VA246, a rocket of European Space Agency from French Guiana in GTO. From GTO the satellite moved into Geo-Stationary Orbit.
- It is part of ISRO's family of **High Throughput communication Satellites** (HTS) fleet that will drive the country's internet broadband from space to untouched areas. For now, the internet broadband is ruled by underground fibres and thus leads to infra problems in remote areas.
- **Other Technical details of GSAT-11**
  - GSAT – 11's multiple spot beam coverage with **40 transponders** – 32 in Ku Band and 8 in Ka band – will deliver an improved service of 16 Gbps over the Indian regions and nearby islands.
  - Life Span – 15 years

5) EARTH OBSERVATION SATELLITES (PHOTOGRAPHY, IMAGING AND SCIENTIFIC SURVEYING)

- Earth Observation Satellites are specifically designed for Earth Observation from Orbit and are used for environmental monitoring, meteorology, map making etc.
- Most earth observation satellites carry instruments that should be operated at a relatively low altitude.

- **Earth Observation Satellites of India**
  - » Starting with IRS-1A in 1988, ISRO has launched many operational remote sensing satellites.
  - » Today, India has one of the largest constellations of remote sensing satellites in operation. Currently, earth observation satellites which are in **Sun-synchronous orbit** include
    - EOS-01, EOS-02, EOS-06 (Oceansat-3)

- RESOURCESAT-1, 2, 2A
- CARTOSAT-1, 2, 2A, 2B etc
- CARTOSAT-3 (Launched in Nov 2019)
- RISAT-1, RISAT-2, RISAT-2B (launched in May 2019 – PSLV C46), RISAT-2BR1 (launched in Dec 2019 – PSLV C-48)
- OCEANSAT-2
- Megha-Tropiques, SARAL and SCATSAT-1
- **HySIS**

- Earth Observation satellites in **Geostationary Orbit include:**
  - EOS-03 (couldn't be put in orbit due to failure of GSLV-F10)
  - INSAT-3D, INSAT 3DR
  - Kalpana & INSAT 3A

» Varieties of instruments have been flown onboard these satellites to provide necessary data in a diversified spatial, spectral and temporal resolutions to cater to different user requirements in the country and for global usage. The data from these satellites are used for several applications covering agriculture, water resources, urban planning, rural development, mineral prospecting, environment, forestry, ocean resources and disaster management

- **Some Recent Earth Observation Satellites in news**

A) EARTH OBSERVATION SATELLITE (EOS-06) / OCEANSAT-3 (NOV 2022)

- The third generation of Indian Satellite for monitoring the oceans, formally named EOS-6 was launched by ISRO in partnership with Ministry of Earth Science from its launch pad at Satish Dhawan Space Centre (SDSC), Sriharikota.
  - » This ocean observing mission is a follow up to Oceansat-1 or IRS-P4 and OceanSat-2 launched in 1999 and 200i, respectively.
- The satellite was launched aboard the proven launch vehicle PSLV (Polar Satellite Launch Vehicle) on its 56th flight (24th flight of PSLV-XL), designated as **PSLV-C54**. This mission also accommodated eight other nano satellites along with OCEANSAT-3.
  - » The eight nanosatellites included ISRO Nano Satellite-2 for Bhutan (INS-2B), Anand, Astrocast (four satellites), and two Thybolt satellites.
- **More Details about OCEANSAT-3**
  - » It was placed in the polar orbit at a height of about 740 kms above sea level. Its weight is ~1100 kgs, it is only slightly heavier than Oceansat-1.
  - » For the first time in this series, it houses ocean observing sensors viz Ocean Color Monitor (OCM-3), Sea Surface Temperature Monitor (SSTM), and Ku-Band scatterometer (SCAT-3). There is also an ARGOS payload. All these sensors have their own importance in India's blue economy aspirations.
    - ARGOS is a component of France and reinforce the existing fleet of Indo-French satellites working on weather surveillance that are already in orbit (Megha-Tropiques and Saral-Altika).
  - » **OCM** will observe day side of the earth every day and will provide crucial data on distribution of ocean algae which is base of the food chain within marine ecosystem. The OCM-3 with high signal to noise ratio is expected to provide improved accuracy in daily monitoring of phytoplanktons having wide range of operational and research applications including fishery resource management, ocean carbon uptake, harmful algal boom alerts, and climate studies.

» While ISRO will continue to maintain the orbit of the satellite and its standard procedures for data reception, archive etc, the major operational **user of this satellite would be MoES institutions** viz Indian National Centre for Ocean Information (INCOIS), Hyderabad and National Centre for Medium Range Weather Forecasting (NCMRWF), Noida that provide a bouquet of services every day for lakhs of stakeholders across the nation.

B) RISAT-2

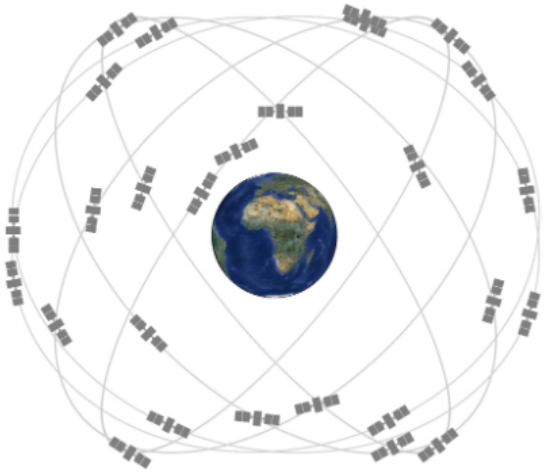
- **Why in news?**
  - » ISRO's RISAT-2 satellite makes re-entry into Earth's Atmosphere (Nov 2022)

- **Details**
  - » ISRO's RISAT-2 satellite, launched in 2009, has made an uncontrolled re-entry into the Earth's atmosphere. ISRO said that the satellite weighing about 300 Kg, made an uncontrolled re-entry in the Indian Ocean near Jakarta on 30th October 2022.
  - » This satellite was launched by PSLV in 2009. Initial design life of the satellite was four years. But due to proper maintenance of orbit, and mission planning by the spacecraft operation team in ISRO and economic usage of fuel, RISAT provided very useful payload data for 13 years.
  - » **No contamination and No Explosion**: Since there were no fuel left in the RISAT.
  - » **No Fragments hitting earth**: Various studied confirmed that the pieces generated due to aero-thermal fragmentation would not have survived re-entry heating and hence no fragments would have impacted on Earth.

6) SATELLITE NAVIGATION (SAT – NAV)

A) GLOBAL POSITIONING SYSTEM (GPS)

- The best-known satnav system, GPS, uses 24 active satellites (including backups). Day and night, 365 days a year, they whiz around earth once every 12 hours on orbital plane inclined 55 degrees to the equator.
- Wherever you are on earth, you are in sight of at least half a dozen of them, but **you need signals from 3 or 4 satellites** to determine your position with an accuracy of just a few meters.



- **How GPS Finds your location?**
  - » It uses **Trilateration**

- **GPS Constellation arrangement**
  - » GPS constellation fly in medium earth orbit (MEO) at an altitude of approx. 20,200 kms. Each circle orbits the earth twice a day.
  - » The satellites are arranged in six equally placed orbital planes surrounding the earth. Each plain contains four slots occupied by baseline satellites. This 24-slot arrangement ensures users can view at least four satellites from virtually any point on the planet.

B) BEIDOU

» **Why in news?**

- China's home-grown Beidou satellite system eyes global footprint (Nov 2022)

» **Details**

- China initiated BeiDou in 1994 with aims to integrate its application in different sectors, including fishery, agriculture, special care, mass-market applications, forestry and public security.
  - » The **roll out of BeiDou** has taken 2 decades. The first BeiDou satellites were launched in 2000, providing coverage to China.
  - » **Second generation BeiDou (BDS-2)** provided **coverage to Asia Pacific region** starting in 2012.
  - » **Third generation BeiDou** (BDS-3) satellite deployment started in 2015 and it started providing navigation services in 2018 to countries taking part in BRI. **In 2020, the system has been completed and it can now provide global services.** With this they have joined United States' GPS and Russia's GLONASS in providing global PNT services, with Europe's Galileo to follow. These are all compatible and interoperable, meaning users can draw services from all of those to improve accuracy.

» **Satellite Constellation**

- **24 satellites in Medium Earth Orbit** (around 21,500 kms above the earth) provide the positioning, navigation, and timing (PNT) services. These satellites use rubidium and hydrogen atomic clocks for highly-accurate timing that allows precise measurement of speed and location.
- **Satellites in geosynchronous Orbit (**including Geo-stationary orbit**)** help BeiDou provide short messaging service through which 120-character messages can be sent to other BeiDou receivers.

» **Plans of Expansion:**

- In Nov 2022, China outlined plans to further expand the global reach of its home grown Beidou satellite navigation system.
  a. **Pakistan** in 2014 became the first foreign country to set up a Beidou network.
  b. **Beidou** has set up a first of three Continuously Operating Reference Stations (CORS) for its network in Thailand in 2013, to serve as a hub for ASEAN.

C) NAVIC (NAVIGATION USING INDIAN CONSTELLATION)

- **Why in news?**

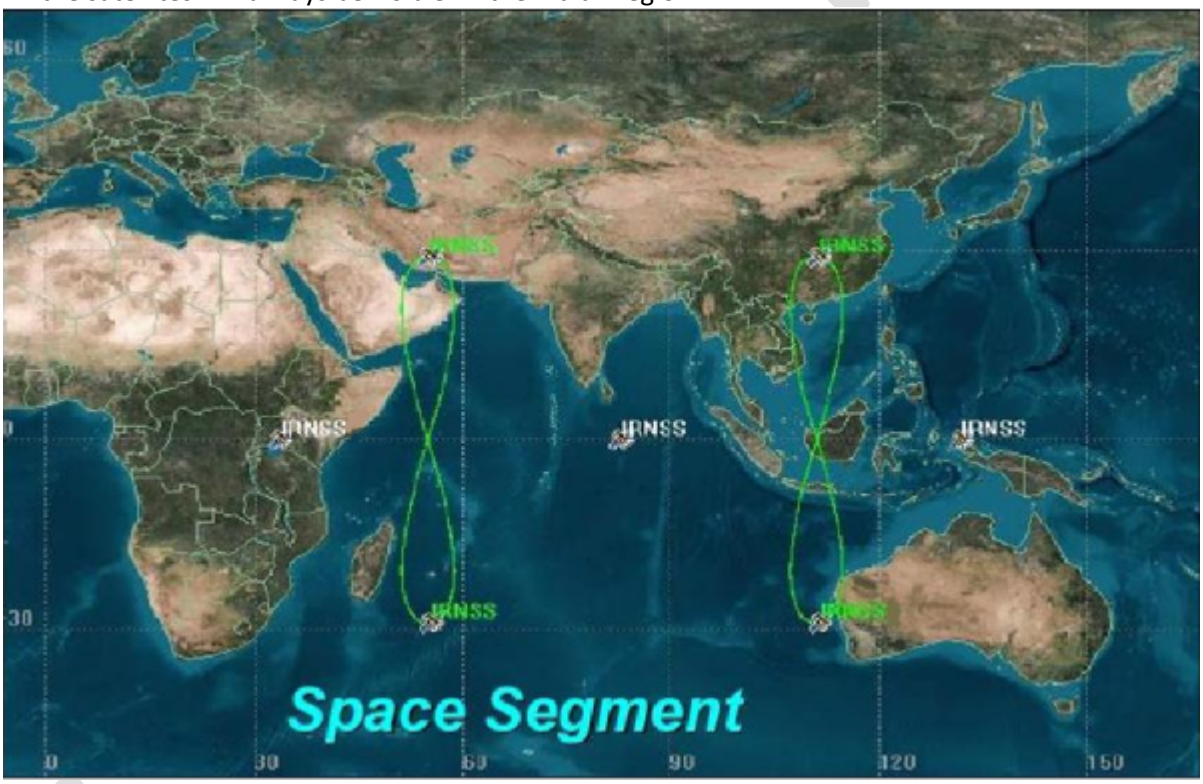
  ISRO to boost NavIC, widen user base of location system (Oct 2022)

- To meet the **user requirement of positioning, navigation and timing services based on indigenous system,** ISRO has a regional satellite navigation system called **Indian Regional Navigation Satellite System (IRNSS)**. (NAVIC)
  - IRNSS is an independent regional satellite-based positioning and navigation system, designed to provide position information in the Indian region and 1500 km around the Indian mainland.
  - **Need:** The access to foreign controlled global navigation satellite systems is **not guaranteed in hostile situations**, as happened to Indian military depending on American GPS during **Kargil War**.
  - **Objective:**
    - » To provide reliable positioning, Navigation and Timing services over India and its neighbourhood, up to 1500 Km from its boundary
    - » To provide fairly good accuracy to the user.

- **Two types of services**
  - » **Standard Positioning Service**
    - Open for civilian use
  - » **Restricted Service**
    - Encrypted one, for authorized users(military)

- NavIC system, in addition to its primary function of providing PNT services, is **also capable of broadcasting short messages**. This messaging service is being used for broadcasting safety-of-life alerts in areas with poor or no communication, particularly in Ocean.
  - In Dec 2021, **ISRO has signed an MoU with OPPO** India to exchange technical information of NaVIC messaging service. This will enable integrating NaVIC messaging service with the mobile handset platform keeping in mind the need of Indian users.

- **Components of IRNSS system**
  - » Space segments consists of **7 satellites**, **3 satellites in GEO stationary orbit (GEO**) and **4 satellites in GEO synchronous orbit(GSO)** with inclination of **29 degree** to the equatorial plane.
  - » All the satellites will always be visible in the Indian region.



- **Global Standards body, 3GPP (3rd Generation Partnership Project) which develops protocols for mobile telephony, has approved India's Regional Navigation System (NAVIC)** (Sep 2019)

- **International Navigation Systems**
  - US's **Global Positioning System (GPS)**
  - Russia's **Global Orbiting Navigation Satellite System (GLONASS)**
  - European Union's **Galileo (GNSS)**
  - China's **BeiDou satellite navigation system**.
    - » BeiDou-3 constellations consist of 35 satellites and is ready to provide global coverage.
  - Japan's **Quasi Zenith Satellite System**

- **Application of NavIC**
  - Terrestrial, aerial and marine **Navigation**
  - Disaster Management
  - Vehicle tracking and fleet management
  - Integration with mobile phones
  - Precise timing
  - Mapping and geodetic data capture
  - Terrestrial navigation aid for hikers and travellers
  - Visual and voice navigation for drivers

- **Where is NaVIC being used presently?**
  - NavIC based applications are being used in various civilian sectors, including, transport, map applications, and timekeeping.
  - Today, major mobile chipset manufacturers like **Qualcomm, MediaTek and Broadcom** already support NavIC across various chipset platforms. Some example phones which have NavIC enabled mobile phones include the Redmi Note 9, Realme 6, the OnePlus Nord etc.

- **Promoting the use of IRNSS**
  - **NavIC** chip -> affordable
  - **Spreading awareness** -> Positional accuracy better than 20 m and timing accuracy better than 50 ns (20);
  - **Make compulsory for** phones marketing in India: Mobile phones haven't been made compatible to process its signals.
    - The Indian Government has been pressing manufacturers to add compatibility, and has set a deadline of Jan 2023. But, media reports suggest that this may not be possible before 2025.
    - Representatives of **Apple, Xiaomi, Samsung and others have pushed bac**k, citing worries that making phones NaVIC-compliant would require high research and production cost.

  - **Government apps** -> start using NaVIC for various purpose.
  - HEIs -> Promote use in Labs, among students etc.

- **How good is NAVIC?**
  - Government says that NAVIC is as good as GPS in terms of position accuracy and availability in its service region.
- **Future:**
  - **ISRO** is working on a series of improvements to the **NavIC**, so that more people are motivated to install it and use it.
  - Plans are also afoot to make it reach global rather than circumscribe it to India and limited territory around it.
  - ISRO is planning to increase the number of satellite in IRNSS to give it a global reach.
  - It also plans to add L1 Band into NAVIC. This bandwidth is part of the GPS and is the most used for civilian navigational use. "*Currently*, NAVIC is only compatible with L5 and S bands and hasn't easily penetrated into civilian sectors".

7) SATELLITES TO STUDY THE SUN: ADITYA AND ADITYA L1

Background: ADITYA: The Aditya-1 mission was conceived as a 400kg class satellite carrying one payload, the Visible Emission Line Coronagraph (VELC) and was planned to launch in an 800 km low earth orbit.

ADITYA L1: A Satellite placed in the **halo orbit around the Lagrangian point 1 (L1)** of the Sun-Earth system has the major advantage of **continuously viewing the Sun without any occultation/ eclipses.** Therefore, the **Aditya-1 mission has now been revised to "Aditya-L1 mission**" and will be inserted in a halo orbit around the L1, which is 1.5 million km from the Earth. The satellite carries additional six payloads with enhanced science scope and objectives

About HALO Orbits: A halo orbit is a, three dimensional orbit near the L1, L2, or L3 Lagrangian point in the three body problem of orbital mechanics. Although the Lagrange point is just a point in empty space, its peculiar characteristics is that it can be orbited.

Scientific Objectives

- Studying solar corona, achieving the fundamental understanding of the physical process that heat the solar corona, accelerating solar wind and producing coronal mass ejections.

