Space Tech + Defence

Rocket Engines

- Rocket engines operate on the principle of Newton's third law of motion: for every action, there is an equal and opposite reaction. In a rocket engine, a propellant (fuel and oxidizer) is ignited in a combustion chamber.
- This combustion produces high-pressure gases that are expelled through a nozzle at high velocity. The force of these gases rushing out of the nozzle creates thrust, propelling the rocket forward.

Rocket Fuels

	Solid Rocket Fuel	**Liquid Rocket Fuel**
Composition	Fuel and oxidizer mixed and bound in solid form	Separate liquid fuel and oxidizer
Storage	Stored as a single solid block	Stored in separate insulated tanks
Ignition	Simple and immediate upon ignition	Requires complex ignition systems

Throttling	Non-throttleable, burns until exhausted	Throttleable, can control thrust output
Complexity	Simple design, easier to manufacture and handle	Complex design, involves pumps and plumbing
Efficiency	Generally less efficient	Higher efficiency, better specific impulse
Usage	Used for boosters and short-duration missions	Used for main engines and long-duration missions
Examples of Use	Space Shuttle Solid Rocket Boosters, Fireworks	Saturn V, SpaceX Falcon 9, Ariane 5
Advantages	Simple, reliable, lower cost	Controllable, higher performance

Disadvantages	Cannot be shut down once ignited, less efficient	Complex, expensive, handling/storage challenges
Examples of fuels	Ammonium perchlorate composite propellant (APCP), Black powder, Zinc-sulfur	Liquid Hydrogen (LH2) with Liquid Oxygen (LOX), RP-1 (refined kerosene) with LOX, Hypergolics like Hydrazine (N2H4) with Nitrogen Tetroxide (N2O4)

Cryogenic Engines

- Uses propellants that are gases at room temperature but are cooled to cryogenic temperatures to become liquids. Common propellants include liquid hydrogen (LH2) and liquid oxygen (LOX).
- Liquid hydrogen and liquid oxygen mix and burn, creating a high-temperature, high-pressure exhaust gas.
- The exhaust gases are expelled through a nozzle, converting thermal energy into kinetic energy.

Comparison with Conventional Engines

Feature	**Conventional Engines (Solid/Liquid Non-Cryogenic)**	**Cryogenic Engines**
Specific Impulse	Lower	Higher
Thrust	Moderate	Higher

Combustion Byproducts	CO_2, H_2O (if hydrocarbon fuels)	Mostly H_2O (cleaner)
Fuel State	Solid or liquid at room temperature	Liquid at cryogenic temperatures
Efficiency	Lower	Higher
Complexity	Simple to moderate	High (due to cryogenic handling)
Use Cases	Boosters, short-duration missions	Upper stages, deep-space missions, heavy lift

Satellite

- A satellite orbits a planet or a star.
- **Two types** - natural (moon) and human-made/artificial (machine);
    - **Artificial satellite**: machine launched into space which moves around the earth or other object.

- **Application**: weather forecasting, study of planets and galaxies, in communication and information technology, GPS.

Satellite Orbits

- It is a repeating path that one object in space takes around another one.
- **Orbits- inclination angle**
  - It is the **angle between the plane of an orbit and the equator**.
  - An orbital inclination of 0° is directly above the equator; 90° crosses right above the pole, and 180° orbits above the equator in the opposite direction of Earth's spin.

Types of satellite orbits

- Satellites orbit around the earth in different planes - **equatorial orbit** (orbit directly above the earth's equator); **polar orbit** (orbit that passes over both the poles.)
- Other orbits are **inclined**; Orbits may be **circular or elliptical**.
- Altitude of communication can be **GEO** (geostationary earth orbit), **MEO** (medium earth orbit), **LEO** (low earth orbit).
- **Polar orbit**
  - An orbit in which a satellite passes above Earth's North and South poles on each revolution.
  - Has an inclination of 90 degrees to the equator.
- **Sun-synchronous orbit (SSO)**
  - Satellites in SSO, travelling over the Polar Regions, are synchronous with the Sun.
  - They are synchronized to be at a fixed position relative to the sun which enables the satellite to always visit the same spot at the same local time.
- **LEO (low earth orbit)**
  - Polar orbit: altitude of 50-1500km and orbital period range (95-120 minutes)
  - **Advantages**
    - Provides a high quality communication link.
    - Provides global coverage and efficient use of spectrum
    - Propagation delay is low.
  - **Disadvantage**
    - Requires large number for whole coverage,
    - requires to be replaced regularly

- **MEO (medium earth orbit)**
    - Positioned somewhere between LEO and GEO altitude of 5000-2000 km inclination towards equatorial plane.; Orbital period of satellite 6hrs; Medium propagation delay
    - Covering a large area requires less handover; Provides true global coverage.
    - Requires a large number of satellites for coverage Long time to deploy a full constellation.
- **GEO (geostationary earth orbit)**
    - Geosynchronous orbit Orbital period of earth (24 Hours); altitude of 35,863 km above earth's surface;
    - Geostationary orbit Inclination of the orbit are zero; appears stationary from earth
    - Disadvantage large propagation delay; affects voice and time data protocol; high launch cost.
- **GTO (geosynchronous transfer orbit)**
    - Elliptical orbit, with an apogee of 35,784km
    - Inclination equal to the latitude of the launch site, into which a spacecraft is initially placed before being transferred to a geosynchronous/ geostationary orbit.

