# Whole-Earth Simulation for Exoplanet Habitability

**Prelims**: *Current events of National and International Importance| Science& technology*

## Why in News?

*Scientists from the University Of Washington (USA) have developed a sophisticated computer simulation of the entire Earth to help identify potentially habitable planets and search for extraterrestrial life.*

The important feature is that scientists simulated **Earth without life** to understand how a planet behaves naturally.

## What is a Whole-Earth Simulation?

- It is a computer-based scientific model that studies the interconnected functioning of the entire planet.
- It combines five major components:
- **Five interconnected Earth systems**
    - **Core –** The innermost region of Earth, responsible for major internal heat and magnetic-field processes.
    - **Mantle –** The thick layer beneath the crust, involved in heat transfer and geological activity.
    - **Crust –** The outer solid layer where geological processes and chemical exchanges occur.
    - **Surface –** Includes oceans, land and interactions between geological and environmental systems.
    - **Atmosphere –** The gaseous envelope surrounding Earth, which regulates temperature and climate.
- The model also considers energy received from the Sun and exchanges between these systems.

## What is special about this simulation?

- The researchers created a virtual Earth in which biological activity was excluded.
- The simulation covered approximately five billion years:
- **Past** – From Earth's formation around 4.5 billion years ago.
- **Future** – Approximately 500 million years from now.
- It reproduced 19 important planetary properties within estimated observational uncertainties.
- It examined how geological and chemical processes could maintain conditions suitable

for liquid water even without life.

## Why simulate Earth without life?

- This is the most important scientific concept in the news.
- Scientists distinguish between two terms:

| Term | Meaning |
|---|---|
| Habitable planet | A planet capable of supporting life |
| Inhabited planet | A planet where life actually exists |

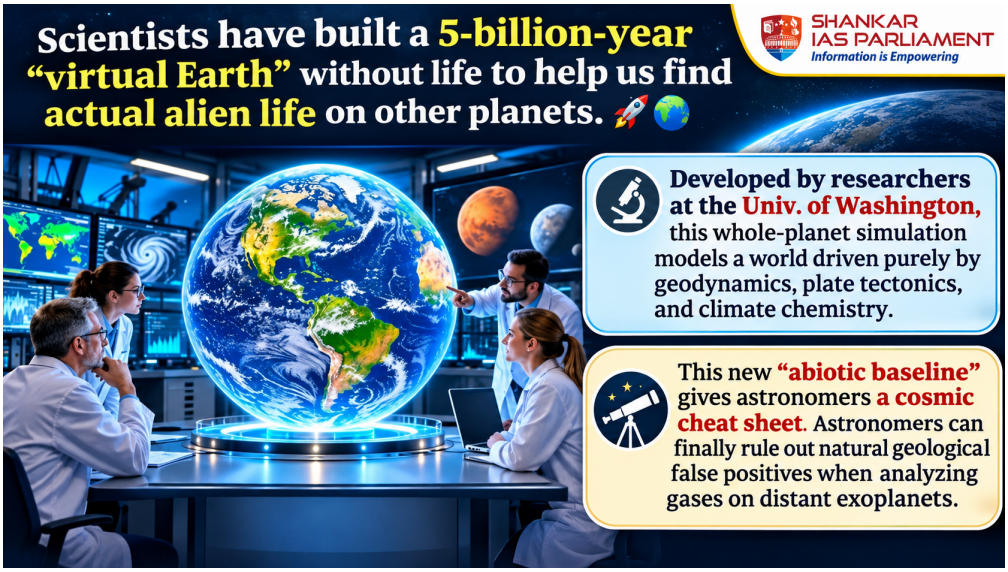
- A planet may have Liquid water, A suitable temperature, An atmosphere, and Appropriate geological conditions.
- But these characteristics do not automatically prove the existence of life.
- **For Example,** Earth's plants and animals release gases such as oxygen and methane into the atmosphere.
- If astronomers detect certain gases in another planet's atmosphere, they must determine whether those gases were produced by biological activity or natural geological and chemical processes.
- The simulation provides a baseline for making this distinction.

## What are Biosignatures?

- **Biosignatures** are substances, patterns or signals that may provide evidence of biological activity.
- Examples:

| Biosignature | Significance |
|---|---|
| Oxygen ($O_2$) | Can be associated with photosynthesis |
| Methane ($CH_4$) | Can be produced by biological and geological processes |
| Ozone ($O_3$) | Can indirectly indicate atmospheric oxygen |

- An important point is that Oxygen alone does not conclusively establish the existence of life because non-biological processes can also produce it.
- Scientists must examine multiple indicators and eliminate non-biological explanations.
- **Role of future space telescopes –** A proposed NASA space telescope designed to study Earth-like planets around other stars and investigate possible signs of life.
- The new simulation could help scientists:
    - Identify potentially habitable exoplanets.
    - Interpret atmospheric chemical compositions.
    - Distinguish biological and non-biological signals.
    - Improve the design and scientific objectives of future telescopes.




## Reference

[Times of India| Whole-Earth Simulation for Exoplanet Habitability]

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