Thus, the enhanced Aditya-L1 project will enable a comprehensive understanding of the dynamic processes of the sun and address some of the outstanding problems in the solar physics

6. OTHER IMPORTANT PROJECTS OF ISRO

1) PROJECT NETRA

- It is an EWS in space to detect debris and other hazards to satellite. It will also provide warning against missile and space attack against India's assets.
- It will consist of many observational facilities, connected radars, telescopes, data processing units, control centers etc.
- **Initially**, it will be launched for **LEO satellites** which inhabits remote sensing satellites. **Eventually,** NETRA will also have the capability to capture **GEO**, where communication satellites mostly reside.
    - **Does India not have any collision avoidance detection mechanism now?**
- Even now, India does collision avoidance maneuvers on our satellites. But for this it depends on data from **NORAD (**North American Aerospace Defense Command**)** and others available in the public domain.
- **NOTE:** NORAD is an initiative of USA and Canada and shares selective debris data with many countries

2) MISSION SHAKTI

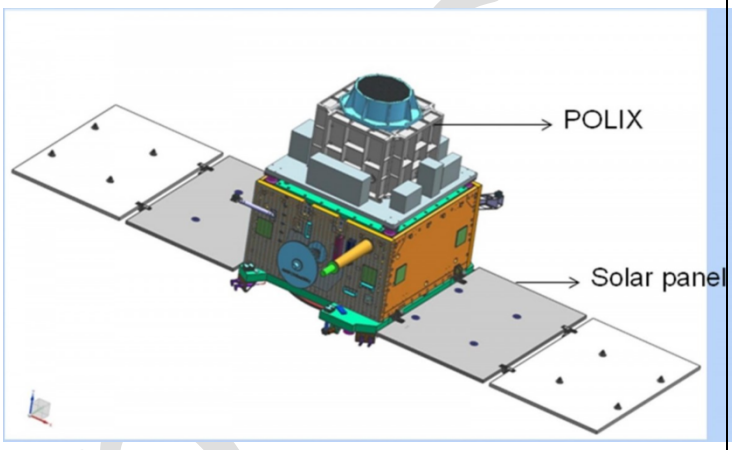
- An ASAT tested by India

3) GAGANYAAN

4) XPOSAT (X-RAY POLARIMETRY SATELLITE)

- **Why in news?**
  - ISRO plans to launch XPoSat, onboard a PSLV in the second quarter of 2023.

- **More Details**
  - XPoSat will be a specialized science mission that will study the **polarization of X-Rays** in space.
    - The mechanization of polarization of radiation gives away the nature of its source, including the strength and distribution of the magnetic field and the nature of radiation around it.
    - Till now, the **Crab Nebula** is the only x-Ray source for which scientists have measured the polarization. XPoSat is expected to provide the same information about 50 brightest known sources in the universe, including pulsars, X-ray binary stars and galactic cores.



- **XPoSAT's polarimeter instrumen**t, which works in the medium X-Ray region (8-30 keV), is being built and tested by scientists at the **Raman Research Institute.**
- The telescope is being developed by the ISRO and Raman Research Institute.
- Like ASTROSAT, XPoSat will also be launched in a low-Earth Orbit.

6) NASA-ISRO SYNTHETIC APERTURE RADAR (NISAR) IMAGING SATELLITE

- **Introduction:**
  - NASA and ISRO are jointly working to co-develop and launch a dual frequency (**L&S band**) synthetic aperture radar (SAR) Imaging Satellite (NISAR) by **2022**.
  - Once launched, it will be **world's most expensive earth-imaging satellite** till date costing around $1.5 billion.

- **Collaboration**
  - NISAR is considered the first big collaboration between ISRO and NASA, certainly on RADAR but just in general as well.
  - The project will consist of two radars.
    - S-Band SAR is being built by ISRO and L-band by NASA
    - » The satellite will be launched from India using **GSLV-MK-2**.
    - » **Uses:** NISAR will provide an unprecedented, detailed view of the earth by using Advanced RADAR imaging. It is designed to observe and take measurements of some of the planet's most complex process, including ecosystem disturbances, ice-sheet collapse, and natural hazards such as earthquakes, tsunamis, volcanoes, and landslides. The satellite thus will be used for:
      - Mapping and monitoring of natural resources
      - Estimating agricultural biomass over full duration of crop cycle.
      - Assessing soil moisture

- Monitoring of floods and oil slicks
- Monitoring coastal erosion, coastline changes, and variation in the wind.

7. ISRO'S INTERPLANETARY MISSION

1) MARS ORBITER MISSION

- **Details**

  - Mars Mission (MOM), also called Mangalyaan is spacecraft orbiting MARS since 24 September 2014.
  - It was launched on 5 November 2013 by the Indian Space Research Organization (ISRO).
  - It is India's first interplanetary mission and ISRO has become the fourth space agency to reach Mars, after the Soviet space program, NASA, and the European Space Agency.
  - It is the first Asian nation to reach Mars orbit, and the first nation in the world to do so in its first attempt.

- **What is MOM doing?**
  - It has been looking for signs of atmospheric methane while studying surface features - just like NASA's MAVEN Mission.
  - Methane is considered a **biomarker**: a substance whose presence indicates the current or historical presence of life.
  - MOM is also exploring and observing Mars surface features, morphology, minerology, and the Martian atmosphere.

- **Mars Orbiter Mission – 2** (Mangalyaan – 2) is expected to be launched in the year 2024. It will consist of an orbiter and may also include a lander and rover.

2) VENUS: SHUKRAYAAN-1

Why in news?

- **ISRO likely to push Venus Mission** 'Shukrayaan – 1' to 2031 (Jan 2023)

Details

- Shukrayaan-1 is a **proposed orbiter to Venus by ISRO** to study the surface and atmosphere of Venus. It will be first mission to Venus by ISRO.
- It will be launched with the help of GSLV MK-II or GSLV MK-III.
- **Instruments:**
  - The **flagship instrument** will be **a synthetic aperture radar** to examine the Venusian surface, which is shrouded by thick clouds that make it impossible to glimpse the surface in visible light.
  - Another instrument will be a Swedish-Indian collaboration known as the Venusian Neutral Analyzer, which will analyze how charged particles from sun interact with the atmosphere of Venus.
  - In Sep 2020, the French Space Agency (CNES) announced that it would also fly an instrument on Shukrayaan. **The Venus Infrared Atmospheric Gases Linker** (VIRAL) is a collaboration with Russian federal space agency Roscosmos.
- **Plan:**
  - The idea of launching Shukrayaan was born in 2012. In 2017-18, ISRO commenced preliminary studies after the Department of Space received a 23% increase in the 2017-18 budget.
  - **Earlier,** ISRO was aiming for a mid-2023, but pandemic related delays have pushed the target to Dec 2024.

- **Note:** This launch opportunity **comes only in 19 months** due to orbital configuration and period of Earth and Venus. So, after Dec 2024, the next opportunity will be available in mid-2026 and 2028.

- **Delays:**
  - Scientists at ISRO said that the organization was yet to receive approval from the Union Government for the Venus mission and that the mission could as a result be postponed to 2031 (Jan 2023)
  - **More optimal windows**, which further reduce the amount of fuel required at lift-off, come around every **eight years**.
  - **Note:** US (**VERITAS**) and ESA (EnVision) also have their Venus mission planned for 2031.
- **Venus Missions in the Past**
  - **Dozens of missions** have flown to Venus since the 1960s, but only a few in recent years.
    - **ESA's Venus Express** orbited the Venus between 2006 – 2014
    - **Japan's Akatsuki** spacecraft entered orbit in 2015 after a previous unsuccessful attempt. Several aircrafts are also performing **flybys** of Venus in the near future, including **NASA's Parker Solar Probe** for Solar Observation, and **Europe's BEPIColombo** en route to Mercury

3) CHANDRAYAAN-1

Chandrayaan-1, India's first mission to Moon, was launched successfully on October 22, 2008 from SDSC SHAR, Sriharikota. The spacecraft was orbiting around the Moon at a height of 100 km from the lunar surface for chemical, mineralogical and photo-geologic mapping of the Moon. The spacecraft carried 11 scientific instruments built in India, USA, UK, Germany, Sweden and Bulgaria

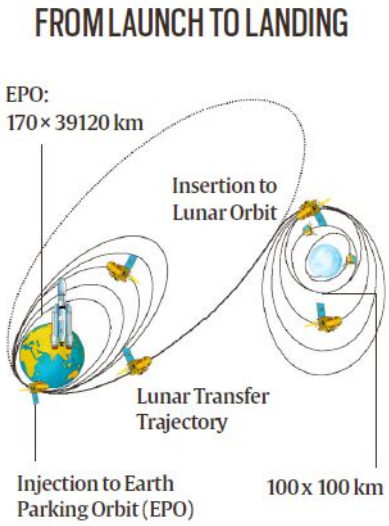
4) CHANDRAYAN-2

- **Introduction**
  - Chandrayan-2, **India's second mission to the moon**, is an advanced version of the previous Chandrayana-1 mission. It originally consisted of an orbiter, Lander (Vikram) and Rover (Pragyan).
  - It was India's first attempt to make a **soft landing** on the moon, but ISRO was not successful in landing the Lander (Vikram) module.
  - It was a completely indigenous mission i.e. all the components of the mission were developed by India. This also led to significant delay in the launch of the mission.
  - 

- **Key differences between Chandrayaan-2 and Chandrayaan-1**

Chandrayaan 1	Chandrayaan-2
Not completely indigenous (help from countries like Russia)	Completely indigenous
Contained an **Impactor module** which provided for **crash landing**	Contains a **lander and Rover** which are meant to make a safe landing and work on moon
PSLV was used as the launch vehicle	**GSLV-MK-III,** the most powerful of the ISRO rockets has been used

- **How has Chandrayaan 2 reached the Moon**
  - GSLV-MK-III vehicle was used to launch Chandrayaan-2 in the orbit around earth. It remained orbiting around earth for **around a month** and kept raising its height. Then it spent around **10 days** orbiting and maneuvering around moon before reaching its final orbit of 100 X 100 (Sep 2, 2019)
  - **On Sep 2**, Vikram **lander** was separate from the orbiter. Two orbit maneuvers were performed on the lander before the initiation of powered descent on **Sep 7**. It **couldn't soft** land on moon.



- **How was the soft landing to be achieved?**
  - Landing was the **most complicated part** of the mission. The Lander and Rover were ejected at a speed of around 6,000 km/hr and had to be slowed down to roughly 3 km/hr before it lands. Since moon doesn't have atmosphere, parachute kind of mechanism can't be used. Here, **thrusters** had to be fired in opposite direction to slow down the lander.

- **What was Chandrayaan-2 supposed to do?**
  - **Demonstrating ISRO's new capabilities** such as ability to land on any extra-terrestrial surface. So far **only three other countries** have developed and demonstrated this capability for moon i.e., USA, Russia, and China. (**failed**)
  - The **Orbiter** is creating a detailed **three-dimensional map of the lunar surface** and providing a lot of other information.

5) CHANDRAYAAN 3.0

- **Why in news?**
  a) ISRO plans the launch of Chandrayaan-3 by the "middle of 2023": ISRO chairperson – Dr K Sivan (Jan 2022)

- **Details**
  a) Chandrayaan 3.0 will not carry an orbiter module. It would only have a lander and rover.
  b) Chandrayaan-3 design changes incorporation and testing has seen a huge progress.

6) LUNAR PROBE EXPLORATION MISSION (LUPEX)

- Indian ISRO, Japanese JAXA join hands for joint Moon Mission – 'Lunar Polar Exploration'
- It is a lunar mission concept by ISRO and JAXA (Japanese Aerospace Exploration Agency) that would send a lunar rover and lander to explore the south pole region of the Moon in 2024.
- According to diagrams released by JAXA – the Japanese will be building the overall landing module and the rover, while scientists from ISRO would be handling the lander development.

8. OTHER IMPORTANT PROJECTS OF ISRO

1) INDIA'S OWN SPACE STATION: PLANS

- **Introduction**
  - A space station is a spacecraft capable of supporting crew members, designed to remain in space for an extended period of time and for other spacecrafts to dock.
  - Currently, there is only one fully functional space station in the earth's lower orbit, the **International Space Station** and the astronauts conduct different experiments in it. It is a partnership between NASA (USA), JAXA (Japan), CSA (Canada), and Roscosmos (Russia). It is world's largest international cooperative program in science and technology. China is also building a space station of its own.
  - **India** also plans to do the same and with this in mind ISRO plans to have its own space station 5 to 7 years after the successful launch of Gaganyaan in 2022.
  - The proposed space station is envisaged to weigh **20 tonnes**, which will be placed in LEO at a height of 400 km and will serve as a facility where astronauts can stay for 15-20 days.
  - The plan is to launch the space station within 5-7 years after Gaganyaan launch.
  - India will become only the fourth country to launch a space station after US, Russia and China which plans to launch it in 2020.
    a) perspective of learning for the futuristic space (both manned and unmanned) missions.

- **What advancements will India need to achieve to have its space Stations?**
  - All the **Gaganyaan requirements** (Space suits, Training facilities for astronauts, Crew Escape Module, making GSLV Human rated, developing a habitable module etc)
  - **Larger bigger rocket** by upgrading the capabilities of GSLV-MK-III (it is right now capable of carrying on 10 tonnes to LEO)
  - Developing ability to perform **space docking.** ISRO has revealed its plan to carry out a space docking experiment, **Spadex**.

a)

9. IMPORTANT TELESCOPES IN NEWS RECENTLY

1) GIANT METREWAVE RADIO TELESCOPE (GMRT)

- **Why in news?**
  - Giant Meterwave Radio Telescope in Pune helps detect atomic hydrogen from far-away galaxy (Jan 2023)
- **Details about GMRT**
  - The Giant Metrewave Radio Telescope, located near Pune in India.
  - It is an array of **thirty fully steerable parabolic radio telescopes of 45 meter diameter**, **observing at metre wavelength**.
  - It has been set up by **NCRA** (National Centre for Radio Astrophysics)**,** a centre of the school of natural science of the TIFR.
  - GMRT is for radio astronomical research at metre wavelengths.
    - It is a very versatile instrument for investigating a variety of radio astrophysical problems.
    - It is **one of the most challenging experimental programmes in basic sciences undertaken by Indian scientists and engineer**s.
  - **Why Metre Wavelength**
    - **Manmade radio interference is considerably lower** in this part of the spectrum in India.
    - There are many outstanding astrophysics problems which are best studied at metre wavelengths, there has, so far, been no large facility anywhere in the world to exploit this part of the spectrum for astrophysical research.
- **A Radio signal originating from atomic hydrogen in an extremely distant galaxy was detected by the GMRT**. (Source: DTE, Jan 2023)
  - This is the largest astronomical distance over which such a signal has been picked up. It was picked up from a distance of 8.8 billion years ago.
  - **Note:** Atomic hydrogen emits radio waves of 21 cm wavelength, meaning the wavelength is direct tracer of the atomic gas content in the nearby and distant galaxies.
  - However, this radio signal is feeble and nearly impossible to detect the emission from a distant galaxy using current telescopes due to their limited sensitivities.

2) VARIOUS TELESCOPES AT DEVASTHAL

- **Why in news?**
  - World's first liquid mirror telescope for astronomy comes to India (June 2022)
- Devasthal observatory is located at Aryabhatta Research Institute of Observational Science (ARIES) in Nainital. It is located at the height of 2,450 metres in Himalayas. It is considered as one of the best sites for astronomical observations. This facility is the result of collaborative work between astronomers from ARIES, Institute of Astrophysics and Geophysics, Liege University, Belgium; the Canadian Astronomical Institutes from Vancouver, University of British Columbia; etc.
- **Telescopes at Devasthal:**

- **Devasthal Optical Telescope (DOT)** is a custom-built instrument of great complexity. It has the distinction of being the **largest telescope in India for study of celestial objects at optical wavelength**. It is a national facility installed at Devasthal in the district of Nainital, India. It was commissioned in 2016 and is being mantained and operated by ARIES (Aryabhata Research Institute of Observational Sciences)
- **Devasthal Fast Optical Telescope** (DFOT): It was commissioned in 2010.

- **The International Liquid Mirror Telescope** (ILMT) is the only liquid mirror telescope operational anywhere in the world. It will also hold the unique tag of being the maiden liquid-telescope globally to be designed exclusively for astronomical purposes. It is the third telescope operating from Devasthal after DOT and DFOT.
  - The telescope was designed and built at the Advanced Mechanical and Optical Systems Corporation and the Centre Spatial de Liege, Belgium. The major instrumentation funding was jointly provided by Canada and Belgium while India will be responsible for the operations and upkeep of the telescope.
  - Unlike the conventional telescopes that can be steered to track specific stellar source objects, the ILMT will be stationary. It will basically carryout observations and imaging at the Zenith, that is, of the overhead sky. This is a survey telescope having high potential for discovering newer objects.
  - ILMT will operate every night for five years and carry out daily imaging except during June – Aug monsoon months, a precaution to protect the instruments from humid conditions.

- **What is liquid mirror telescope?**

  - LMTs are telescopes with mirrors made with a reflective liquid. The most common liquid is mercury, but other liquid will also work including (low melting alloys of gallium).
  - The liquid is rotated at a constant speed around a vertical axis, which causes the surface of liquid to assume a paraboloidal shape. This parabolic reflector can serve as the primary mirror of a reflecting telescope.
  - **Advantages:**
    - Low-cost alternative to conventional large telescopes.
  - **Limitations:** It can only be used as zenith telescopes (i.e. for looking straight up), so it is not suitable for investigation where the telescope needs to be continuously moved.

