INTERNATIONAL THERMONUCLEAR EXPERIMENTAL REACTOR – SCIENCE & TECHNOLOGY

NEWS: *Prime Minister Modi makes history as first head of government to visit the International Thermonuclear Experimental Reactor (ITER) facility.*

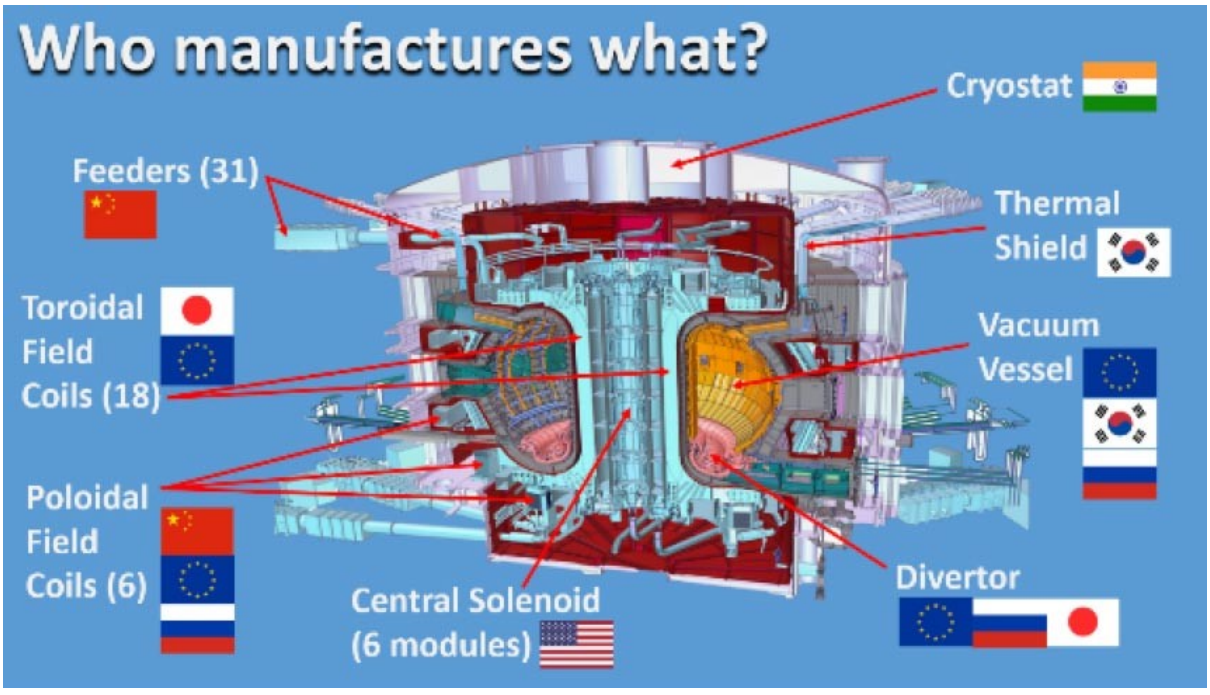
WHAT' S IN THE NEWS?

PM Modi's Visit to ITER

1. **Historic Visit** – Prime Minister Narendra Modi, along with French President Emmanuel Macron, visited the International Thermonuclear Experimental Reactor (ITER) in Cadarache, France.
2. **Warm Reception** – Both leaders were welcomed by the Director-General of ITER, who briefed them on the project's progress.
3. **Commendation of ITER Efforts** – Modi and Macron praised ITER's advancements, particularly the assembly of the world's largest tokamak.

About ITER

1. **Objective** – ITER is an international collaborative project aimed at demonstrating the feasibility of fusion energy as a large-scale, carbon-free energy source.
2. **Global Collaboration** – A total of 33 nations, including India, are working together on the project. The seven main ITER members are:
    - China
    - India
    - European Union
    - Japan
    - Korea
    - Russia
    - United States



3. **Location & Development** – ITER is currently under construction in the south of France. The idea for ITER was conceived in 1985, and the project officially commenced in 2005.
4. **Timeline & Goals** – ITER is expected to initiate deuterium-tritium fusion reactions by 2039, with a goal of producing 500 MW of fusion power.
5. **No Direct Electricity Generation** – ITER will not convert the generated heat into electricity. Instead, it aims to lay the foundation for future machines to utilize fusion energy for electricity generation.
6. **Key Scientific Objective** – ITER will investigate "burning plasmas," where the energy produced from fusion reactions maintains the plasma temperature without the need for external heating.
7. **Technological Research** – The project will also study the feasibility of tritium breeding modules for achieving tritium self-sufficiency in future fusion reactors.

Significance of ITER Project

1. **Future of Energy** – Fusion energy is considered the next-generation energy source, offering an unlimited supply of clean energy.
2. **Efficiency & Sustainability** – A small amount of fuel (deuterium and tritium) can generate massive amounts of energy without greenhouse gas emissions.
3. **Climate Change Mitigation** – Fusion energy does not produce carbon emissions, making it a viable solution for combating climate change.
4. **Largest Fusion Experiment** – As the world's largest fusion reactor, ITER holds immense importance in the development of practical fusion energy solutions.

India's Role in ITER

1. **PM Modi's Historic Visit** – Modi became the first Head of State or Government to visit ITER.
2. **Indian Contributions** – India has been an active participant in ITER for over two decades.
3. **Indian Workforce & Industry Involvement** – Around 200 Indian scientists, engineers, and companies are contributing to ITER, including:
    - Larsen & Toubro (L&T)
    - Inox India
    - Tata Consultancy Services (TCS)
    - Tata Consulting Engineers (TCE)
    - HCL Technologies

    India's Contribution:

    - India also mentioned about its fair share in terms of its in-kind contributions, viz., the cryostat, cryogenic and cryo-distribution systems, auxiliary heating devices, multi megawatt power supplies, etc.