Satellite Launch vehicle

- Rocket powered vehicles used to transport any spacecraft into earth's atmosphere.
- Used to send various satellites, spacecraft and space probes into space.
- India's used launch vehicle- **RLV-TD, SLV, ASLV, PSLV, GSLV.**

Satellite launch vehicle (SLV) and augmented satellite launch vehicle (ASLV)

Satellite launch vehicle	Augmented launch vehicle
• First generation launch vehicle of India • SLV-3 was the first in this generation to be successfully launched. • Capable of placing 40 kg class payloads in low earth orbit (LEO) at a distance of 400km.	• It was designed to augment the payload capacity to 150 kg in low earth orbit (LEO) • Five stage launch vehicle technology. • All had solid propellant • Not in use

• It had four stages. Not in use	

PSLV (polar satellite launch vehicle): third generation

- Most reliable and popular launch vehicle in service for over 20 years; First Indian launch vehicle to have liquid stages;
- **Payload:** PSLV can take up to 1,750 kg of payload to Sun-Synchronous Polar Orbits of 600 km altitude and up to 1425kg to geostationary orbits.
- It has a **four stage multi propellant launcher** that has a height of 44 meters and a lift off 320 tons (PSLV XL).

First stage (SOLID) PS1	• It uses an S139 engine with Hydroxyl-terminated polybutadiene (HTPB) as fuel and has 6 strap-ons as boosters.
Second stage (LIQUID) PS2	• It uses Vikas engine with Unsymmetrical dimethylhydrazine (UDMH) as fuel and Dinitrogen tetroxide (N2O4) as oxidiser.
Third Stage(SOLID) PS3	• It provides upper stage high thrust after atmospheric phase with Hydroxyl-terminated polybutadiene (HTPB) as fuel .
Fourth Stage (LIQUID) PS4	• The uppermost stage uses Monomethyl Hydrazine (MMH) as the fuel and mixed oxides of nitrogen (MON) as oxidiser.

Note - **Chandrayaan-1 in 2008 and Mars Orbiter Spacecraft in 2013** were launched through **PSLV-XL** (most remarkable mission of ISRO).

Geosynchronous satellite launch vehicle (GSLV): fourth generation

- Developed to launch geosynchronous satellites into geostationary orbit.
- 3 stage launch vehicle, first two stages are similar to PSLV with same solid and liquid natures of fuel; third stage is cryogenic stage.
- Three variants include:
    - GSLV Mark I (a) (capability of 1500 kg's)
    - GSLV Mark I (b) (capability of 1900 kg's)

- GSLV M ark II (uses Indian cryogenic engine and is capable of launching 2,500 kg's of payload to geostationary orbit and up to 5000 kg's of payload to LEO.)

First Stage GS1 (SOLID)
It is derived from the PSLV's first stage (PS1). This stage uses Hydroxyl-terminated polybutadiene (HTPB) as its fuel. The four liquid engine strap-ons for extra thrust.
Second Stage GS2 (LIQUID)
This stage was derived from the second stage (PS2) of PSLV using the Vikas engine. It uses Unsymmetrical dimethylhydrazine (UDMH) as fuel and dinitrogen tetroxide (N2O4) as oxidiser.
Third stage GS3 CUS (CRYOGENIC)
Third Stage is the Cryogenic Upper Stage and it uses liquid oxygen and liquid hydrogen as its fuel.

- **GSLV MK-III**
  - **Three -stage** heavy lift launch vehicle.
  - Intended for carrying **4 ton class of satellites** into geosynchronous transfer orbit (**GTO**) or about 10 tons to low earth orbit (LEO), which being double the GSLV Mk II capacity.
  - **GSLV Mk III-M1**, successfully injected **Chandrayaan-2, CARE mission** (crew module atmospheric re-entry experiment.), India's second lunar mission, into earth parking orbit.
  - Will be used to launch **Gaganyaan mission.**

Ariane -5

- European heavy-lift launch vehicle that can carry payloads weighing more than 10 metric tons to GTO and over 20 metric tons into low-earth orbit (LEO).