3) INDIA'S FIRST DARK SKY RESERVE (SEP 2022)

- **Why in new?**
  - **Dr Jitendra Singh**, Minister of State (Independent Charge) for Science and Technology announced that India will establish the country's first **Dark Sky Reserve** in the Cold Desert regions of Ladakh by the end of 2022 (Sep 2022)

- **What is a Dark Sky Reserve?**
  - A Dark Sky Reserve is a designation given to a place that has policies in place to ensure that a tract of land or region has minimal artificial interference.
  - **The International Dark Sky Association** (IDSA) is a US based non-profit that designates places as International Dark Sky Places, Parks, Sanctuaries, and Reserves, depending on the criteria they meet. Several such reserves exist in the world. **Between 2001 and Jan 2022**, there have been **195 sites** recognized as **International Dark Sky Places** globally. But, so far, no such reserve is in India.

- These reserves "consist of a **core area** meeting minimum criteria for sky quality and natural darkness, and a **peripheral area** that supports dark sky preservation in the core".

- **How does a site become a 'Dark Sky Reserve'?**
  - Individuals or groups can **nominate a site** for certification to the **IDSA**. There are five designated categories, namely International Dark Sky parks, communities, reserves, sanctuaries, and Urban Night Sky Places.
  - The certification process is similar to that of a site being awarded the **UNESCO World Heritage Site tag** or getting recognized as a Biosphere Reserve.
  - **Note:** India is still in the process of filing its nomination to IDSA.

- **Who is developing India's first Dark Sky Reserve?**
  - The **Ladakh UT administration** is leading the efforts to establish the country's first Dark Sky Reserve. The Department of Science and Technology (DST) and experts from Indian Institute of Astrophysics (IIA), Bengaluru, are providing scientific and technological support in developing this first of its kind facility. The formal decision to set up this Dark Sky Reserve was made through a MoU signed between officials from the **IIA, Bengaluru, the Ladakh UT and the Ladakh Autonomous Hill Development Council** in June 2022.
  - It will be situated at a height of 4,500 metres above sea level, **the Hanle Dark Sky Reserve** (HDSR) will come up within the **Changthang WLS**.
  - The IIA **already manages the Indian Astronomical Observatory (IAO) complex at Hanle, Ladakh**. Here scientists have been carrying out astronomical observations using the existing gamma ray, an infrared and an optical telescope to study exoplanets, galaxies, and stars through the pristine skies of Hanle.
  - **For Dark Sky Reserve**, in the pilot phase, IIA has procured ten small and easy to handle telescopes and light reflecting shields. IIA's scientific and outreach experts will identify locals and train them to use these telescopes. This will include basic sky gazing, identification of constellations, and locating the pole star, among others. These telescopes will be **installed at the homestays,** which is a popular option for tourist accommodation in Ladakh.

- **Why was Ladakh chosen for the project?**
  - It is a unique cold desert located about 3,000 metres above sea level with high mountainous terrains. Very cold temperature and long and harsh winter makes the UT very inhabitable. This **aridity, limited vegetation, high elevation, and large area with sparse populations** – all make it the **perfect setting for long-term astronomical observatories and dark sky places**.

- **Promotion of Astronomy Tourism** in an environment friendly and sustainable manner is one of the primary objectives of the proposed reserve. Scientific methods would be used here to keep light pollution under control.

A) THE INDIAN ASTRONOMICAL OBSERVATORY (IAO)

- The Indian Astronomical Observatory, the **high-altitude station of IIA**, is situated to the north of Western Himalayas, at an altitude of 4,500 meters above mean sea level.
- It is located atop Mt. **Saraswati** in the **Nilamkhul Plain in the Hanle Valley in Changthang**, it is a dry, cold desert with sparse human population and has the **Hanle monastery as its nearest neighbours**.

- The cloudless sky and low atmospheric water vapor make it one of the best sites in the world for optical, infrared, sub-millimeter, and millimeter wavelengths.
- **Prominent Telescopes located at the Hanle Observatory:**
  a) The Himalayan Chandra Telescope
  b) High Energy Gamma Ray Telescope (HAGAR)
  c) The Major Atmospheric Cherenkov Experiment Telescope (MACE)
  d) Growth-India

4) SARAS RADIO TELESCOPE

- **Why in news?**
  - India's SARAS Radio telescope provides astronomers clues to the nature of Universe's first stars and galaxies (Nov 2022)

- **Details about Saras Telescope**
  a) **Shaped Antenna measurement of the background Radio Spectrum 3 (SARAS) telescope** – indigenously designed and built at Raman Research Institute – was deployed over **Dandiganahalli Lake** and **Sharavati backwaters**, located in Northern Karnataka, in early 2020.

- **How are distant galaxies studied:**
  - Scientists study the properties of very early galaxies by observing radiation from hydrogen atoms in around the galaxies, emitted at a frequency of approximately 1420 MHz (wavelength of 21 cm). The radiation is stretched by the expansion of the Universe, as it travels across space and time, and arrives on earth in lower frequency radio bands (50 – 200 MHz) also used by FM and Radio transmission.
  - These signals are very faint buried in orders of magnitude brighter radiation from our own galaxy and man made terrestrial interference.

- **Details about the Findings:**
  a) Using data from SARAS 3, researchers from Raman Research Institute (RRI), Bengaluru, and various other foreign institutions, estimated energy output, luminosity, and masses of the first generation of galaxies that are bright in radio wavelength.
  b) The results from SARAS 3 telescope are the first time that radio observation of the averaged 21 cm line have been able to provide an insight to the properties of the earliest radio loud galaxies that are usually powered by supermassive blackholes.

  It has improved the understanding of **astrophysics** of **Cosmic dawn**, telling us that less than 3% of the gaseous matter within early galaxies was converted into stars, and that the earliest galaxies that were bright in radio emissions were also strong in X-Rays, which heated the cosmic gas in and around the early galaxies.

10. IMPORTANT PERSONALITIES

A) DR VIKRAM SARABHAI (12TH AUG 1919 – 30TH DEC 1971)

- Vikram Sarabhai, **father of Indian Space Program**, was born on 12th of Aug,1919 in Ahmedabad.

- **Key contributions**
  - He was a great institution builder and established or helped to establish a large number of institutions in diverse fields. He established **Physical Research Laboratory (PRL)** in 1947. PRL was the cradle of space sciences in India. PRL had a modest beginning at his residence, the RETREAT, with research in cosmic rays. It was formally established at M.G. Science Institute, Ahemedabad, on 11th Nov 1947
  - He played an important role in establishment of a number of institutions including IIM Ahemedabad.
  - The **establishment of ISRO** was one of his greatest achievements. He successfully convinced the government of the importance of space program after the Russian Sputnik launch.
    - He was the first chair of Indian National Committee for Space Research (INCOSPAR) which was predecessor to ISRO (established in its current form in 1969).
    - He also contributed in the setting up of Thumba Equatorial Rocket Launching Station at Thiruvananthapuram, with its inaugural flight in 1963.
  - He was also chairperson of Atomic Energy Commission.
- **Recognition**
  - **i)** He received Shanti Swarup Bhatnagar Medal in 1962
  - **ii)** Was awarded Padma Vibhushan (posthumously) in 1972. Earlier was awarded Padma Bhushan in 1966.
- **Other Key Positions held:**
  - **i)** President of the Physics Section, Indian Science Congress (1962)
  - **ii)** President of General Conference of the I.A.E.A, Vienna (1970)

B) S SOMNATH

- Sreedhar Panicker Somanath is the current chairperson of the ISRO. Earlier he has served as the chairperson of Vikram Sarabhai Space Centre (VSSC), Thiruvananthapuram and Director of Liquid Propulsion Systems Centre (LPSC), Thiruvananthapuram.
- He was associated with the PSLV project during its Initial days. He was also the project director of the GSLV-MK-III launch vehicle in from 2010 to 2014.

11. COMMERCIALIZATION AND PRIVATIZATION IN SPACE SECTOR

A) PRARAMBH MISSION

- **Why in news?**
  - Launch of Vikram-S (i.e., Vikram Suborbital) rocket by Skyroot Aerospace is being hailed as an important milestone in India's outer space journey (Nov 2022)

- **Details:**
  - **Skyroot Aerospace**, an Indian private sector space enterprise, created history by launching India's first privately developed rocket **Vikram-S**.
  - **Vikram-S** is a single stage rocket. It is India's first privately developed cryogenic hypergolic-liquid and solid fuel-based rocket engine. It was developed using advanced composite and 3-D printing technologies.
  - It carried three customer payloads in a sub-orbital flight. It was launched from the sounding rocket complex of the ISRO's Satish Dhawan Space Centre in Sriharikota, Andhra Pradesh
  - The rocket reached a peak-altitude of 89.5 kms and has met all flight parameters.
  - **More About Skyroot:**
    - It is a relatively new entity that was set up in 2018. In 2020, after government announced opening up of space sector for private entities, it became the first startup to sign an MoU with ISRO to launch a rocket.
    - It is producing a series of Vikram Satellite, named after Dr Vikram Sarabhai. The goal is to launch small satellites using this rocket.
  - **Future Plans of SkyRoot:**
    - **Vikram-1** is being developed to carry 480 kg payload to Low inclination Orbit.
    - **Vikram-2** which will follow Vikram-1, will carry 595 kg to low inclination orbit.
    - **Vikram-3** will carry 815 kg to Low inclination orbit.
    - Skyrocket also says that the rockets will be able to undertake multi-orbit insertion ans inter-planetary missions as well as offer "customized, dedicated and ride share options covering a wide spectrum of small satellite customers needs".

B) SPACETECH INNOVATION NETWORK (SPIN)

- **Why in news?**
  - ISRO has signed an MoU with Social Alpha to launch SpaceTech Innovation Network (SpIN) [Dec 2022]

- **Details**
  - SpIN is India's first **dedicated platform for innovation, curation, and venture development** for the burgeoning space entrepreneurial ecosystem.
  - In Dec 2022, ISRO has signed an MoU with **Social Alpha**, a multistage innovation curation and venture development platform for science and technology start-ups to launch SpaceTech Innovation Network (SpIN)
  - The MoU (tie up) is a one-of-a-**kind public private collaboration for start-ups and SMEs in the space agency**. It will contribute to unleashing market potential of the most promising space tech innovators and entrepreneurs in India.

  - **SpIN** will focus on **facilitating space tech entrepreneurs in three distinct categories**:
    1) Geospatial Technologies and Downstream applications
    2) Enabling technologies for space mobility
    3) Aerospace Materials, Sensors, and Avionics

- **First Innovation Challenge announced:**
  - In line with the partnership announcement, SpIN has launched its first innovation challenge.
    - **Early-stage start-ups for developing solutions in areas of maritime and land transportation**, urbanization, mapping and surveying, disaster management, food security, sustaining agriculture, environment monitoring, and natural resources management, among others are encouraged to apply.
  - The selected startups and innovators will be able to access both Social Alpha's and ISRO's infrastructure and resources as per the prevailing guidelines.
  - They will also get active handholding in critical areas, including access to product design, testing and validation infrastructure, IP management, go to market strategy, and access to long term patient capital, among other technical and business inputs.

- **About Social Alpha:**
  - It is a multistage innovation, curation and venture development platform for S&T startups that address the most critical social, economic, and environmental challenges through the power of entrepreneurship and market-creating innovation.
  - Since its inception in 2016, it has supported more than 200 startups.

1) NEW INSTITUTIONS

A) NEW SPACE INDIA LIMITED (NSIL)

- NSIL is a **wholly owned government of India undertaking/CPSE**, under the administrative control of Department of Space (DOS). It was established in March 2019 to **commercially utilize the R&D work of ISRO Centers** and other constituent units of DOS.

- **Roles and Functions:**
  - **a)** **Small Satellite technology transfer to Industry**, wherein NSIL will obtain license from ISRO/DOS and sub-license it to industry
  - **b)** Manufacture of SSLVs in collaboration with Private sector.
  - **c)** Productionization of PSLV through Indian Industry.
  - **d)** Productionization and marketing of space-based products and services, including launch and applications
  - **e)** Transfer of technology developed by ISRO Centres and constituent units of DOS
  - **f)** Marketing spin-off technologies and product/services, both in India and abroad.
  - **g)** Any other subject which GoI deems fit.

- **Significance:** NSIL was set up to meet the ever-increasing demands of Indian Space Program and to commercially exploit the emerging global space market. The emergence of NSIL would spur the growth of Indian industries in the space sector and enable Indian industries to scale up manufacturing and production base.
- The **launch of Brazil's Amazonia-1 satellite** in March 2021, was the first dedicated communication mission of NewSpace India Limited. Earlier launches facilitated by NSIL were piggybacked with ISRO's primary satellites.

B) IN-SPACE (INDIAN NATIONAL SPACE PROMOTION AND AUTHORIZATION CENTRE)

- It is an independent nodal agency under Department of Space (DoS). It was set up in 2020 to boost commercialization of Indian Space Activities and encourage private sector participation.

- It will permit and oversee the following activities of **non-Government Private Entities** (NGPEs):
    a) Building of launch vehicles and satellites and providing space-based service as per the definition of space activities.
    b) Sharing ISRO infrastructure/premise etc.
    c) Establishment of temporary facilities within the premise of ISRO
    d) Establishment of **new space infrastructure and facilities**, by NGPEs, in pursuance of space activities based on safety norms and other statutory guidelines and necessary clearance.
    e) Building of Spacecrafts by NGPEs for registration as Indian satellites and all associated infrastructure
    f) Using of spacecraft data and rolling out of space based services and all other associated infrastructure for the same.
- It will **draw up integrated launch manifest** – considering the needs of ISRO, NSIL, and NGPEs based on priorities and readiness.
- It will **draw up suitable mechanism for promotion, handholding, infra-sharing** etc. to encourage participation of NGPEs.
- The **decision of IN-SPACe** shall be final and binding on all stakeholders including ISRO, NSIL etc. NGPEs will not be required to seek separate permission from ISRO.
- **Structure of In-SPACe** – It has a Chairman, technical experts for space activities, safety experts, experts from academia and industries, legal and strategic experts from other departments, members from PMO and MEA of GoI.
- **Monitoring and Promotion Directorate of IN-SPACe** will have the oversight of the activities as per IN-SPACe decisions and shall report back to IN-SPACe for corrective actions and resolutions if any.

C) INDIAN SPACE ASSOCIATION (ISPA)

- **Indian Space Association** (ISpA) is the premier industry association of space and satellite companies. It is represented by leading home grown and global corporations with advanced capabilities including ISRO, Bharti Airtel, L&T, NELCO (Tata group), OneWeb, MapmyIndia, etc.
- It was launched by PM Modi in Oct 2021.

2) CIVILIAN APPLICATIONS OF SPACE TECHNOLOGY

1) SCIENCE: SPACE: "SPATIAL DATA INFRASTRUCTURE GEOPORTAL – 'GEO-LADAKH' FOR UT-LADAKH (DEC 2022 – SOURCE: PIB)

- Union Minister of State (Independent Charge) Science & Technology, Dr Jitendra Singh have informed that Government of UT – Ladakh has approached the Indian Institute of Remote Sensing, a unit of ISRO for developing "Spatial Data Infrastructure geoportal 'Geo-Ladakh' for UT-Ladakh".

- An MoU was signed between IIRS (ISRO) and UT-Ladakh Administration on Jan 1, 2022, towards carrying out the above work on 1st Jan 2022.
- It involves spatial database generation (water resources, vegetation and energy potential) using remote sensing, geospatial techniques and the development of a Geo-Portal for hosting this database.

- The portal provides geospatial data visualization and analytics for UT-Ladakh, consisting of Spatial viewer, carbon neutrality, Geospatial utility mapping and Geo-Tourism.
- It also aims towards training of UT-Ladakh officials in Geospatial techniques and applications.

12.INTERNATIONAL EFFORTS

1) SPACE GOVERNANCE: GLOBAL NORMS

- **Current Space Regulations: Gaps and Loopholes**
  - » **United Nations Committee on the Peaceful Uses of Outer Space** (UNCOPUOS) was established in 1958 with UN Office for outer space affairs as its secretariat. It oversees the implementation of **five UN treaties related to outer space:**
    - » Treaty on **Principles Governing Activities of States** in the Exploration and Use of Outer Space, including the Moon and Other Celestial bodies of 1967 (**Outer Space Treaty**)
    - » Agreement on the Rescue of Astronauts, the Return of Astronauts and Return of Objects Launched into Outer Space of 1968 **(Rescue Agreement)**
    - » Convention on International Liability for Damage Caused by Space Objects of 1972 (**Liability Convention**)
    - » Convention on Registration of Objects Launched into outer space of 1976 (**Registration Convention**) and;
    - » The Agreement Governing the Activities of States on the Moon and other Celestial Bodies of 1979 (**Moon Treaty**).
    - » It also oversees **other related treaties** including Treaties Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space, and under Water **(NTB) of 1963** and the **Brussels Convention Relating to the Distribution of Programme** – Carrying Signals transmitted by Satellite **(BRS) of 1979** among others.