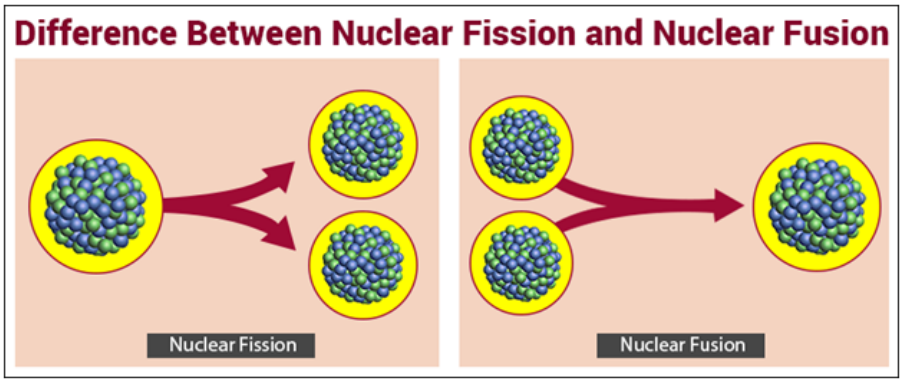
- ITER cryostat is manufactured by **India (Larsen and Tourbo).** Cryostat is a chamber that can maintain **very low temperatures.**

    - It is the largest stainless steel high-vacuum pressure chamber ever built (16,000 m^3) providing the high vacuum, ultra cool environment for the ITER vacuum vessel and the superconducting magnets.
    - The target for the **first plasma is 2025.** At extreme temperatures, electrons are separated from nuclei and a gas becomes a plasma—**an ionized state of matter similar to a gas.**
- **European Union (EU)** is responsible for the **largest portion of construction costs** (45.6%); the remainder is **shared equally** by China, Japan, South Korea, Russia, USA including **India (9.1% each).**

Nuclear Reactions

- **Description:**

    - A nuclear reaction is the process in which **two nuclei,** or a nucleus and an external subatomic particle, collide to produce one or more new nuclides.
    - Thus, a nuclear reaction must cause a transformation of at least one nuclide to another.



Types:

Nuclear Fission:

The nucleus of an **atom splits** into two daughter nuclei.

- This decay can be **natural** spontaneous splitting by radioactive decay, or can actually be **simulated** in a lab by achieving necessary conditions (bombarding with neutrons, alpha particles, etc.).
- The resulting fragments tend to have a combined **mass which is less than the original.** The missing mass is usually converted into nuclear energy.
- Currently all commercial nuclear reactors are **based on nuclear fission.**

- **Nuclear Fusion:**

- Nuclear Fusion is defined as the combining of two lighter nuclei into a heavier one.
- Such nuclear fusion reactions are the **source of energy in the Sun and other stars.**
- It takes considerable energy to force the nuclei to fuse. The conditions needed for this process are extreme – millions of degrees of temperature and millions of pascals of pressure.
- The **hydrogen bomb** is based on a thermonuclear fusion reaction. However, a **nuclear bomb based on the fission** of uranium or plutonium is **placed at the core of the hydrogen bomb** to provide initial energy.

International Thermonuclear Experimental Reactor

- **Establishment:**
    - International Thermonuclear Experimental Reactor (ITER) is a collaboration of **35 nations** launched in **1985.**
    - It is located in **France.**
- **Aim:**
    - It aims to build the **world's largest tokamak** to prove the **feasibility of fusion** as a **large-scale and carbon-free** source of energy.
        - The **tokamak** is an experimental machine designed to harness the energy of fusion. Inside a tokamak, the energy produced through the fusion of atoms is absorbed as heat in the walls of the vessel. Like a conventional power plant, a fusion power plant uses this heat to produce steam and then electricity by way of turbines and generators.
- **Applicable Principle:**
    - The project is based on **fusion** which is also an **energy source** for the **Sun and stars.**
        - Every fusion reaction in the Sun, in which two hydrogen atoms fuse into one helium atom, releases two **neutrinos.**
- **Significance:**
    - ITER will be the **first fusion device** to maintain **fusion for long periods** of time and also **to test the integrated technologies,** materials, and physics regimes necessary for the commercial production of fusion-based electricity.
- **Participation:**
    - The ITER members include **China, the European Union, India, Japan, South Korea, Russia and the United States.**

- According to the **ITER Agreement (2006),** the above mentioned seven members will share the cost of project construction, operation and decommissioning.
- They also share the experimental results and any intellectual property generated by the fabrication, construction and operation phases.

Understanding the Tokamak

1. **What is a Tokamak?** – A tokamak is an experimental fusion machine designed to harness the energy produced by nuclear fusion reactions. It uses magnetic confinement to contain and stabilize the superheated plasma required for fusion.
2. **Heat Absorption & Energy Conversion** – The walls of a tokamak absorb energy from fusion reactions, which can be used to generate steam and drive turbines for electricity production.
3. **ITER's Tokamak Assembly** – The ITER tokamak building was taken over for machine assembly in March 2020. A key milestone was the installation of the 1,250-tonne cryostat base in May 2020.
4. **Historical Development** – The tokamak was originally developed by Soviet scientists in the late 1950s and is now the most widely accepted design for magnetic fusion reactors.
5. **Largest Tokamak in the World** – ITER's tokamak will be the largest ever built, measuring twice the size of the biggest existing machine and featuring six times the plasma chamber volume.

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