Types of Satellite

A. Earth Observation

- Satellite imaging and remote sensing - spectral fingerprint;
- Most orbit at altitudes above 500 to 600 kilometres; Orbits have significant air-drag;
- Remote sensing - acquisition of information without making physical contact; Active or Passive;

Types

- **Passive** - studying reflected light e.g. IR, Radiometers;
- **Active** - RADAR & LIDAR;
- **Synthetic aperture radars**; multi-spectral imaging; Hyperspectral imaging (vast portion of the electromagnetic spectrum. continuous scan); Acoustic - Ultrasound - water levels;

Uses

- **Military** - surveillance, espionage, intelligence;
- **Non-military**- such as environmental monitoring, meteorology, cartography and others; Topographic maps; Resource mapping and monitoring; meteorological data;

B. Communication Satellite

- Relays and amplifies radio signals via a transponder;
- **Orbit** - largely Geosynchronous, geostationary;
- **Uses**: television, telephone, radio, internet, and military applications
- Frequency ranges or "bands" - minimize interference; Assigned by ITU; E.g. C-band 4-8 Ghz, KU band- 12-18 GHz, KA band;
- E.g. INSAT, GSAT;

C. Telescopes

Frequency	Characteristics	Examples	Advantages	Challenges

Infrared	Detects heat, sees through dust clouds	Spitzer,Herschel	Observes cool objects, sees through dust	Requires cooling, atmospheric absorption
Ultraviolet	Observes hot stars, quasars, interstellar medium	Hubble, Galex	Studies young stars, active galaxies	Absorbed by atmosphere, needs space-based observatories
X-ray	Studies high-energy processes	Chandra, XMM-Newton	Observes black holes, neutron stars, hot gas	Absorbed by atmosphere, requires advanced technology
Gamma-ray	Detects highest energy events	Fermi, Compton	Studies gamma-ray bursts, AGNs, supernovae	Absorbed by atmosphere, needs specialized instruments

D. Ground Telescopes

- **GMRT (PUNE):** Giant Meterwave Radio Telescope: Array of 30 fully steerable radio telescopes
- **Thirty Meter Telescope**: Multi wavelength; near-UV to mid-infra; Mauna Kea (Hawaii) or Hanle (India)
- **Meerkat**: South Africa; Largest telescope in Southern Hemisphere;

Navigation

A. IRNSS

- **Objective:** provide reliable position, navigation and timing services over India and its neighborhood;
- India became one of the 5 countries having their own navigation system like GPS of USA, GLONASS of Russia, Galileo of Europe and BeiDou of China
- **Constellation:** Consists of eight satellites, 3 in geostationary and 5 satellites in geosynchronous.
- Range: India + 1,500-km radius over the sub-continent;
- **Satellites:** The satellites are named as- IRNSS – 1A, 1B, 1C, 1D, 1E, 1F, 1G. (3 Geostationary, 4 Geosynchronous)
- **Services:**
    - Standard positioning service: open for civilian use and
    - Restricted service: encrypted for authorised users like military
- **Applications:**
    - Terrestrial, aerial and marine navigation; Disaster management; Vehicle tracking and fleet management; Integration with mobile phones; Precise timing (as for ATMs and power grids);
- **Working of GPS**
    - Global Positioning System (GPS) is a US based navigation system.
    - It has 32 satellites (24 active at a time) that continuously broadcast signals with time stamps.
    - Devices such as mobile, laptops, cars receive these signals and compare signals from 4 or more satellites.
    - Trilateration: Based on this comparison, devices calculate distance between themselves and satellites to determine their location (longitude, latitude and altitude).

B. GAGAN

- Space Based Augmentation System (SBAS) jointly developed by ISRO and AAI; GAGAN GEO footprint expands from Africa to Australia

- System of satellites and ground stations that provide GPS signal corrections;
- Only four Space-Based augmentation systems are available in the world namely India (GAGAN), US (WAAS) Europe (EGNOS) and Japan (MSAS).

ISRO's Third Launch Pad

- Union Cabinet approved the establishment of 'Third Launch Pad' (TLP) project at Satish Dhawan Space Centre of ISRO at Sriharikota, Andhra Pradesh.
- It is designed to support the launch of **Next Generation Launch Vehicles (NGLV)** and **Launch Vehicle Mark-3 (LVM3)** with a semi-cryogenic stage and upgraded NGLV configurations.
- It is also supported as a standby launch pad for the Second Launch Pad at Sriharikota.
- It is expected to be operational within 4 years.
- **Significance**:
    - **Increases Launch Capacity**: Enhances launch frequency and supports future human spaceflight and space exploration missions.
    - **Advances India's Space Vision**: Essential for India's long-term goals, including the Bharatiya Antariksh Station (BAS) by 2035 and an Indian Crewed Lunar Landing by 2040.
    - **Future Space Transportation**: Ensures India meets evolving space transportation needs for the next 25-30 years.