  - » **The Outer Space Treaty** of 1967 (OST) designates space as the "**province of all mankind**" and states that the exploration of the outer space would be for the benefit of all countries, irrespective of their degree of economic or scientific development. It also **prohibits deployment of weapons of mass destruction** in space, and establishment of **military bases, installations, and fortifications**.
    - » But, it doesn't clearly prohibit **weapons other than weapon of mass destruction** and doesn't properly cover modern day technologies like lasers for communication.
    - » Further, it doesn't provide a detailed mechanism to decide if activities are inconsistent with the treaty and it failed to address issues like growing weaponization of the space.

  - » The **Liability Convention and OST** have the potential to impede the private sector investment as it makes state liable for all the damages thus compelling states to impose license and insurance on such entities.
  - » **The Registration Convention** has in a way helped in the development of an international registration system. Full knowledge of the presence of objects in space is crucial for peaceful and safe use.
    - » It can be further strengthened by bringing norms for ASAP reporting, reporting precise function at pre-decided, universally accepted time period.

» Similarly, the current norms **don't put any restrictions on ASAT**. There have been initiatives like The Prevention of an Arms Race in Outer Space (PAROS), under which several proposals have come, but nothing has moved forward.

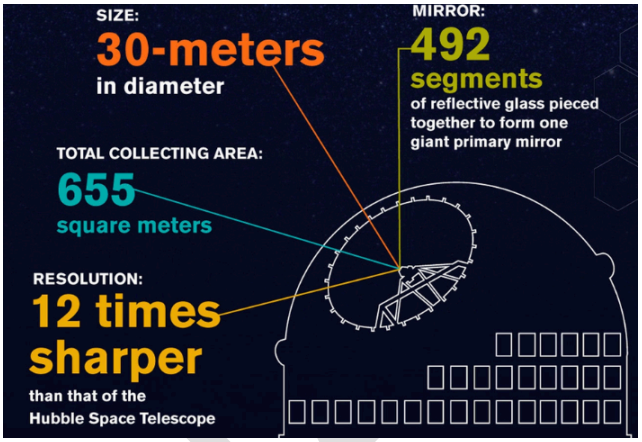
» Thus we can conclude that these regulations are quite old (agreed upon in 1960s during cold war). Since then space capabilities as well as power equations have drastically evolved. Thus, these regulations may not be suitable in the current times.

2) INTERNATIONAL SPACE STATION

- **Why in news?**
  - Russia has announced that it will leave the ISS "after 2024" (July 2022)
    - » The next step is to notify a body called the **Multilateral Control Board**, comprising of all the ISS partners – The USA, Russia, Europe, Japan and Canada.
    - » This raises important questions for the outpost's future viability. Since the space shuttle has retired, the ISS has relied on Russian Propulsion systems for periodic boosts to maintain its orbit.
      - The USA has recently taken strides in gaining an independent propulsion system through Northrop Grumman's Cygnus spacecraft, which successfully carried out a re-boost test in June 2022.
  - **Why Russia decides to leave?**
    - » Increasing tensions – between Russia and the West (Ukraine issue)
- **What is International Space Station?**
  - The International Space Station (ISS) is a modular space station (habitable artificial satellite) in LEO. It was launched in 1999.
  - It is a multinational collaboration between the NASA, ESA, ROSCOSMOS, Canadian Space Agency, and JAXA. The ownership and use of the space station is established by intergovernmental treaties and agreement.
  - The station provides platform for multi-gravity and space environment research laboratory.

3) THIRTY METER TELESCOPE (TMT)

- **What is thirty-meter telescope?**
  - Thirty-meter telescope is a new class of extremely large telescopes that will allow us to **see deeper into space** and **observe cosmic objects with unprecedented sensitivity**.
  - With its **30 m prime mirror diameter**, TMT will be three times as wide, with nine time more area, than the largest currently existing visible light telescope in the world. The images of TMT will be **12 times sharper than Hubble Space Telescope**.
  - The TMT will **observe wavelengths** ranging from the ultraviolet to the mid-infrared.
  - **Who is building TMT?**
    - » It is being built by **TMT International Observatory LLC (TIO).**



- The TIO is a **non-profit international partnershi**p between the California Institute of Technology, the University of California, the National Institute of Natural Science of Japan, the National Astronomical Observatory of Chinese Academy of Sciences, the **DST India** and the National Research Council, Canada.

4) SPACE BASED INTERNET

- **Space X Plan**
  - **The Starlink Network** of SpaceX eventually plans to install 42,000 satellites to ensure non-stop internet services throughout the earth at a cost-effective rate. These satellites will be connected with their neighboring satellites using lasers.

- **China's "Guowang" (GW)** constellation has also been announced which is meant to meet satellite-based internet services.
  - It will also be a LEO based system with satellites operating at different heights (500-1145 km), inclinations (30-85 degrees) and frequency bands.

- **Other such projects:** Several other companies including Amazon, OneWeb and O3B have also planned large constellation of satellites in LEO and MEO – but these projects are very small compared to Starlink.

- **Comparing Geostationary vs LEO satellites** for providing internet services [Advantages of LEO – Low latency-> allows real time communication; Disadvantage -> need more satellites for coverage as they cover small part of earth]

- **Significance**
  - The space-based internet services can provide **reliable and uninterrupted internet services universally** to everyone on earth.
  - **Services during emergency**: For e.g. During Russia Ukraine war in 2022, the Starlink played an important role in strengthening the Ukrainian military might after the European SATCOM system was cyber attacked.
  - IOT services

- Better e-governance

- **Concerns:** The ambitious space-based internet services (especially Starlink of SpaceX and Guowang of China come along with a number of downsides:
  - **Increased Space debris**
  - Increased **chances of collision of satellites.** In fact, on Sep 2, 2019, only, ESA had to perform, for the first time ever, a 'collision avoidance maneuver to protect one of its live satellites from colliding with a mega constellation.
  - **Difficulty in Space Observation -> Light Pollution**
  - **Increased crowding in LEO and signal interference** in space may emerge as another problem

13.NASA INITIATIVES

1) GREAT OBSERVATORY PROGRAM

- NASA's series of Great Observatories satellite are four large, powerful space-based telescopes. The four missions were designed to examine a specific region of the electromagnetic spectrum using very different technologies. The program was developed in 1994**.**

- **Great Observatories**

A) THE HUBBLE SPACE TELESCOPE (HST)

- The Hubble Space Telescope was deployed on April 25, 1990 from the space shuttle Discovery.
- It primarily observes **visible light and near-ultraviolet**. A servicing mission in 1999 added capability **in near infrared range** and one last mission in 2009 was to fix and extend the life of Hubble which resulted in some of the best results to date.
- Hubble is one of the largest and most versatile, and is well known as both vital research tool and a public relation boon for astronomy.
- Hubble's orbit outside the distortion of Earth's atmosphere allows it to take extremely **high-resolution images** with the negligible background light.
- Hubble has recorded some of the most detailed visible light images ever, allowing a deep view in space and time. Many Hubble observations have led to breakthroughs in astrophysics, such as accurately determining the rate of expansion of the universe.

B) THE COMPTOM GAMMA RAY OBSERVATORY (CGRO) (NOT OPERATING CURRENTLY)

- Primarily observed gamma rays, though it extended into hard x rays as well. It was launched in 1991 aboard Atlantis and was deorbited in 2000 after failure of a gyroscope.

C) THE CHANDRA X-RAY OBSERVATORY (CXO)

- It is primarily observing soft x-rays. It was launched in 1999 aboard Columbia and was initially named advanced X-ray Astronomical Facility (AXAF).
- Because X-Rays are absorbed by Earth's atmosphere, Chandra must orbit above it and therefore is a space based telescope.

D) THE SPITZER SPACE TELESCOPE (SST)

It observes the infrared spectrum. It was launched in 2003 aboard a Delta II rocket and was called the Space Infrared Telescope Facility (SITF) before launch.

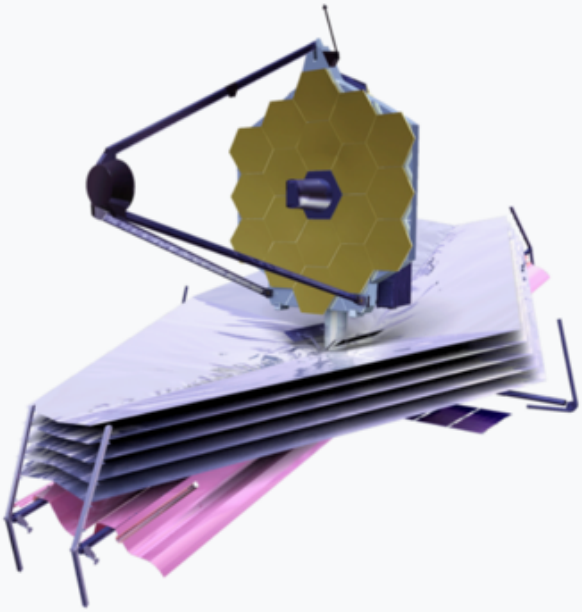
2) JAMES WEBB SPACE TELESCOPE

- **Introduction:** The quest to probe the universe received a major impetus with the commissioning of the James Webb Space Telescope (JWST). It is the **largest, most powerful, and complex space telescope ever built and launched into space**. It is an **infrared telescope** with a 6.5-meter primary mirror.

- **International Collaboration:** JWST is an international collaboration between **NASA**, **European Space Agency (ESA)**, and the **Canadian Space Agency (CSA)**.

- **Some innovative technologies**
  - **Primary Mirror made of 18 separate hexagonal segments that unfold and adjust to the shape after launch**. The mirrors are made of ultra-lightweight beryllium and are gold coated. A single large mirror would have been too large for existing rockets to carry.

  - Biggest feature is a tennis court sized **five-layer sunshield that attenuates heat from the Sun more than a million times**. This sunshield is constructed from **Kapton E**, a commercially available polyimide film with membranes especially coated with aluminium on both sides and a layer of doped silicon on the sun facing die of the two hottest layers to **reflect the sun's heat back into space**.



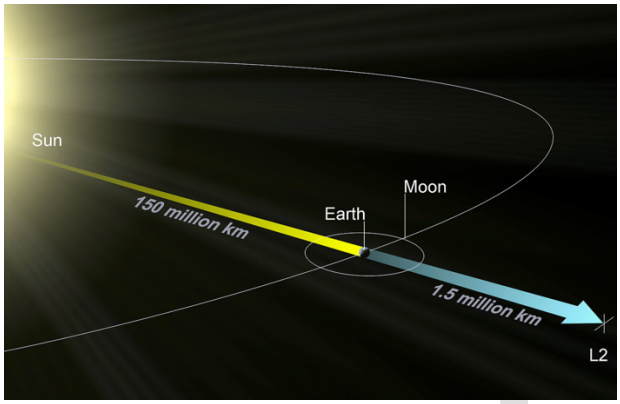
A rendering of the James Webb Space Telescope with its components fully deployed.

  - **Two basic reasons for it being more powerful than Hubble**

    - It has the **biggest telescope mirror** to fly in space.
      - 7 times light will be caught than collecting area of Hubble

    - It is **designed to collect infrared light**, which Hubble is not very sensitive to.
      - **Why infrared observation?**
        - **High redshift (very old and distant)** objects have their visible emissions shifted into the infrared, and therefore their light can only be **observed today via infrared astronomy**.
        - **Colder objects** and planets emit strongly in the infrared.

- Infrared rays can better pierce cosmic dusts and thus would be able to give details about the earliest and furthest galaxies. (Infrared wavelength can penetrate gas and dust)



- **Why from L2 and what is the purpose of sunshield?**
  - Earth's atmosphere glows in the infrared, so measurement can't be made from the ground.
  - Hubble emits its own heat, which could obscure infrared readings.
  - JWST will **run close to absolute zero (around 50K or -232.2 degree C) in temperature** otherwise, infrared radiation from the telescope itself would overwhelm its instruments. For this, it would rest at a point in space called the **Lagrange Point 2**, which is directly behind earth from the sun's perspective. Further, the **five-layer sunshield** would attenuate heat from sun more than a million times.

- It was launched in 2021, and it reached its final orbit at a distance of around 1.5 million km from the Earth in early 2022 and it took the engineers and scientists another six months to ready the instruments before it could be used.

  - allow us to compare earliest galaxies to those we observe today in our cosmic neighborhood.

- **The first five images released by NASA** (captured by JWST) (July 2022)
  - **Understand the beginning of stars and end of stars:** The deep field images **of SMACS 0723 cluster of galaxies** (5.12 billion light years away) has images that **date back to times when the first stars were born**.
  - The images from Carina Nebula vividly show the **birth of new stars**.
  - In contrast the southern ring nebula image details a **dying star**.
  - In **Stephen quintet**, the JWST has captured **the cataclysmic cosmic collision of galaxies**.
  - By analysing the spectrum of the radiation from WASP-96B, an exoplanet (a planet orbiting distant star), the telescope has **shown conclusively the presence of water vapors in the atmosphere of this hot, puffy gas giant planet orbiting distant Sun like sun**.

3) NASA'S ARTEMIS ACCORD

- **What is Artemis Accord?**
  - Artemis accord was announced by NASA in Oct 2020 with an initial group of **eight signatories (USA, Canada, UK, Luxemburg, Italy, UAE, Japan, and Australia**). Later more countries (New Zealand, Ukraine, South Korea, Brazil, Mexico etc.) have joined.
  - It is a set of principles outlining the way of responsible exploration and resource utilization of moon. As per NASA, it is fully consistent with pre-existing treaties, including the most important – 1967's Outer Space Treaty (OST).

- The parties who sign this would be able to participate in NASA's Artemis Program of crewed Lunar Exploration.
- The accord serves as preamble to bilateral, government-to-government agreements that participating nations will sign with the USA.

- **Key Provisions:**
  - **Peaceful purposes:** Conduct all space activities peacefully and in accordance with international law.
  - **Heritage Protection:** Help protect space heritage, such as Apollo landing sites.
  - **Transparency:** Publicly release scientific data in a timely manner
  - **Emergency Assistance:** Render aid to astronaut who need it
  - **Interoperability:** Make their (signatory countries) hardware and other systems "interoperable" to maximize cooperative system.
  - **Registration of Space Objects:** The Artemis accord reinforces the critical nature of registration and urges any partner which isn't already a member of the Registration Convention to join ASAP.
  - **Space Resource**: Space resource extraction and utilization can and will be conducted under the auspices of the Outer Space Treaty, with specific emphasis on Article II, VI, and XI.
  - **Deconfliction of Activities**: NASA and partner nations will provide public information regarding the location and general nature of operations which will inform the scale and scope of 'Safety Zones'

4) NASA'S ARTEMIS LUNAR PROGRAM

- This is NASA's program for Crewed Lunar Exploration. Under this NASA aims to land two astronauts (including 1 women) near the Lunar south pole in 2024 and establish a sustainable human presence on and around the moon by the end of the decade.

- Perhaps the most ambitious of the Artemis mission's objectives involve using the moon as a **stepping stone for a mission to Mars**. Robots have done all the detective work on Mars so far, but NASA aims to send astronauts there by 2030s.

- NASA is collaborating with other countries and Private sector for this project.

- **Rockets and Spacecrafts**:
  - At the center of the Artemis Program are NASA's new megarocket, the **Space Launch Rocket** (SLS) and the **Orion Spacecraft**.
  - The **SLS** is a 322 foot tall (98 meters) rocket consisting of a core stage, upper stage, and twin five segment solid rocket boosters to launch payload into space. This rocket will launch the Orion Spacecraft to the moon.
  - **Orion** is a space capsule larger than the Apollo command modules that are designed to carry four astronauts on missions to the moon.

5) ARTEMIS-1 MISSION

- **Why in news?**
  - NASA successfully launched Artemis-1 from NASA's Kennedy Space Centre in Florida (NOV 2022)

- **Artemis-1** is the **first integrated test of NASA's deep space exploration systems**: the Orion spacecraft, Space Launch System (SLS) rocket and the ground system at Kennedy Space Centre in Cape Canaveral, Florida.
- It tests the safety of the SLS rocket, and the Orion capsule's ability to reach moon, perform in lunar orbit and return to Earth for an ocean splashdown.
- It is an uncrewed flight test that will provide foundation for human deep space exploration and demonstrate NASA's commitment and capability to extend human existence to the Moon and beyond. It will pave the way for many moon missions including ones that will land the first woman and the first person of color on the Moon.

A) ORION SURPASSES APOLLO 13 RECORD DISTANCE FROM EARTH (NOV 2022)

- On day 11 of the Artemis 1 mission, Orion continued its journey beyond Moon after entering a distance retrograde orbit. Orion will remain in this orbit for six days before exiting lunar orbit to put the spacecraft on a trajectory back to earth.
- **Orion surpassed** the distance record for a mission with a spacecraft designed to carry humans to deep space and back to Earth, on Nov 26, 2020.

B) ARTEMIS-2: 2024

- Carrying the first four Artemis astronauts, the Orion Capsule will take the crew farther from earth than humans have ever travelled before.
- Over the approximately 10-day mission, the crew will complete a lunar flyby and return to Earth, evaluating the spacecraft's systems while carrying humans.

C) ARTEMIS-3: 2025

- It will see the **next man and first woman step onto the lunar surface**. Astronauts will land on the South pole of the moon using lunar lander. They will remain on the moon for around a week.

D) NASA'S GATEWAY LUNAR ORBIT OUTPOST

- **Details**
  - Gateway Lunar Orbit Outpost is basically a **spaceship that will orbit the Moon**. It will act as an airport, where spacecraft bound for lunar surface or surface of Mars can refuel or replace parts and resupply things like food, oxygen. It will also act as a temporary office and living quarters and lab for astronauts around 2,50,000 kms away from earth.
  - **Other Features**
    - It will have a docking port for the visiting aircraft.
    - It can be moved to other orbits around the moon to conduct more research..
    - The gateway is much smaller in size compared to ISS.
    - It will be placed in a **new kind of Orbit** called the **Near Rectilinear Halo Orbit**, (NRHO)
      - Watch: https://www.youtube.com/watch?v=dfOvZygyiCo to understand NRHO and the purpose of GATEWAY LUNAR ORBIT OUTPOST

- Astronauts will use Gateway at least once per year and not stay around the year as they do on the International Space Station. Once docked, the astronauts will be able to stay there for three months at a time, conduct science experiments and take trips to the surface of the moon.
- **Target dates:**
  - Nasa currently targets to complete the Gateway by 2026. By 2022 NASA want to ready the power and propulsion for the spaceship, which is being built in a public private partnership and will be launched on a partner provided commercial rocket.

E) ARTEMIS MAY BE LAST MISSION FOR NASA ASTRONAUTS

- Expensive (each launch would cost between $2 billion to $4 billion)
- Advancement in Robotics, AI etc: Improvements in sensors and AI will further enable the robots themselves to identify particularly interesting sites, from which to gather samples for return to earth. Within the next one or two decades, robotic exploration of the Martian surface could be almost entirely autonomous, **with human presence offering little advantage**.

F) NASA ON BUILDING A NUCLEAR REACTOR IN SPACE AND WHAT'S NEXT

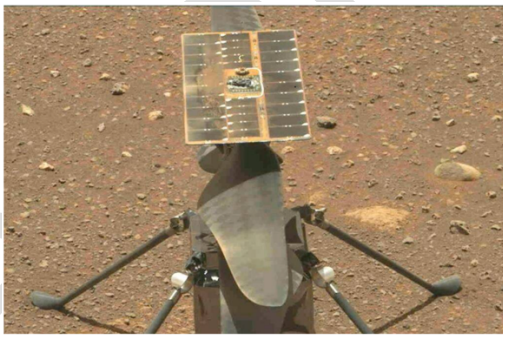
- **In 2022**, US Department of Energy awarded three contacts to three companies for design proposals for a nuclear fission surface power system that can be deployed to the Moon.
- **Significance of Nuclear Fission Reactors:**
  - Comparatively small and light weight
  - Reliably generate power without dependence on location, available sunlight, and other natural conditions
  - If such a technology is successfully developed and deployed, it could pave the wave for long-duration missions to the Moon, Mars, and beyond
- **Challenges:**
  - Making **nuclear reactors and nuclear material reach moon** (since an accident may cause radioactive pollution on moon)
  - **Rejecting power processing heat** will be a challenge on surface of moon (where water- or air-cooling system like that of earth can't be used).
    - NASA will need thermal radiators to cool the reactor by rejecting waste heat into space.
- **Operating power plant** around 3.5 lakh kms away from earth. Autonomous control system must be developed and tested to ensure safe operation and fault detection

6) NASA'S MARS 2020 MISSION - PERSEVERANCE ROVER

- **Why in news?**
  - NASA's perseverance rover finds igneous rocks altered by water (Aug 2022)
- **Details**
  - Perseverance (six-wheeled robot) is NASA's Martian rover. In Feb 2021, it touched down on the Martial soil when it successfully landed in **Mar's Jezero Crater**.

- It's design is similar to **its predecessor rover- curiosity**, from which it was moderately upgraded. It carries seven primary payload instruments, 19 cameras, and **two microphones**. It also carries a mini-helicopter ***Ingenuity***, which in April 2021 made the **first ever powered flight on another planet**.
- The rover has **four science objectives** that support the **Mars Exploration Program's Science goals:**
  - **Looking for habitability** – identify past environment that was capable of supporting microbial life
  - **Astrobiology: Seeking biosignatures** –of possible past microbial life in those habitable environments, particularly in specific rock types known to preserve signs overtime.
  - **Caching samples** – Collect core rocks and soil samples and store them on Martian surface which can be extracted by future programs.
  - **Preparing for crewed missions** – Test oxygen production form the Martian atmosphere.
- The two microphones would listen to Martian sounds like the wind or the rover moving on the Martian soil.
- **Why Jajero Crater:**
  - Jajero **crater preserves the evidence that it was once a lake** with an inflow channel and an outflow channel. There are good chances that if life existed on Mars in the past, the microorganisms could have lived here and preserved in the form of fossil here.
  - **In Aug 2022**, NASA's perseverance found surprising volcanic rocks in Mars' **Jezero Crater**. The discovery was a complete surprise as the researchers initially expected to find sedimentary rocks formed by mud and detritus laid down by the ancient lake. These water altered rocks indicate the presence of water, which is an essential ingredient for a habitable environment.

- **In April 2021, NASA's Ingenuity Mars Helicopter** became the first aircraft in history to make a powered, controlled flight on another planet.
  - It is a **solar powered** helicopter.



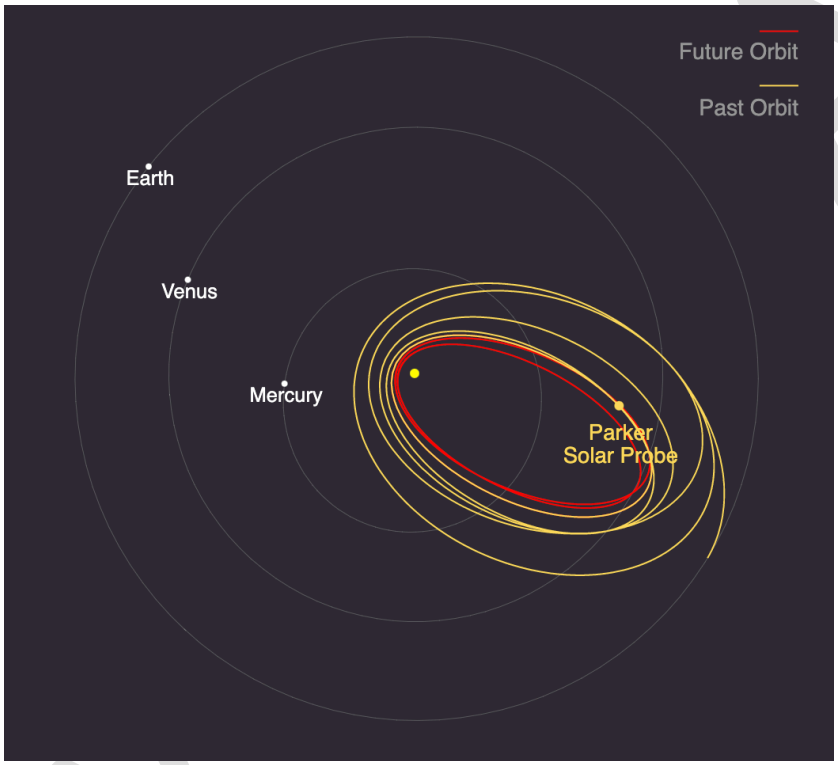
  - **Why flying on Mars is a challenge?**
    - Atmosphere density is only 1% of Earth's atmosphere.
    - To sustain flight, helicopter blades have to rotate at 2400 rpm (rotation per minute). For a helicopter to fly few meters from the ground on Mars, is equivalent for a helicopter to fly 2-3 times the height of Mt Everest.

7) PARKER SOLAR PROBE

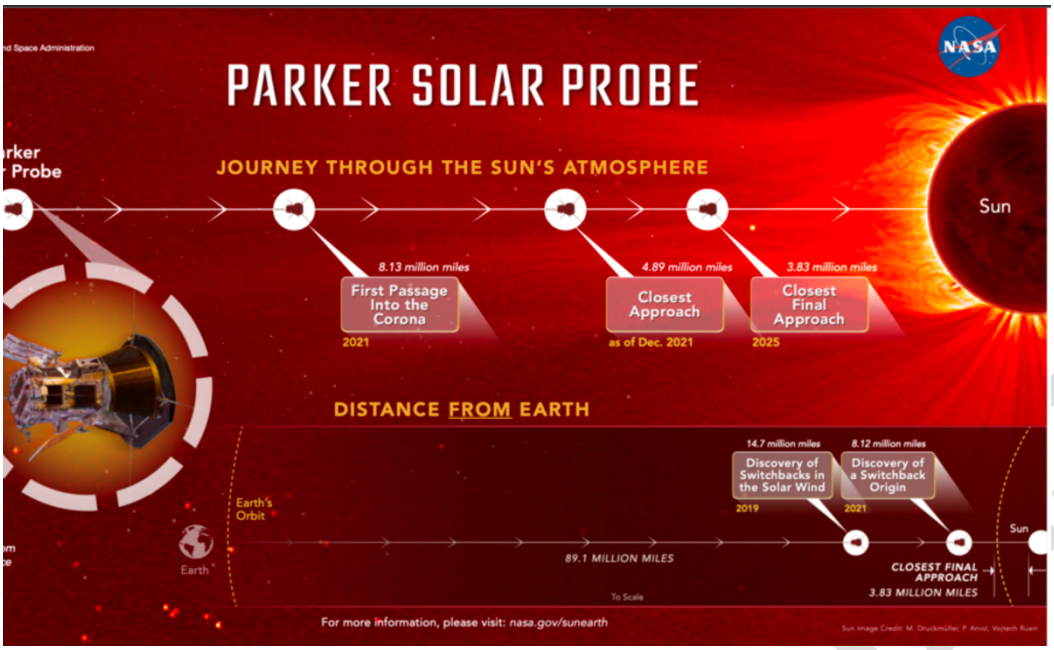
- **Why in news?**

- NASA enters the Solar atmosphere for the first time. It has entered Sun's upper atmosphere – the **Corona** – and sampled particles and magnetic field there. (Dec 2021)

- **Introduction**
  - The parker solar probe was launched in Aug 2018. It is designed to swoop through the sun's super-hot outer atmosphere and help scientists understand the way our star shapes the solar system.
    - **Using Venus' Gravity:** The parker probe has used Venus' gravity during seven flybys over nearly seven years to gradually bring its orbit closer to sun. It is done to slowdown the spacecraft to reduce gravitational pull of the Sun.
      - In June 2020, the probe reached as close as 832 kms above the planet's surface.
    - **Launch Site:** NASA's Kennedy Space Center, Florida
    - **Launch Vehicle:** Delta IV – Heavy with upper stage.



  - It is designed to go closer to the sun (3.8 million miles from the solar surface), seven times closer than any other spacecraft before, facing brutal heat and radiation conditions – and ultimately provide humanity with the closest ever observation of the star. **In 2021 it has entered into the outermost part of sun's atmosphere**, known as the Corona. It is using in situ measurements and imaging to revolutionize our understanding of the Corona. It is a **monumental moment** for solar science and a truly remarkable feat.
  - The first passage through Corona – and the promise of more flybys to come – will continue to provide data on phenomena that are impossible to study from afar.



- **Significance**
    - Improve our understanding of the sun, where changing conditions can propagate out into the solar system, affecting Earth and other worlds.
    - It will expand our knowledge of the origin and evolution of the solar wind.
        - Corona gives rise to Solar wind (a continues flow of charge particles that permeates the solar system). Unpredictable solar winds cause disturbances in our planet's magnetic field and can play havoc with communication technology on the earth.
        - NASA hopes the findings will enable scientists to forecast changes in the earth's space environment which affects life and technology on earth.

8) LUCY MISSION

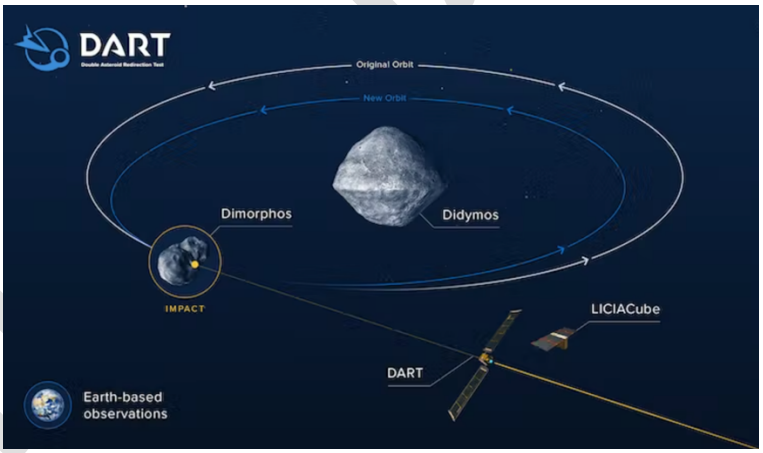
- NASA has launched the LUCY spacecraft in Oct 2021, on a 12-year cruise to the Jupiter Trojan asteroids. It will fly by eight asteroids – 7 trojans and one main belt asteroid – over the next 12 years. It is NASA's first single aircraft mission which will explore so many asteroids at one go.
- LUCY will run on solar power out to 850 million kms away from sun. This makes it the farthest-flung solar powered spacecraft ever.

- **Significance**: It will look back into the origins and evolution of the solar system formed over 4 billion years ago through these celestial bodies.
- **Why named Lucy?**
    - Lucy is the name given to a hominin that lived 3.2 million years ago. She is known to be one of the most famous pre-human fossil in history.
    - Nearly, 40% of the fossilized skeleton of this hominin was discovered in 1974 by a team of Paleoanthropologists led by Donald Johanson. The name was inspired from the famous Beatles song "Lucy in the Sky with Diamonds", which Johanson's team listened to at camp the night of their discovery.

9) DART MISSION

- **Why in news?**
  - NASA'S DART intentionally crashed a refrigerator-sized spacecraft into Diomorphos, a small moon orbiting the near-Earth asteroid called **Didymos** (Sep 2022)

- **Introduction**
  - DART is a **planetary defense-driven test of technologies** for preventing an impact of Earth by a hazardous asteroid.
  - Under this NASA launched a mission in Nov 2021, aboard Space X Falcon 9 rocket. It sent a space capsule of the size of a fridge towards an asteroid to shoot it off course. The target asteroids were 11 million kms away from Earth and DART mission reached here after 11 months of journey.
  - **Target Asteroid:**
    - DART's test target was an **asteroid (Diomorphos/Didymos B)** that passed the earth in 2022 and will come back two years later.
    - It's primary body (Didymos A) is approx. 780 meters across, its secondary body (or "moonlet") – Didymos B is about 160 meter in size, which is more typical of the size of asteroids that could pose the most likely significant threat to Earth.
    - NOTE: DART's target asteroid was **NOT** a threat to earth, and it is only a test mission.



  - In Sep 2022, this space capsule was crashed into **Dimorphous/Didymos**-B.
  - It used **autonomous targeting**, using images of the asteroids it acquires as it approaches. DART needed to recognize the asteroid itself, automatically lock onto Dimorphous, and adjust its trajectory to hit it. This is while it was moving at a speed of 24,000 km per hour.

  - **Technology**
    - » DART is the first mission to demonstrate the **Kinetic Impactor Technique** - striking the asteroid to shift its orbit - to defend against potential future asteroid impact.

- **Why Didymos system was chosen**?
  - Because it is a binary pair, it will be possible for astronomers on Earth to **assess the results of the impact**.
  - These asteroids post **no risk to Earth** and have been chosen as the target for partly due to that fact.

- **How observations were made:**
  - Measurements from telescopes on Earth.
  - **LICIACube**: It is an Italian Space Agency CubeSat (a small type of satellite) that was deployed from a spring-loaded box aboard the craft on 11th Sep. LICIACube followed along and photographed the collision and its aftermath.

- **Outcome:**
  - **For the first time**, human has changed the orbit of a planetary body. The impact shortened Dimorphos' orbit time by 32 minutes.

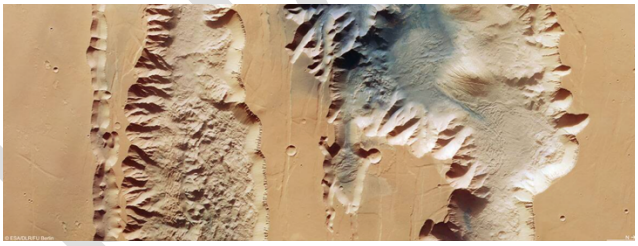
- **Proof**: The test was a proof of concept for many technologies, that NASA has invested over the last few years.
- **DART** has also given some fascinating data about both asteroid properties and the effectiveness of a kinetic impactor as a planetary defence technology.

- **Video:**
  - https://www.youtube.com/watch?v=N-OvnVdZP_8&ab_channel=JHUAppliedPhysicsLaboratory

14.EUROPEAN SPACE AGENCY

1) ESA'S MARS EXPRESS

- **Why in news?**
  - ESA's Mars express captures image of 'Martian Grand Canyon' – **Valles Marineries** (July 2022)
- **Details: Valles Marineris**
  - **Valles Marineris** is the largest known canyon system in our Solar System. It is almost 10 times longer, twenty times wider and five times deeper than the Grand Canyon. It is 4,000 km in length, 200-km in width and a depth of upto 7 kms. This canyon is supposed to be formed through the drifting apart of **tectonic plates**.



  - The image shown by Mars Express shows two trenches (or Chasma) that form part of the western region of Valles Marineris.