Reasons for Choosing Sriharikota for Satellite Launch Pads

- **Eastern Coast Location** – Enables launches in an easterly direction.
- **Proximity to the Equator** – Provides an extra boost for payloads.
- **Safety Considerations** – Reduces risks due to fewer maritime and airline routes.
- **Other Factors** – Features uninhabited land and proximity to the sea for safer launches.

Scramjet Engine

- A Scramjet engine (Supersonic Combustion Ramjet) is an **improved version of the Ramjet**, designed to operate at extremely high speeds.
    - A **ramjet is an air-breathing jet engine** that relies on the **vehicle's forward motion** to compress incoming air for combustion, eliminating the need for a rotating compressor
- It works by using supersonic airflow to generate thrust and functions at hypersonic speeds (**Mach 5+)**
- **Key features:**

    - **Air-Breathing Engine:** Unlike traditional rocket engines, Scramjets use atmospheric oxygen for combustion, eliminating the need to carry heavy oxygen tanks.
    - **No Moving Parts:** Scramjets rely on supersonic airflow, making them highly efficient for sustained high-speed travel.
- **Significance:**
    - Next-generation hypersonic missiles with unmatched speed and accuracy.
    - Faster air travel, potentially reducing flight times drastically.
    - Low-cost satellite launches, making space access more affordable.

Mission in news

Chandrayaan 3

- India's **third** lunar exploration mission, led by the Indian Space Research Organisation (ISRO).
- **Objective**: To demonstrate end-to-end capability in landing and roving on the lunar surface, specifically targeting the south pole.
- **Launch Vehicle:**
    - GSLV Mk III (Geosynchronous Satellite Launch Vehicle Mark III).
    - Height: 43.43 meters.
    - Payload capacity: Up to 4,000 kg to Geosynchronous Transfer Orbit (GTO).
- **Components**:
    - **Lander**: Equipped with navigation, hazard detection, and landing technology.
    - **Rover**: Designed to explore the lunar surface and conduct scientific experiments.
    - **Propulsion Module**: Provides necessary thrust for the journey from Earth to lunar orbit.
- **Modules and Corresponding Payloads**
    - **Lander (Vikram):**
        - **Payloads**:
            - Chandra's Surface Thermophysical Experiment (ChaSTE): Measures thermal conductivity and temperature.
            - Instrument for Lunar Seismic Activity (ILSA): Detects seismic activities on the Moon.
            - Langmuir Probe (LP): Measures the plasma density near the lunar surface.
    - **Rover (Pragyan):**
        - **Payloads:**
            - Alpha Particle X-ray Spectrometer (APXS): Analyzes the elemental composition of the lunar surface.

        - Laser Induced Breakdown Spectroscope (LIBS): Identifies elements present on the lunar surface.
    - **Propulsion Module:**
        - **Payload:**
            - Spectro-polarimetry of Habitable Planet Earth (SHAPE): Studies the spectral and polarimetric characteristics of Earth from lunar orbit.

NISAR (NASA-ISRO-SAR)

- A collaborative mission between the National Aeronautics and Space Administration (NASA) and the Indian Space Research Organisation (ISRO) scheduled for launch in 2024.
- **Objective**: To utilize advanced radar technology for comprehensive monitoring of Earth's dynamic surfaces and ecosystems.
- **Technical Specifications**:
    - **Dual-frequency Radar System:**
        - L-band (longer wavelength) (ISRO Contribution): Offers superior ground penetration, ideal for biomass assessment and subsurface structure analysis.
        - S-band (shorter wavelength) (NASA Contribution): Provides high-resolution imagery for detailed observations.
    - **High-Resolution Data:** Generates topographic data with resolutions ranging from 3 to 10 meters, enabling precise mapping.
    - **Temporal Resolution:** Repeats observations every 6 days, facilitating the monitoring of changes over time.

Artemis Accords

- The Artemis Accords are a set of international agreements outlining principles for peaceful cooperation in exploring the Moon, Mars, and other celestial bodies.
- Established by the **US (NASA) with several other countries.**
- **India** is a member! It became the **27th nation** to sign on.
- **Key points**:
    - Promotes peaceful exploration and scientific discovery.
    - Encourages transparency and public awareness.
    - Establishes guidelines for resource utilization in space.
    - **Not a binding treaty**, but promotes collaboration.

Mission SCOT

- It is the **world's first commercial satellite** for surveillance of Resident Space Objects (as small as 5cm) orbiting the Earth to ensure safer space operations. .

- It aims to improve space safety, optimise traffic management and strengthen national security initiatives.
- The SCOT satellite has been launched onboard **SpaceX Transporter-12 mission**.
- SCOT will be **deployed in a sun-synchronous orbit**. This will enable it to track objects in Low Earth Orbit (LEO) with greater efficiency as compared to the existing sensors.