- **Details: Mars Express:**
  - It is a space exploration being conducted by ESA. It is exploring the planet Mars and is first planetary mission attempted by the agency.
  - Mars express is successfully performing scientific measurements since early 2004, namely, high resolution imaging and mineralogical mapping of the surface.
  - It also had a lander component, but it had failed to land.

2) EXOMARS 2022

- **Why in news?**
  - EU scraps ExoMars 2022 launch for this year after suspending cooperation with Russia's Roscosmos (IE: March 2022)
- **Details**
  - **ExoMars 2022** was a **planned mission.** It was a collaboration of ESA and ROSCOSMOS. It has **two parts.**
    - The **first part** launched an orbiter and a lander in 2016, but the lander crashed.
    - The Sep 2022 launch would have been second attempt to land the rover on Mars. Note that the second part was originally planned for July 2020, but it was postponed until Sep 2022 due to technical issues.
  - **But** the European Space Agency have said that the **ExoMars 2022** mission won't launch in Sep 2022 as planned after the **agency suspended all cooperation with Russia's space program**.

- The ExoMars 2022 mission won't launch in Sep as planned after the agency suspended all cooperation with Russia's space program Roscosmos.

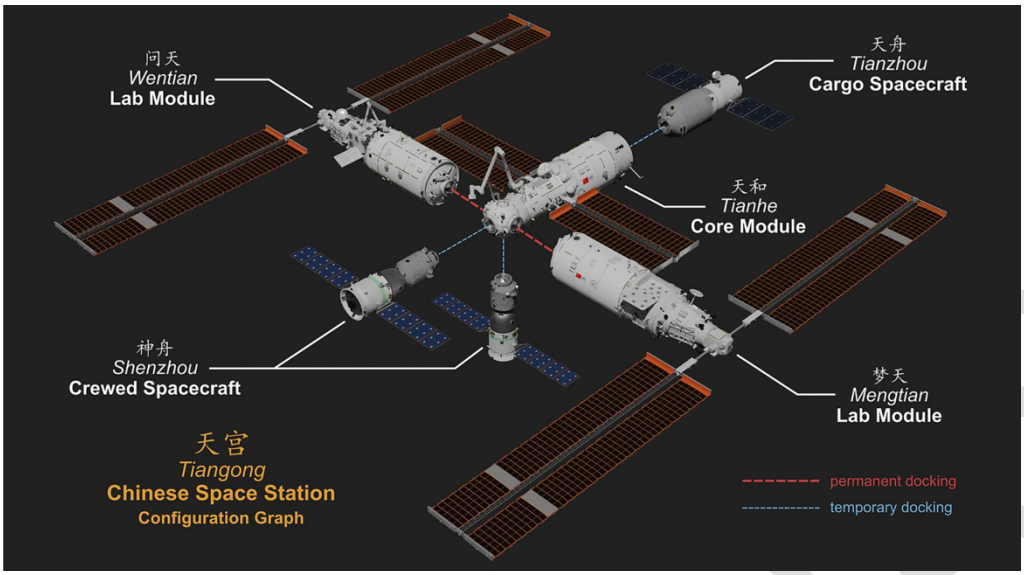
15.CHINA

1) CHINA'S SPACE STATION: TIANGONG

- **Why in news?**
  - **China** prepares to send new three-person crew to space station (Nov 2022)

- **Details**
  - **Background:**
    - China's crewed space program is officially three decades old. It truly got underway, when in 2003, China became only third country in the world, after USA and Russia, to put a human into space using its own resources.
    - Work on the space station programme began a decade ago with the launch of a **space lab Tiangong-1 in 2011**, and later, **Tiangong-2 in 2016**.

  - **Details of the Space Station - Tiangong:** When the space station completes, it will be a **T-Shaped space station** which will be able to accommodate 25 lab cabinets, each a micro lab that can be used to conduct experiments. The space station will weigh 66 tonnes – a fraction of ISS which weighs 465 tonnes.
    - It will have **three modules**
      - **Tianhe Module** (launched in April 2021) on Long March-5B.
      - **Wentian Module** (launched in July 2022) will be equipped to support life science research. It will also have airlock cabins for extravehicular trips, as well as short-term living quarters for astronauts during crew rotation.
      - **Mengtian Module** (launched in Oct 2022) will focus on microgravity experiment. It is the third and final module which docked with the station in Nov 2022.
    - The space station is designed for a lifespan of at least a decade.
    - It has facilities for long term accommodation of just three astronauts (compared to 7 of ISS). Still China has invited foreign astronauts in an effort to internationalize the space station.
    - **Scope of expansion in future**: The Three module T Shaped station could be expanded into a four-module cross shaped configuration in future.



- **Other developments in the process of setting up a**
  - **The Tianzhou-2 cargo spacecraf**t "the delivery guy for China's space station" was launched in **May 2021** on Long March-7 rocket from the island of Hainam and locked eight hours later with the space station's first core module called Tianhe.
  - **In June 2021**, the **Shenzhou-12 spaceship,** carrying the three astronauts, completed an "automated rendezvous and docking" with the Tianhe Module. Here, for the first time the Chinese had entered their own space station.
  - Another manned mission **Shenzhou-13** took place in Oct 2021.
  - **In June 2022**, 3 astronauts were sent on a six-month mission to oversee a pivotal period of construction of its space station whose final modules are likely to be launched in coming month. This launch used Long March-2F rocket, and **Shenzhou-14** aircraft.
  - **In Nov 2022**, China was preparing to send new three-person crew to space station. This is being called **Shenzhou-15 mission** and will again use **Long March-2F rocket**. This will be the last mission in the construction phase of the mission. These astronauts will overlap briefly onboard the station, with the previous crew, who arrived in early June for a six-month stay.

Next Year (2023), China plans to launch **the Xuntian space telescope**. It is not part of Tiangong, it will orbit in sequence with the station and can dock occasionally with it for maintenance.

2) CHANG'E-5

- **Details**
  - The Chang'e-5 probe, comprising an orbiter, a lander, an ascender, and a returner was launched on Nov 24, 2020, and its lander-ascender combination touched down on the north of the Mons Rumker in Oceanus Procellarum, also known as the ocean of Storms, on the near side of the Moon on 1st Dec 2020.
  - It was the third Chinese mission to land on the moon.
  - The Chang'e-5 probe returned to earth in Dec 2020 and it brought along with it about 1,731 grams of samples. Scientists will carry out the storage, analysis, and research of the country's first samples collected from the extra-terrestrial object.

The Chang'e-5 mission marks a successful conclusion of China's current three-step lunar exploration programme of orbiting and landing and bringing back samples which began in 2004

3) QIMINGXING-50 (OR MORNING STAR – 50): CHINA'S FULLY SOLAR POWERED, SEMI-SATELLITE DRONE

- **Why in news?**
  - China's first fully **solar powered unmanned aerial vehicle** has successfully completed its maiden test flight with all onboard systems functioning optimally (Sep 2022)

- **Details of QIMINGXING-50:**
  - It is a drone with wingspan of 164 feet. It is powered entirely by solar panels. It flies above 20 km altitude where there is very little airflow and no cloud. This allows efficient use of solar equipment.
  - The High altitude, long-endurance (HALE) UAV can stay airborne for long durations. The designer of the drone said that it can work without break for months and even years.
- It may be considered a **cross between drone and satellites:**
  - This can provide satellite like functions as it is located at very high altitude. It would specially be useful for time sensitive functions or in case of wartime disruptions.
- **Other Advantages:** Cost Effective, easy to launch and operate etc. It can help boost China's capabilities to operate in near-space and over the ocean. This HALE HUV is capable of conducting high-altitude reconnaissance, apart from monitoring forest fires, providing communication and environmental relay.

16.SPACE TOURISM

1) SUB-ORBITAL FLIGHTS AND SPACE TOURISM

- **What is suborbital Flight?**
  - » Suborbital flights don't have enough speed to escape into orbit. Any orbit without enough energy to reach orbit will instead follow a parabolic trajectory, looping up and then back down again. This will be a suborbital space mission or suborbital flight.
  - » Such flights are short, but passengers can experience mind-blowing view of Earth and will also experience several minutes of weightlessness. This thus can **attract space tourists**.
  - » **Why weightlessness?**
    - During downward path, a section of the flight is a free fall.
  - » **Other Significances:**
    - **Microgravity experiments** can also be carried out on these flights. This would be much cheaper than doing these experiments in International Space Stations.
    - It could also be a cheaper way of **testing space flight technologies** or experiments before they are sent on more expensive orbital or deep space missions.

- **Space Tourism**
  - » Space Tourism is the segment of space travel which provides non-astronauts the ability to go to space for recreational, leisure or busines purposes. The idea is to make space more accessible for anyone who can afford it.

» In the past, NASA and Russian Space Agency used to take tourists for space travel. For e.g. **Dennis Tito** was the first commercial spaceflight passenger before which only astronauts used to go to space. He went to space on Russian Soyuz TMA Launch Vehicle in **April 2001**. After him, between 2001-2009, few other space tourists went to space, aboard a Russian Soyuz space to ISS, brokered by Space Adventures (an American Space Tourist company) in conjunction with Roscosmos.

- **Details of Richard Branson's flight**
  - » **Virgin Galactic** is a company which was established by British Entrepreneur Richard Branson in 2004.
  - » In July 2021, Richard Branson and five others undertook a brief trip to the edge of the space, taking off on a **VSS unity spaceship**.
  - » They went in **S**pace**S**hip**T**wo which is a reusable **space plane** that can fly into suborbital space. The Spaceship was carried aboard the **mothership VMS Eve** and was released at about **15 km** above sea level. The spaceship fired its rocket engines and launched to the edge of space (around 85 km) and landed back to the Spaceport runway. The travellers were estimated to experience about 4 minutes of weightlessness. With this, Branson also became the first person to blast off in his own spaceship, beating Mr. Bezos by nine days.

- **Bezos Flight**
  - » **Blue Origin** was established by Jeff Bezos in 2000. It's reusable rocket **New Shepherd** successfully completed first human flight to space recently (**20th July 2021**) with **four private citizens onboard** in Jeff Bezos. The flight went about **107 km** high.

- **SpaceX's Inspiration4** – debut of SpaceX's tourism business (Sep 2021)
  - » Falcon 9 rocket took a crew Dragon spacecraft with 4 civilians (first all civilian space flight) into space. They travelled to an altitude of 575 km, even higher than HST and ISS. In the orbits around the planet, they would see 15 sunsets and sunrise everyday.

- Other than these three, companies such as Virgin Atlantic, XCOR Aerospace, Armadillo Aerospace are working on providing space tourism services to people.

- **Flight upto what height can be considered Spaceflight:**
  - » There is **no legal definition** of "outer space", and thus there is no official boundary where airspace ends and outer space begins.
  - » According to the International Aeronautic Federation, an **altitude above 100 KM** above sea level i.e. **Karman Line** is **space**. But, this doesn't coincide with the boundary of any of the atmosphere's scientifically defined layers. It also considers that an altitude of **80.47 km** (50 miles) would qualify as spaceflight.

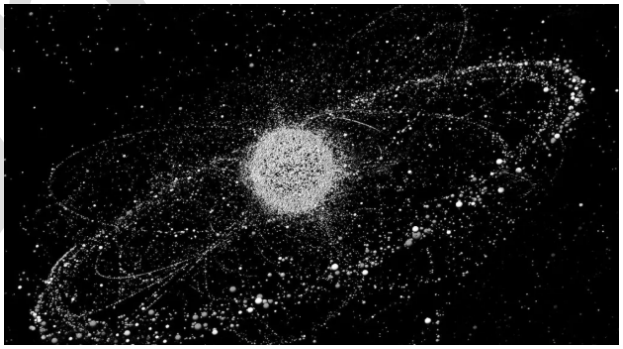
	BLUE ORIGIN	GALACTIC
Flies above the Kármán line (internationally recognized boundary of space, 100 km)	Yes	No
Vehicle type	Rocket	High altitude airplane
Windows	Largest windows in space 42" x 28" (107 cm x 71 cm)	Airplane-sized windows
Escape system	Yes	No
Ozone layer impact*	Minimal Exhaust is water with minimal impact on environment	High Hybrid rocket engine with HTPB & nitrous oxide. 100x more harmful
Flight history	15 Safe flights	3 Flights above 80 km

17.GENERAL ASTRONOMY TOPICS

1) SPACE DEBRIS

- **Introduction**
  - The term "space debris" refers to **defunct human made objects which are moving in orbit around earth**. It includes big and small things like discarded boosters, retired satellites, leftover bits and pieces from spacecrafts, screwdrivers, tools, nuts, bolts, lost gloves, flecks of paints etc.
  - There are more than 20,000 pieces of debris that are larger than 5-10 cms and can be tracked and catalogued. There are hundreds of millions that we cannot because of their small size. They are all dangerous as thy are moving at very high speeds.

- **How are Space Debris created?**
  - **Breakup of older spacecrafts:** For e.g., breakup of US' spacecraft called **USA 109** in 2015, created 100 debris pieces and 50,000 shards larger than 1 mm.
  - **Accidently left-over objects**
  - **Testing of Space Weapons**
    - For e.g., China's testing of A-SAT missile in 2007 created more than 34,000 debris.
  - **Further breakup of space debris:** More debris increase the chance of collision – a cascade effect known as the **Kessler Syndrome**. The fear is that the space could eventually become inoperable.
  - **Mega constellations** (e.g., Starlink satellite internet constellation) would launch thousands of satellites in coming years and would make space more vulnerable to collision and debris creation.



- **Key Concerns Raised by Space Debris**
  - **Endanger the prospects for Space Missions** (Civilian, Commercial or military)
  - **Sometimes crash land on earth** harming life and livelihood of people
    - Recently parts of Zenit rocket debris are reported to have ended up crash-landing in Peru.

18.SUN

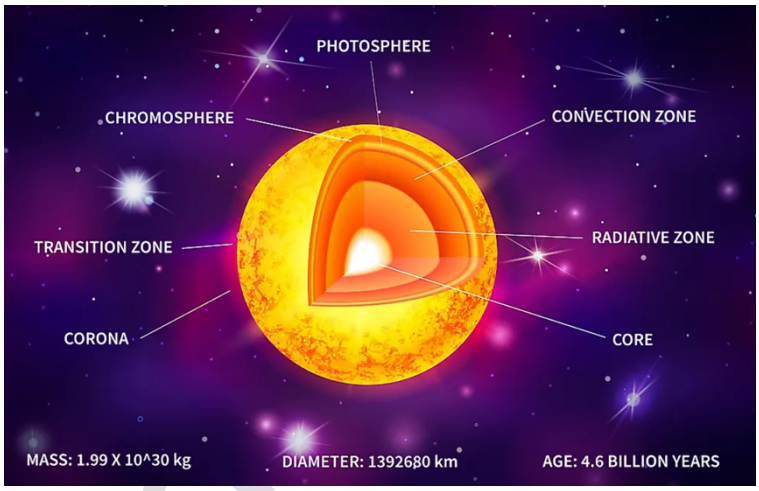
A) BASICS ABOUT SUN

- Distance: 150 million km away from earth
- Radius: 696,000 km

B) SUN'S STRUCTURE – 3 ATMOSPHERIC LAYERS

- Sun has **six layers**. The core, radiative zone and convection zone consist of the inner layers or the parts of the sun which is not visible. Photosphere, Chromosphere and Corona comprise of the sun's atmosphere or outer layer.

- **Inner Layer**
  a) **Core:** It is the innermost layer of sun. The Core is Plasma, but its movement is extremely similar to gas. The temperature in Sun's core is nearly 15-million-degree Celsius.
  b) **Radiative Zone:** It is the second layer of sun and sits outside the core. This zone has temperature of **millions degree Celsius**. The layer serves as a **passage for all the energy that is released by the core**.
  c) **Convection Zone**: It is the outermost layer and completely surrounds Radiative zone. In this layer, all the hot material found near the center of the Sun rises cools down and drops back into the radiative zone to get more heat. This is the movement that creates **sunspot** and **Solar flares**.



- **Outer Layers:**
  a) **Photosphere** is the deepest layer of the sun that we can **observe directly**. It reaches from the **surface to about 250 miles** above that. Temperature varies from about 6700-degree Celsius to 3,700-degree celsius. Most of the photosphere is covered by granulations (caused by convection current) of the plasma within the Sun's convective zones.
  b) **Chromosphere:** The chromosphere is a layer in the Sun between about 250 miles and 1300 miles above the solar surface (the photosphere). The temperature in the chromosphere varies between (3700 (**lowest temperature**) at the bottom to 7700-degree C at the top), so in this layer (and higher layers) **it actually gets hotter if you go further away from the sun**, unlike in the lower layers, where it gets hotter if you go closer to the centre of the sun.
  c) **Transition Zone:** The transition region is very narrow (60 miles / 100 km) layer between the chromosphere and the corona where the **temperature rises abruptly** from about 7700-degree celsius to 5,00,000-degree C)
  d) **Corona:** It is the outermost layer of the Sun, starting at about 13,00 miles above the solar surface (the photosphere). The temperature in the Corona is 5,00,000-degree celsius or more upto a few million-degree celsius. It can't be seen with naked eyes except during a total solar eclipse or with use of a coronagraph. It **doesn't have any upper limit**.