PUNCH Mission

- NASA is gearing up for a new and first-of-its-kind solar mission called PUNCH mission that will closely observe the solar atmosphere
- The Polarimetry to Unify the Corona and Heliosphere (PUNCH) mission will be launched by **SpaceX.**
- **Time Period:** The expected mission life is **two years**.
- It is the first time that a solar mission has been specifically designed to **make use of the polarisation of light to measure the corona and solar wind, that too, in 3D**.
- It will provide scientists with new information which could lead to more accurate predictions about the arrival of space weather events on Earth and impact on humanity's robotic explorers in space.
- It will **measure polarised light using polarising filters**, enabling scientists to look into the inner solar system.

GAIA Mission

- The European Space Agency (ESA) has officially decommissioned its Global Astrometric Interferometer for Astrophysics (GAIA) mission.
- It aimed to create the largest and most precise **3D map of the Milky Way** by surveying about 1% of its 100 billion stars.
- It was launched in 2013.
- **Position**: Gaia orbits the Sun at **Lagrange Point 2,** about 1.5 million kilometers (930,000 miles) from Earth.

Moonlight Programme

- **The European Space Agency** has launched the **Moonlight Lunar Communications and Navigation Services (LCNS)** programme.
- **Objective**: To support over **400 moon missions** planned by space agencies and private companies over the next 20 years.
- **Structure**: A **constellation of five satellites** orbiting the Moon.

- **Benefits**:
  ▪ Enable precise and autonomous lunar landings and surface mobility.
  ▪ Facilitate high-speed communication and data transfer between Earth and the Moon.
  ▪ Provide coverage at the Moon's South Pole.
- **Timeline**: Initial services to begin by the end of **2028**, with full operational capacity by **2030**.

Analog Space Mission

- **ISRO** has launched **India's first analog space mission** in **Leh, Ladakh**, to prepare for lunar mission experiments.
- It was developed in collaboration with **ISRO's Human Spaceflight Center**, **AAKA Space Studio**, the **University of Ladakh**, and **IIT Bombay**.

About Analog Missions

- Analog space missions simulate the physical and operational conditions of space environments on Earth.
- **Purpose**:
  ▪ Testing new technologies, equipment, and vehicles.
  ▪ Training astronauts for future missions.
  ▪ Studying the behavioral and psychological effects of isolation and confinement.
  ▪ Conducting experiments in space-like conditions.
- **Why Leh (Ladakh)?** Its dry, cold climate, barren land, high altitude, and isolation resemble Martian and lunar landscapes.

RISE Mission

- **RISE**, the **European Space Agency's** first **in-orbit servicing mission**, represents a major step toward enabling **refueling, refurbishment, and in-orbit assembly**— key elements for building a **circular economy in space**.
- **Launch Year**: **2028**
- **Capabilities**: Docking with **geostationary satellites** and controlling their orbits.
- **Mission Scope**: RISE will ascend to the **geostationary graveyard orbit**, about **100 km** above the active satellite zone, where decommissioned satellites are parked.

Note: The **circular space economy** mirrors the principles of a circular economy, focusing on **reducing waste** and **improving resource efficiency** in space.

ADITYA-L1 MISSION

- ISRO's Aditya-L1 completes its first halo orbit around the Sun-Earth L1 point

Key Highlights:

- Aditya-L1 was placed into its halo orbit in early 2024
- It took 178 days to complete one revolution around the Lagrange L1 point
- **Lagrange Points:**
    - Positions where the gravitational pull of two large masses equals the centripetal force required for a small object to move with them
    - There are five Lagrange points in a two-body system: **L1, L2, L3, L4, and L5**
    - **L4 and L5** are considered stable

About Halo Orbit

- A halo orbit is a repeating, three-dimensional orbit around one of the **L1, L2, or L3** Lagrange points in a three-body system

Advantages of placing Aditya-L1 in a Halo Orbit:

- Ensures a mission lifetime of **5 years**
- Minimizes fuel usage by reducing **station-keeping maneuvers**
- Maintains a **clear, uninterrupted view of the Sun**

About Aditya-L1 Mission (Launched in 2023)

- India's **first space mission** dedicated to studying the Sun
- **Objectives:**
    - Investigate the Sun's **corona**, **solar emissions**, **solar winds**, **flares**, and **Coronal Mass Ejections (CMEs)**
    - Enable **continuous imaging of the Sun**
- **Payloads:**
    - Equipped with **7 payloads**, including:
        - **Visible Emission Line Coronagraph (VELC)**
        - **Solar Ultraviolet Imaging Telescope (SUIT)**
        - And others

Dragonfly Mission

- It is the fourth mission in NASA's New Frontiers Program, alongside New Horizons, Juno, and OSIRIS-REx