C) UNDERSTANDING SOLAR WINDS

- The solar wind is a **stream of charged particles released from the upper atmosphere of the sun, the Corona**. The solar wind streams plasma (a mix of positively and negatively charged particles) and particles from the sun out into space.
- **Cause**
  - The temperature of Corona reaches upto 1.1-million-degree celsius (2-million-degree Fahrenheit).
  - As rising heat and pressure push that material away from the Sun, it reaches a point where gravity and magnetic field are too weak to contain it. That point, known as the **Alfven Critical Surface,** marks the end of Solar Atmosphere and beginning of **Solar Wind**.

- **Why does the property of solar winds change with time?**
    - The sun's activity shifts over the course of its 11 year cycle, with sun spot numbers, radiation levels, and ejected material changing over time.
    - The wind also differs based on where on the sun it comes from and how quickly that portion is rotating.
    - As the plasma material leaves the sun, carried by solar wind, it becomes more gas-like.

- **How does it affect the earth?**
    - As the wind travels off the sun, **it carries charged particles and magnetic clouds**. This is constantly hitting our planet with interesting effects.

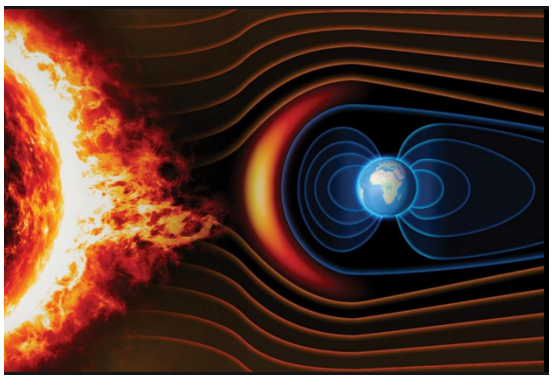
    - If the solar wind reached the earth's surface, its radiation would do severe damage to any life that might exist. They can **affect Earth's satellite and the Global Positioning Systems (GPS)**.
    - But **earth's magnetic field** acts as shield, redirecting the material around the planet so that it streams beyond it.

    - The force of the wind stretches out the magnetic field so that it is **smooshed inward on the sun-side** and **stretched out on the night side**.

    - **Solar Storms** (**Coronal Mass Ejections - CMEs**)
        - » Sometimes, especially during the active period of the cycle - known as the **solar maximum**, the sun spits out **large burst of plasma known as Coronal mass ejections (CMEs).** These have stronger effect than the standard solar wind.
        - » When the solar wind carries CMEs and other powerful bursts of radiation into a planet's magnetic field, it can cause the **magnetic field on the back side to press together**, a process known as **Magnetic Reconnection**.
        - » Charged particles in case of magnetic reconnection stream back towards the **planet's magnetic poles**, causing beautiful displays known as the **aurora borealis** in the upper atmosphere.

    - **About Auroras**
        - » In the north the phenomenon is called the aurora borealis or the northern light. In the southern hemisphere, it's the aurora australis, or southern lights.
        - » Even though the earth's magnetic field stretches symmetrically from the north to the south, recent satellite images of the entire planed showed mismatched auroras happening at the same time in the two hemispheres.
        - » **Why?** Our magnetic field is **squeezed asymmetrically by solar winds approaching from an angle**, twisting and displacing the northern and southern lights in different forms and locations.

    - **Useful video to understand Auroras:** https://youtu.be/PgIKsuZ3RZU



D) SOLAR MINIMAS: RESEARCHERS FIND WHAT HAPPENS WHEN THE SUN GOES TO SLEEP (OCT 2022: DTE)

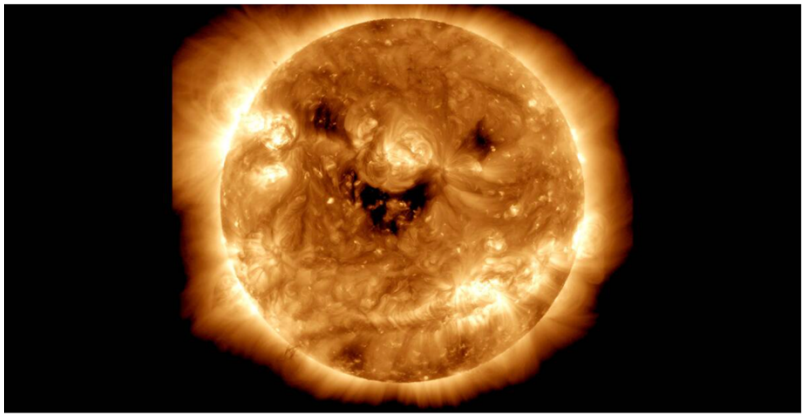
- **What is Solar Minimum?**

- It is a regular period of **least solar activity in the sun's 11-year solar cycle**. During solar minima, sunspot and solar flares actively diminishes and often doesn't occur for days at a time.
- **Grand Solar Minima** occur when several solar cycles exhibit lesser than average activity for decades or centuries. Very few sunspots appear on the surface and the sun's overall brightness decreases.
- In the last 10,000 years, the sun has gone to sleep or has entered the grand solar minima phase at least 23 times.
- The last grand solar minimum occurred in **Maunder Minimum (1645-1710)**. Temperatures across much of the Northern Hemisphere dropped when the sun entered this phase.

- The sun's **magnetic activity doesn't shut down during the inactive phases**, contrary to previous notions (New Study)
  - It persists in the form of weak cycles in the convection zone. They are incapable of producing sunspots.

E) SMILING SUN

- **Why in news?**
  - NASA's image shows Sun 'smiling' down at us (Nov 2022)



In this image, the Sun seems to have two eyes, a bright round nose and a wide smile. (Image credit: NASA)

- **Details**
  - NASA has released an image taken by its Solar Dynamics Observatory (SDO) where sun seems to have two dark eyes, a bright round nose and a wide-open smile.
  - Seen in ultraviolet, these dark patches on the Sun are known as Coronal Holes.
  - A Coronal Hole is a temporary region of relatively cool, less dense plasma, in the Solar Corona.
    - » Usually in Corona, the magnetic field arches between regions of opposite magnetic polarity. But, in case of Coronal hole, the magnetic field is open and extends into interplanetary space. This allows solar wind to escape into space at a much quicker rate. It results into **decreased temperature and density of the plasma** at the site of the Coronal hole, as well as an increased speed in the average solar wind measured in interplanetary space. Decreased temperature also leads to Coronal holes appearing **much darker** than their surroundings.
    - » Coronal holes can last between a few weeks to months. These holes are not a unique phenomenon. They appear throughout the sun's approximately 11-year solar cycle. They can last much longer during Solar minimum.

  - **What causes Coronal Holes?**

» It is not clear.

▫ **Scientists study these fast solar wind streams** because they sometimes interact with earth's magnetic field, creating what's called a geomagnetic storm, which can expose satellites to radiation and interfere with communications signals.

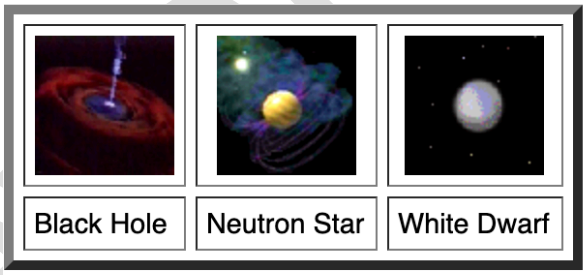
- **About Solar Dynamic Observatory (SDO)**:
  - ▫ It is a NASA spacecraft that was launched in 2010 to study sun.
  - ▫ It studies how solar activity happens and how that impacts the entire solar system. It takes observation of sun's interior, surface and atmosphere.

In the interior, it studies the **solar dynamo**, which is churning of the star's interior that creates a magnetic field and drives space weather. It studies solar surface to measure this magnetic field and the Solar atmosphere to help scientists understand how magnetic energy is linked to the interior and how it causes space weather events.

1) LIFE CYCLE OF STARS: STARS – DWARF STARS – NEUTRON STARS – BLACK HOLES

A) LIFE CYCLE OF A STAR

- ▫ Where a star ends up at the end of its life depends on the mass it was born with.
  - **Stars with lots of mass** may end their lives as black holes or neutron stars.
  - **A low or medium mass star** (with mass less than 8 times the mass of sun) will become a **white dwarf**.



- ▫ **Life of a medium Star -> Star – Red Giant – White Dwarf**

B) MEDIUM STARS - > RED GIANT -> WHITE DWARF -> BLACK DWARF

- Class Discussion

C) NEUTRON STAR

- **Neutron Star**: It is formed by catastrophic collapse of the core of a massive star. While a white dwarf is supported by electron degeneracy pressure, **neutron stars are supported by neutron degeneracy pressure**.

- **How is Neutron Star formed**: In its dying phase, when a star with a core containing mainly iron exhausts all its fuel, it collapses under gravity and explodes as supernova. The extreme high pressure causes protons and electrons to combine together to form neutron (thus forming a neutron star). They energy released during the process blows away the outer layer of the star.
- **Would a neutron star further collapse into blackhole? ->** It would depend on the mass of the neutron star's core. If the mass is less than three solar masses it remains as a neutron star, but if the star's mass more than about 3 solar masses, then it collapses further to form a black hole.
- **The highest possible mass** of a neutron star is not very well known, but it can't be theoretically more than 3 solar masses (beyond which, it should be a black hole). The **maximum mass** for a neutron star, which has been precisely measured so far, is around 2.1 solar mass.
- The neutron stars are among the densest objects in the universe. They have a radius of 10-20 km but carry a weight of upto 2.5 times the mass of Sun.
- A **big difference between Neutron star and Black Hole** is that neutron star has a hard surface unlike that of a black hole.

D) BLACK HOLE

What is a Black Hole?

- A Black hole is a place in space where gravity pulls so much that **even light can't get out**. This strong gravity is because matter has been squeezed into a tiny space. This can happen when a star is dying.
- Since, no light is emitted from them, they are invisible.
- They are generally **detected** by telescopes by analyzing the behavior of stars that are very close to this black hole.
- **How large is a black hole?**
  - A black hole can be as small as an **atom** (but having the mass of a mountain) and they can be **very large as well**.
  - **Stellar** is a kind of blackhole whose mass is around 20 times the mass of sun. There are many many steller blackholes in our Milky Way Galaxy.
  - **"Supermassive"** are the largest black holes. These black holes have masses that are more than 1 million suns together. Every large galaxy contains a supermassive blackhole at its center. The Supermassive blackhole at the center of the **Milky Way galaxy** is called **Sagitarrius**. It has a mass of 4 million suns and would fit inside a very large ball that could hold a few million earths.

- **Singularities and Blackhole**
  - In 1915 Karl Schwarzschild noticed that Einstein's then new-general theory of relativity predicted the existence of strange objects known as "**singularities**". They were places where his new equation describing gravity seemed to go haywire. Inside them there was a bizarre place where **time stopped, and space became infinite**. Over the years evidence have piled up explaining that **singularities do exist** in our universe as **black holes**.

- **Recent Updates about Blackholes**

a. **Binary Supermassive blackholes discovered in a system which could be site of future gravitational waves detection (June 2022)**

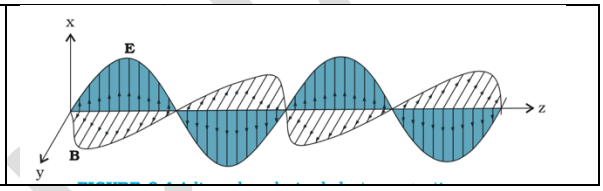
- An international collaboration of astronomers has discovered a binary supermassive black hole in a system which will be a strong candidate for future detection of gravitational waves (GWs).
- **Blazars** are supermassive blackholes (SMBH) feeding on gas in the heart of a very distant galaxy. These are among the most luminous and energetic objects in the unique universe.

20.ELECTROMAGNETIC WAVES

- As per Maxwell's theory **accelerated charges radiate electromagnetic waves**.

- **Key contribution of various scientists:**
  - **Hertz:** He experimentally demonstrated that accelerated charged particles emitted electromagnetic waves. [Hertz Experiment 1887] (He did it for low frequency – Radio waves)
  - **JC Bose** working at Kolkata succeeded in producing and observing electromagnetic waves of much shorter wavelength (25 mm to 5mm). His experiment like that of Hertz was confined to the laboratory.
  - **Guglielmo Marconi** followed Hertz work and succeeded in transmitting electromagnetic waves over distances of many kilometers. **Marconi's experiment marked the beginning of the field of communication using electromagnetic waves**.

- **Key Features of Electromagnetic Waves**:
  - Electric and Magnetic field are perpendicular to each other, and to the direction of propagation.

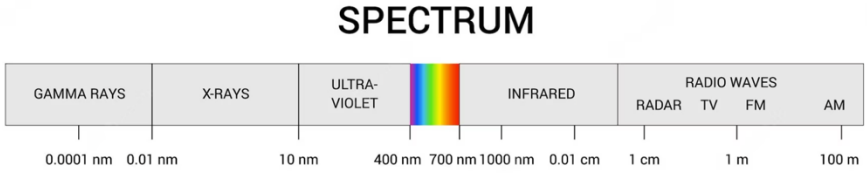
The adjacent figure shows a linearly polarized electromagnetic wave propagating in the z-direction with the oscillating **electric field E** along the x direction and the oscillating **magnetic field B** along the y-direction.	

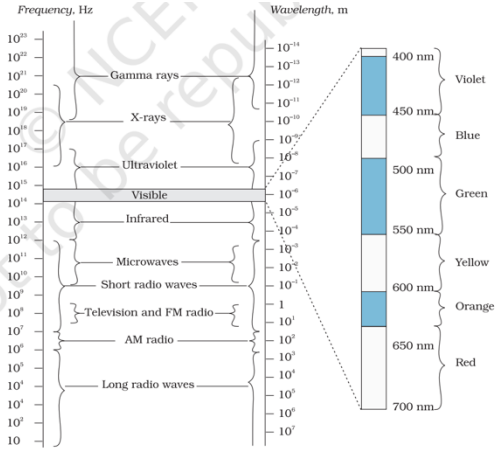
  - They are self-sustaining oscillations of electric and magnetic fields in free space or vacuum.
  - It can travel in vacuum and no material medium is involved in the vibrations of the electric and magnetic fields.
  - In vacuum (free space), electromagnetic wave travels with a speed of light 2.99792458 x 10^8 m/s (or roughly 3 x 10^8 m/s).
    - » The constancy of the velocity is **EM** waves in vacuum is so strongly supported by experiments and the actual value is so well known now that this is used to define a standard of length.
  - Hertz has also established wave nature of the radiation. He demonstrated that the waves, which had wavelength ten million times that of the light waves, could be **diffracted**, **refracted**, and **polarized**.

3) ELECTROMAGNETIC SPECTRUM

At the time Maxwell predicted the existence of electromagnetic waves, the only familiar electromagnetic waves were the visible light waves. The existence of ultraviolet and infrared waves was barely established. By the end of the nineteenth century, X-rays and gamma rays had also been discovered

- Electromagnetic Waves include radio waves, microwaves, infrared, visible light, ultraviolet, x rays and gamma rays. The classification of **EM waves** according to frequency is the **electromagnetic spectrum**. Note, that there is no sharp division between one kind of wave and the next. The classification is based on roughly on how the waves are produced and/or detected.





Different Types of Electromagnetic waves, in order of increasing frequency/decreasing wavelength:

A) RADIO WAVES:

- They are produced by accelerated motion of charges in the conducting wires.
- **Uses:** They are used in **Radio and Television** communication.
- **Wavelength:** They range from around a foot long to several kms.
- **Frequency ~: 500 KHz to 1000 MHz**
  - The AM (Amplitude Modulated) band is from 530 KHz 1710 KHz.
  - The FM (Frequency Modulated) band is from 88 MHz to 108 MHz.
  - The TV waves range from 54 MHz to 89 MHz.
  - Cellular phones use radio waves to transmit voice communication in the **Ultra High Frequency (UHF)** band.
    - » For e.g., in 2014, the DoT auctioned 2G telecom spectrum in the frequency range of 900 MHz and 1800 MHz.
    - » For e.g., In 2022 auction, Jio bought frequencies in 700 MHz as well as in 1800 MHz band.
    - » In 2022, 700 MHz was sold for the first time. Jio bought the spectrum.

B) MICROWAVES

- **Microwaves** (short wavelength radio waves) are produced by special vacuum tubes (called klystrons, magnetrons, and Gunn Diodes).
- **Frequency: GHz** range
- **Applications:**
  - **Radar**: There short wavelength makes them suitable for Radar system in aeroplanes. Due to their short wavelength, they are suitable for **Radar systems used in aircraft navigation**. Radar also provides the basis for the **speed guns** used to time fast balls, tennis serves, and automobiles.
  - **Microwave Ovens** are an interesting application of these waves. In such ovens, the frequency of microwaves is selected to match the resonant frequency of water molecules so that energy from the waves is transferred efficiently to kinetic energy of the molecules. This raises the temperature of any food containing water.

Details of how microwave oven works:

When the temperature of a body rises, the energy of the random motion of atoms and molecules increases and the molecules travel or vibrate or rotate with higher energies.

The **frequency of rotation of water molecules is about 300 crore hertz, which is 3 gigahertz (GHz)**. If water receives microwaves of this frequency, its molecules absorb this radiation, which is equivalent to heating up water. These molecules share this energy with neighbouring food molecules, heating up the food.

One should use porcelain vessels and **not metal containers** in a microwave oven because of the danger of getting a shock from accumulated electric charges. Metals may also melt from heating. **The porcelain container remains unaffected and cool, because its large molecules vibrate and rotate with much smaller frequencies, and thus cannot absorb microwaves**. Hence, they do not get heated up. Thus, the **basic principle of a microwave oven is to generate microwave radiation of appropriate frequency in the working space of the oven where we keep food**. This way energy is not wasted in heating up the vessel. In the conventional heating method, the vessel on the burner gets heated first, and then the food inside gets heated because of transfer of energy from the vessel. In the microwave oven, on the other hand, energy is directly delivered to water molecules which is shared by the entire food.

F) INFRARED WAVES

- Produced by hot bodies and molecules. They are sometimes also referred as heat waves. This is because, water molecules produced in most materials readily absorb infrared waves (many other molecules, for example, CO2, NH3, also absorb infrared waves). After absorption, their thermal motion increase i.e. they heat up and heat up their surroundings.
- **Infrared lamps** are used in physical therapy.
- Infrared waves also play a crucial role in maintaining the earth's warmth or the average temperature through Greenhouse Effect.
- Infrared Emitting Devices (IrEDs) are used in remotes of TV, AC etc.

G) VISIBLE RAYS

- Part of the spectrum detected by Human eyes.
- **Frequency range: 4 * 10^{14} Hz** to about **7*10^{14} Hz**.
- **Wavelength:** 700 nm to 400 nm (note: Speed of light = frequency * Wavelength)
- **Note:** Different animals are sensitive to different electromagnetic spectrum. For e.g. snakes can detect infrared waves, and the 'visible' range of many insects extends well into ultraviolet.

H) ULTRAVIOLET RAYS

- **Wavelength:** 400 nm to 0.6 nm
- UV radiations are produced by special lamps or **very hot objects**. For e.g. Sun is an important source of ultraviolet rays, but fortunately, most of the radiation is absorbed in the ozone layer. This is because UV radiation in large quantities will be harmful for human health and other forms of biodiversity.
- **Applications**:
    - Due to very short wavelengths, UV radiation can be focused on very narrow beams for high precision application such as **LASIK** (Laser assisted in situ keratomileusis) eye surgery.
    - **UV lamps** are used to kill germs in water purifiers.

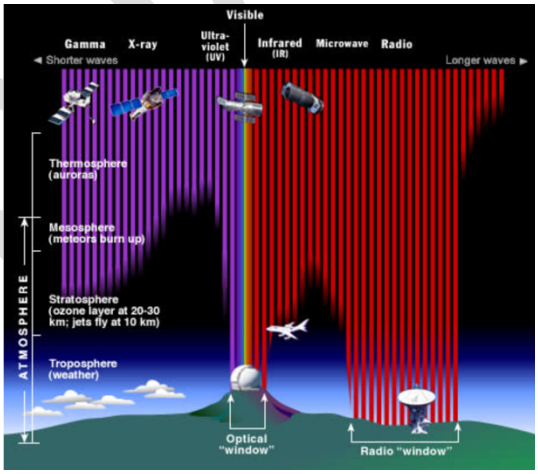
I) X-RAYS

- **Wavelength:** 10 nm to 10^{-4} nm (10^{-13}m)
- One common way of generating X-Rays is to bombard a metal target by high energy electrons.
- **Applications:**
  - They are used in diagnostic tools in medicine and as a treatment for various kinds of cancer.

J) GAMMA RAYS

- **Wavelength:** 10^{-10} m to 10^{-14} m
- Produced in nuclear reactions and also emitted by radioactive nuclei. They are used in radiative cancer therapies.

4) PENETRATION OF VARIOUS EM WAVES IN EARTH'S ATMOSPHERE



The Earth's atmosphere stops most type of EM radiation from reaching earth's surface. This illustration shows how far into the atmosphere different parts of EM spectrum can go before being absorbed. **Only portions of radio and visible light reach the surface**. **Radio frequencies, visible light and some part of ultraviolet lights** makes it to sea level. These wavelength ranges are called atmospheric window. **Ground based astronomical observation employs** optical and radio telescopes that take advantage of atmospheric windows.
Astronomers can observe some infrared wavelengths by putting telescopes on mountain tops.
But, **earth's atmosphere absorbs the majority of ultraviolet, X-Rays, and gamma rays**. So they can only be absorbed using **balloons and astronomical satellites** outside the earth's atmosphere.
Note: Long wavelength radio waves and infrared rays also don't reach the surface.

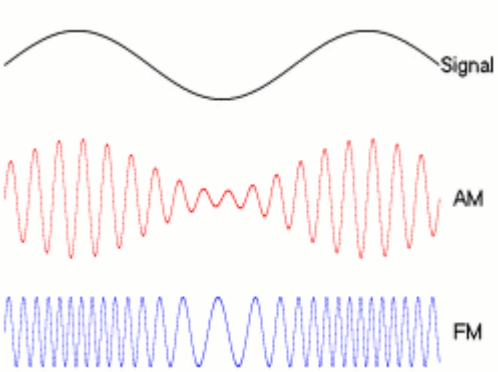
5) WIRELESS COMMUNICATION – DIFFERENT FREQUENCY BANDS AND THEIR APPLICATIONS

A) RADIO WAVES (500 KHZ – 1 G HZ)

1. The AM (Amplitude Modulated) band is from 530 KHz 1710 KHz.
2. The FM (Frequency Modulated) band is from 88 MHz to 108 MHz.

- The TV waves range from 54 MHz to 89 MHz

- Used for broadcasting radio and TV Programmes. Anyone with receiver can tune it to the radio frequency to pick the signal. When radio stations use similar transmission frequencies the waves sometimes interfere with each other.
- Medium wavelength radio waves are **reflected from the ionosphere** so they can be used for long distance communication, but not for communicating with satellite above the ionosphere. Thus, they can only be used for low earth orbit satellite communication.
- **AM vs FM**



	AM	**FM**
Full form	AM stands for Amplitude modulation	Frequency modulation
First used	AM method of audio transmission first carried out in the mid-1870s	FM radio was developed in the US states in the 1930s, mainly by Edwin Armstrong
Modulating difference	In AM, a radio wave known as the "carrier" or "carrier wave" is modulated in amplitude by the signal that is to be transmitted. The frequency and the phase remain same	In FM, a radio wave known as carrier wave is modulated in frequency by the signal that is to be transmitted. The amplitude and phase remains the same.
Pros and Cons	AM has poorer sound quality compared with FM, but is cheaper and can be transmitted over long distances. It has lower bandwidth so it can have more stations available in any frequency range.	FM is less prone to interference than AM. However, FM signals are impacted by physical barriers. FM has better sound quality due to higher bandwidth.
Frequency Range	AM radio ranges from 535 to 1705 KHz (OR) Up to 1200 bits per second.	FM radio ranges in a higher spectrum from 88 to 108 MHz. (OR) 1200 to 2400 bits per second
Bandwidth requirement	Twice the highest modulating signal. In AM radio broadcasting, the modulating signal has bandwidth of 15 KHz, and hence the bandwidth of an amplitude-modulated signal is 30 KHz	Twice the sum of the modulating signal frequency and the frequency deviation. If the frequency deviation is 75 KHz and the modulating signal frequency is 15 KHz, the bandwidth required is 180 KHz.
Zero crossing in modulated signal	Equidistant	Not Equidistant
Complexity	Transmitter and receiver are simple but synchronization is needed in case of SSBSC AM carrier.	Transmitter and receiver are more complex as variation of modulating signal has to be converted and detected from corresponding variation in frequencies (i.e.

		voltage to frequency and frequency to voltage conversion has to be done)
NOISE	AM is more susceptible to noise because noise effects amplitude, which is where information is stored in AM.	FM is less susceptible to noise because information in an FM signal is transmitted through varying of frequency, and not amplitude.

B) MICROWAVES

- Microwaves have shorter wavelength and thus can **pass through ionosphere**. They can thus be used for **long distance satellite communications**.
- **Line of sight -> Prerequisite:**
- Signals are sent to and from satellites, which relay signals around the Earth. This may be for TV programmes, telephone conversations or monitoring the earth, for example weather forecasting.
- **Types**

L BAND: 1-2 GHZ

- Low bandwidth -> not suitable for streaming applications like video, voice, and broadband connectivity.
- Radars, GPS signals
- **Other advantages** -> least expensive and easiest to implement.

S BAND:

- It is a part of microwave band of the electromagnetic spectrum. It is defined by IEEE standard of radio waves with frequencies that range from **2 to 4 GHz**, crossing the conventional boundary between UHF (Ultra High Frequency) and SHF (Super High frequency) at 3.0 GHz.
- **Used by**
  - » Weather radar
  - » Surface ship radar
  - » Some Communication Satellites

C BAND

- The C Band is the name given to certain portions of the electromagnetic spectrum, including wavelength of microwaves that are used for long-distance radio-telecommunication.
- The IEEE C Band **(4 - 8 GHz)** and its slight variations contain frequency ranges that are used for many satellite communication transmission, some Wi-Fi devices, some cordless telephones, and some weather radar system**.**

K_U BAND

- Name given to 12-18 GHz portion of electromagnetic spectrum in the microwave range of frequencies.
- Uses
  - » Primarily used for satellite communication, most notably for fixed and broadcast services

K BAND (18-27 GHZ)

KA BAND (27 – 40 GHZ)

V BAND (40 – 75 GHZ)

W BAND **(75-110 GHZ)**

MILLIMETER BAND **(110-300 GHZ)**

21. PRACTICE QUESTIONS

	Ques
1	[2005]: Consider the following statements: 1. A Geostationary satellite is at an approximate height of 10000 km 2. FM transmission of music is of very good quality because the atmospheric or manmade noises can do little harm. a. 1 only b. 2 only c. Both 1 and 2 d. Neither 1 nor 2
2	*[2011] Satellites used for telecommunication relay are kept in a geostationary orbit. A satellite is said to be in such an orbit when:* *1. The orbit is geosynchronous* *2. The orbit is circular* *3. The orbit lies above the earth's equator* *4. The orbit is an altitude of 22,236 km* *Choose the correct answer using the code given below:* *a. 1, 2 and 3 only* *b. 1,3 and 4 only* *c. 2 and 4 only* *d. 1,2,3 and 4*
3	[2011]An artificial satellite orbiting around the earth does not fall down. This is so because the attraction of earth: a. Doesn't exist at such distance b. Is neutralized by the attraction of the moon

	c. Provides the necessary speed for its steady motion d. Provides the necessary acceleration for its motion
4	Consider the following statements about Sun-Synchronous Polar Orbit: 1. It is a type of Geo-Synchronous orbit 2. It's only possible around oblate planets like Earth Which of the above statement(s) is/are correct? a. 1 only b. 2 only c. Both 1 and 2 d. Neither 1 nor 2
5	Consider the following statements about Satellite Orbits: 1. A satellite in circular orbit travels with a uniform speed 2. A satellite in elliptical orbit changes its speed as it moves in its orbit Which of the above statement(s) is/are correct? a. 1 only b. 2 only c. Both 1 and 2 d. Neither 1 nor 2
6	Consider the following statements about circular satellite orbits around earth: 1. Satellites in smaller circular orbit around Earth has higher speed when compared to satellite in larger circular orbit around Earth 2. Satellites in smaller circular orbit has lower angular velocity when compared to satellites in larger circular orbit around Earth Choose the correct answer from the codes provided below: a. 1 only b. 2 only c. Both 1 and 2 d. Neither 1 nor 2
7	Consider the following about Geo-stationary Orbits: 1. Three satellites placed at 120 degree from each other in geostationary orbit can ensure that every point on the surface of earth can have at least one of the three satellite in line of sight for it 2. Communication satellites are put in geostationary orbit because it leads to lower latency and data loss when compared to Low Earth Orbit Which of the above statement(s) is/are correct? 1. 1 only 2. 2 only 3. Both 1 and 2 4. Neither 1 nor 2
8	Which of the following spacecrafts are placed in **low earth orbit**? 1. Cartosat-2 series 2. GPS satellites

	3. IRNSS Satellites 4. International Space Stations Choose the correct answer from the codes provided below: a. 1 only b. 2 and 4 only c. 1 and 4 only d. All 1, 2, 3 and 4
9	Consider the following about Geostationary Transfer Orbit: 1. It is an Hohmann Transfer Orbit used to reach, geosynchronous or geostationary orbit. 2. It is a circular orbit. Which of the above statement(s) is/are **incorrect**? a. 1 only b. 2 only c. Both 1 and 2 d. Neither 1 nor 2
10	Which of the following is/are **not** true about PSLV? 1. It is the India's first generation satellite launch vehicle 2. It is the first Indian launch vehicle to be equipped with Liquid Stage 3. It is used for launching satellites in LEO as well as in Geostationary Transfer Orbit Choose the correct answer from the codes provided below: a. 1 only b. 2 and 3 only c. All 1, 2 and 3 d. None of the above
11	Arrange the following PSLV versions in terms of their capabilities in ascending order: 1. PSLV-CA 2. PSLV-DL 3. PSLV-G 4. PSLV-XL Choose the correct answer from the codes provided below: a. 1-2-3-4 b. 2-1-3-4 c. 1-2-4-3 d. 3-2-1-2
12	Consider the following statements about PSLV Engine: 1. PSLV has a four-stage engine 2. It has an expandable engine 3. 3rd Stage of PSLV is a Cryogenic engine Which of the above statement(s) is/are correct? a. 1 and 2 only b. 2 and 3 only

	c. 3 and 1 only d. 1, 2 and 3
13	Consider the following statement about LVM3 M2 / OneWeb India-1 Mission: 1. It was the first commercial mission of LVM3 2. It was the first multi-satellite mission of LVM3 3. It was the first launch of LVM3 to Low Earth Orbit 4. It was the first Indian rocket with about six ton of payload 5. It was the first NSIL mission with LVM3 6. It was the first OneWeb Mission with NSIL/Department of Space Which of the above statements is/are correct? A. 1 and 2 only B. 4, 5 and 6 only C. 1, 3, 4, 5, 6 only D. 1, 2, 3, 4, 5 and 6
14	LVM3 M2 mission was used to launch satellite for which of the following companies? A. SpaceX B. OneWeb C. Blue Origin D. Virgin Gelectic
15	Consider the following statements about GSLV-MK-III launch vehicle? 1. The first experimental flight of GSLV-MK-III took GSAT-19 to Geostationary Transfer Orbit (GTO) 2. GSLV-MK-III is planned to be used in India's Gaganyaan mission Which of the above statements is/are correct? a. 1 only b. 2 only c. Both 1 and 2 d. Neither 1 nor 2
16	Consider the following statements about Cryogenic engine: 1. Cryogenic engines provide higher specific impulse when compared to a solid fuel engine 2. PSLV, GSLV and Sounding rockets all use a cryogenic engine Which of the above statements is/are correct? a. 1 only b. 2 only c. Both 1 and 2 d. Neither 1 nor 2
17	**With reference to the Indian Regional Navigation Satellite System (IRNSS), consider the following statements:** (PRE 2018) 1. IRNSS has three satellites in geostationary and four satellites in geosynchronous orbits. 2. IRNSS covers entire India and about 5500 sq. km beyond its borders. 3. India will have its own satellite navigation system with full global coverage by the middle of 2020 Which of the statements given above is/are correct? a. 1 only

	b. 1 and 2 only c. 2 and 3 only d. None
18	ISRO is planning to place it's satellite to study Sun (Aditya-L1) at Lagrangian Point -1 (L1) of the Sun Earth System. Which of the following is the most important reason behind it? A. From L1, Aditya will have a clear view of Earth B. From L1, the satellite will have continuous view of sun without any eclipse C. L1 point is much nearer to Sun D. Non of the above
19	Consider the following statements about the Human Spaceflight Program - Gaganyaan: 1. The Gaganyaan mission aims to carry humans to Geo-stationary orbit 2. The missions plans to use GSLV-MK-III for the purpose 3. ISRO has recently inaugurated a Human Space Flight Centre at the Sriharikota, Andhra Pradesh Which of the above statement(s) is/are correct? a. 1 only b. 2 only c. 1, 2 and 3 d. None of the above
20	*[2016]**: Consider the following statements:*** *The Mangalyaan launched by ISRO* *1. Is also called the Mars Orbiter Mission* *2. Made India the second country to have a spacecraft orbit the Mars after the USA* *3. Made India the only country to be successful in making its spacecraft orbit the Mars in its very first attempt* *Which of the statements given above is/are correct?* a) 1 only b) 2 and 3 only c) 1 and 3 only d) 1,2 and 3 only


Level Up IAS
PRELIMS MASTER PROGRAM 2.0
FOR CSE PRELIMS 2023
54 CLASSES
2 Months Duration
2 Full Length (GS)
10 TESTS
Daily 4 Hours
Intensive classes for Comprehensive Coverage
FOCUSED SUBJECT AREA
CLASSES PER SUBJECT
6 Science & Technology
6 Environment and Ecology
6 Geography & modern history
2 International Bodies
9 Indian Economics
6 Ancient, Medieval, Art & Culture
9 Indian Polity
2 Government Schemes
1 Internal Security/Defense
1 Mapping/Places in News
Fee
₹ 15,000 + 18% GST (Offline)
₹ 12,000 + 18% GST (Online)
OFFLINE/ ONLINE
COMMENCING FROM : 6th FEB, 2023
Scan code for more details
info@levelupias.com
www.levelupias.com
8826-486-658/ 8826-496-658
Office Complex No. 6, 3rd Floor, Old Rajinder Nagar, New Delhi-110060