- **Objective:** It is an astrobiology mission to Titan aimed at evaluating its potential for microbial life and examining its prebiotic chemistry at multiple sites
- It marks the first time NASA will fly a vehicle for science on another planetary body
- It will reach Titan in 2034

Technical Specifications

- **Design:** Dragonfly is a "dual quadcopter" about the size of a car, capable of traveling tens of kilometers on Titan in under an hour
- **Power Source:** Dragonfly will use a radioisotope power system, like the one used by the Curiosity rover on Mars

About Titan

- It is Saturn's largest moon, featuring an Earth-like cycle of liquid flowing across its surface and being the only moon with a dense atmosphere

ISRO'S RLV LEX-02 Mission

About Reusable Landing Vehicle (RLV) LEX-02 developed by ISRO

- It is the second in a series of test flights designed to showcase the autonomous landing capability of a reusable launch vehicle (RLV)
- The mission featured a winged vehicle named **Pushpak**, which was lifted to an altitude of 4.5 kilometers by an Indian Air Force Chinook helicopter
- Pushpak was released and had to autonomously execute a series of maneuvers to land accurately on the runway

About Reusable Landing Vehicle

- The reusable launch vehicle is essentially a spaceplane with a low lift-to-drag ratio, which means it must approach at steep glide angles and land at high speeds of 350 km/h

Lunar Polar Exploration Mission (LUPEX) Mission

- It is a joint mission of Japan Aerospace Exploration Agency (JAXA) and Indian Space Research Organisation (ISRO)
- **Objective:** To explore the Moon's southern polar region for water and other elements, possibly in the form of surface ice

- **Contributions:** For the LUPEX mission, the **launch vehicle and rover** are supposed to be contributed by the Japanese agency, while the **lander** will come from ISRO
- It will also carry instruments from **NASA** and the **European Space Agency (ESA)**

Defence

Weapons/Systems in News (India)

Pinaka Multiple Rocket Launch Systems (MRLS)

- It is a battle-proven, all-weather, indirect area fire **Artillery Weapon System**.
- **Developed by** DRDO's Armament Research and Development Establishment (ARDE).
- **First used during the Kargil War**, where it successfully neutralized Pakistan Army positions on the mountain tops.
- It delivers a variety of warheads, including high-explosive and submunitions.
- It has a **range of 60 to 75 kilometers.**

Nag Mark-2

- It is an indigenously developed **anti-tank guided missile (ATGM)** that works in all weather conditions.
- It is a **fire-and-forget missile with lock-on after launch capability**.
- Developed by: Defence Research and Development Organisation (DRDO).
- The missile is launched from NAMICA (Nag Missile Carrier), an anti-tank armored vehicle used by the Indian Army.
- **Estimated range**: 7 to 10 kilometers.

Vertically Launched Short-Range Surface-to-Air Missile (VL-SRSAM)

- **Developed by**: Defence Research and Development Organisation (DRDO).
- This quick-reaction missile is capable of neutralizing various aerial threats at close ranges, including sea-skimming targets.
- **Initially designed for the Indian Navy** with a strike range of 40 km, it has now been enhanced to attack targets up to 80 km.
- Additionally, it is being developed for the Indian Air Force to safeguard its air bases.
- It is capable of reaching Mach 4.5 and can achieve a maximum altitude of 16 km.

Bhargavastra

- **India's first indigenous micro-missile system,** developed by Economic Explosives Ltd., is specifically designed to counter the threat posed by swarm drones.
- This system can be rapidly deployed on mobile platforms and effectively target threats over 2.5 km.
- It has the capability to detect small flying objects from distances exceeding 6 km and neutralize them using guided micro munitions.
- The system is **capable of launching more than 64 micro missiles simultaneously**.
- It is **built to operate across diverse terrains**, including high-altitude regions, it meets the specialized needs of the armed forces.

SANJAY System

- Sanjay is an **automated surveillance system** that **combines real-time data from ground and aerial sensors to create a unified view of the battlefield**. This helps commanders make quick, informed decisions during both conventional and unconventional warfare.
- **Developed by:** Indian Army and Bharat Electronics Limited (BEL).

Advanced Ballistic for High Energy Defeat (ABHED) Jackets

- These jackets are made from polymers and indigenous boron carbide ceramic material.
- Developed by **DRDO** and **IIT Delhi**.
- They offer 360-degree protection with modular design and front/rear armour plates.
- Their weight ranges from 8.2 kg to 9.5 kg for different **BIS** levels.

India's Fourth Nuclear Submarine

- India's fourth nuclear-powered ballistic missile submarine (SSBN), referred to as **S4**, was launched into water at the Ship Building Centre in Visakhapatnam.
- S4 features about 75% indigenous content.
- It is armed exclusively with **K-4 nuclear ballistic missiles** (range: 3,500 km).
- India currently has two SSBNs operational: **INS Arihant** (commissioned in 2016) and **INS Arighaat** (commissioned in 2024).
- The third SSBN **Aridhman** is undergoing sea trials and is expected to be commissioned next year.

INS ARIGHAAT

- It is India's second indigenously built nuclear-powered ballistic missile submarine (SSBN).
- It joins INS Arihant to strengthen India's nuclear triad.
- It was constructed at the Indian Navy's Ship Building Centre (SBC) in Visakhapatnam.

Features:

- It has a length of 111.6 meters and a submerged displacement of 6,000 tons.
- It has a seven-blade propeller powered by an 83-MW pressurised light water reactor using enriched uranium.
- It can carry up to 12 K-15 SLBMs, each with a range of 750 km.

RHUMI-1

- India's first reusable hybrid rocket RHUMI-1 was launched from Thiruvidandhai in Chennai.
- RHUMI-1 was developed by Tamil Nadu-based startup Space Zone India in collaboration with the Martin Group.
- It was launched into a sub-orbital trajectory using a mobile launch system.

Key Features of RHUMI-1

- RHUMI-1 is a hybrid rocket engine that integrates both solid and liquid propellants.
- It is equipped with an electrically triggered parachute system, which is an advanced and eco-friendly descent mechanism.
- It has an adjustable launch angle (0 to 120 degrees), allowing for precise trajectory control.
- It is completely free of pyrotechnics (fireworks) and TNT (Trinitrotoluene), making it environmentally friendly.

Zorawar Tank

- It has been indigenously developed by the Defence Research and Development Organisation (DRDO) along with Larsen & Toubro (L&T).
- It is named after the great military general Zorawar Singh Kahluria.
- It is a lightweight tank with a maximum weight of 25 tonnes.
- It features advanced technologies such as artificial intelligence (AI) and drone integration.

- It is amphibious and can operate in varied terrain.

Rudram-1 Missile

- It is an air-to-surface missile developed by the Defence Research and Development Organisation (DRDO).
- The IAF's Sukhoi-30MKI fighter jets serve as its launch platform.
- It can be launched from altitudes ranging from 500 meters to 15 kilometers, with a range of up to 250 kilometers.
- It is equipped with Inertial Navigation System (INS), GPS navigation, and a Passive Homing Head to precisely strike radiation-emitting targets.

Astra Mark 1 Missile

- It is a Beyond-Visual-Range (BVR) **air-to-air missile**.
- It will be deployed on fighter jets of the Indian Air Force and Indian Navy.
- It has been indigenously developed by DRDO and manufactured by Bharat Dynamics Limited (BDL).
- It has a range of 80 to 110 km in a head-on chase.
- It can travel at a speed of Mach 4.5.

GAURAV

- It is an air-launched, 1000-kg glide bomb capable of precisely hitting long-distance targets.
- It uses an Inertial Navigation-based guidance system.
- It can be integrated with fighter jets.
- It has been designed and developed indigenously by the Research Centre Imarat (RCI), Hyderabad.

Indigenous Technology Cruise Missile (ITCM) Flight Tested

- It has been developed by the Aeronautical Development Establishment of DRDO, with contributions from other laboratories and Indian industries.
- It is a **long-range subsonic cruise missile** designed to hit targets with precision.
- It is powered by an indigenous propulsion system.
  ✓ A subsonic cruise missile flies at a speed lower than that of sound (<1 Mach).

Agni Prime Successfully Flight-Tested

- It is a **surface-to-surface ballistic missile**.
- It is a nuclear-capable, two-stage canisterised missile with a maximum range of 1,000 to 2,000 km.

- It is lighter than all previous missiles in the Agni series.

Submersible Platform for Acoustic Characterisation and Evaluation (SPACE)

- It is a premier testing and evaluation hub for sonar systems for the Indian Navy.
- It has been set up by DRDO.
- It consists of two distinct platforms:
  A) Floating Platform
  B) Submersible Platform (submersible up to 100m depth)
- It will bolster anti-submarine warfare research capabilities.

Project 28

- **Objective**: To build four indigenous Anti-Submarine Warfare (ASW) corvettes, also known as Kamorta-class corvettes.
- These four ASWs are: INS Kamorta, INS Kadmatt, INS Kiltan, and INS Kavaratti.
- These ships can be deployed in nuclear, biological, and chemical warfare conditions.
- Designed by: Indian Navy's Directorate of Naval Design
- Built by: Garden Reach Shipbuilders & Engineers (GRSE), Kolkata

Nagastra-1

- It is **India's first indigenous loitering munition** (suicide drone).
- It has been developed by Solar Industries, Nagpur.
- It has the capacity to carry a 1-kilogram warhead.
- It can carry out GPS-enabled precision strikes with an accuracy of up to 2 meters.
- It has an indigenous content of over 75%.
- It features a parachute recovery mechanism.

RudraM-II Missile

- It is an indigenously developed, solid-propelled, air-launched missile system.
- It has been designed for air-to-surface operations.
- It has been developed by the Defence Research and Development Organisation (DRDO).

Weapon Development in News – World

Dragon Drone

- Dragon drones are powerful UAVs equipped with thermite and rain down fire from the sky
- Thermite is a mixture of aluminium and iron oxide.
- When ignited, it produces a self-sustaining reaction that is extremely difficult to extinguish.
- Dragon Drones were used by **Ukraine** against **Russia** in the ongoing Russia-Ukraine War.

THAAD Missile Defence System

- It is an advanced defense system that can destroy short, medium, and intermediate-range ballistic missiles.
- Developed by **Lockheed Martin Corporation**.
- Employs a '**hit-to-kill**' approach to target missiles.
- Its target range varies between **150–200 kilometers**.

Crystal Maze 2 (also known as ROCKS)

- It is a medium-range ballistic missile.
- It has been developed by Israel.
- It is an air-to-surface missile with a strike range of over 250 km.
- It has the capability to strike high-value stationary and relocatable targets in GPS-denied environments.

C-Dome Defense System

• It has been developed by Israel.
• It is a naval version of Israel's Iron Dome air defense system.
• It is designed to shield against missile and rocket attacks.
• Unlike the Iron Dome which features its own radar, C-Dome is integrated into ship's radar to detect incoming targets.

Hermes-900

• It is an advanced, Medium Altitude Long Endurance (MALE) unmanned aerial vehicle.
• It is of Israeli origin.
• It is also known as Drishti-10 drone.
• It features Automatic Take Off and Landing (ATOL) capability, Terrain Avoidance Warning System (TAWS), Synthetic Aperture Radar (SAR).
• It can be employed for Intelligence, Surveillance, Target Acquisition and Reconnaissance (ISTAR) missions.

Igla-S Air Defense System

• It is a man-portable air defense system (MANPADS).

• It has been developed by Russia.
• It is a handheld, very short range defense system (VSHORAD).
• It has an interception range of up to 6 kms and can destroy targets at altitudes of up to 3.5 km.

MQ-9B Drones

- These drones are Unmanned Aerial Vehicles (UAVs) with high altitude and long endurance capabilities, created for surveillance, reconnaissance, and precision strike operations.
- They have a maximum endurance of 40 hours and can hit targets on land, sea, and air.
- They have two variants: **SkyGuardian** and **SeaGuardian**.

Exercises in News

- **Dharma Guardian** – Joint military exercise between India and Japan.
- **Ekuverin** – Bilateral military exercise between India and the Maldives.
- **Cyclone 2025** – Joint military exercise between India and Egypt.
- **La Perouse** – Multilateral naval exercise hosted by France, involving India, Australia, Canada, USA, Indonesia, Malaysia, UK, and Singapore.
- **KAZIND 2024** – Joint military exercise between India and Kazakhstan.
- **Naseem Al Bahr** – Bilateral naval exercise between India and Oman.
- **Garud Shakti** – Joint special forces exercise between India and Indonesia.
- **VINBAX 2024** – Bilateral army exercise between India and Vietnam.
- **SIMBEX-2024** – Bilateral maritime exercise between India and Singapore.
- **Poorvi Prahar** – High-intensity tri-services exercise conducted by the Indian Army.
- **Sanyukt Vimochan 2024** – Humanitarian Assistance and Disaster Relief (HADR) exercise conducted by the Indian Army.

- **SAREX-24** – National maritime search and rescue exercise conducted by the Indian Coast Guard (ICG).

- **Exercise Antariksha Abhyas 2024** – India's first-ever space exercise conducted by the Defence Space Agency under the Ministry of Defence.

- **Rim of the Pacific (RIMPAC)-** World's largest biennial maritime exercise, held in Hawaii.Led by the US Navy; 29 countries participated, including India.

- **Exercise Pitch Black-** Biennial multinational air exercise hosted by the Royal Australian Air Force.

- **Exercise Mitra Shakti-** Annual joint exercise between India and Sri Lanka.

- **Exercise Tarang Shakti-** India's first multinational air exercise, inspired by the US Red Flag.

- **Exercise Udara Shakti-** Bilateral air exercise between India and Malaysia.

- **Exercise Eastern Bridge-** Bilateral air exercise between IAF and Oman's RAFO.

- **Exercise Al Najah-** Biennial joint military exercise between India and Oman since 2015.

- **Tarkash Exercise-** India–US joint counter-terrorism exercise.

- **Shakti Exercise-** Biennial India–France military exercise

- **HOPEX Exercise- Type**: India–Egypt Air Force joint exercise