

Atomic Clock and India's NavIC System - Explained

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Atomic Clock Latest News

- The atomic clock onboard the IRNSS-1F satellite of India's **NavIC Navigation System** recently failed, weakening the operational capacity of India's indigenous satellite navigation network.

About Atomic Clock

- An atomic clock is a highly precise timekeeping device that measures time using the natural oscillations of atoms, typically caesium or rubidium atoms.
- Unlike traditional clocks that rely on mechanical or electronic oscillators, **atomic clocks operate based on the consistent frequency of atomic transitions.**
- In an atomic clock, atoms are exposed to microwave radiation. The radiation causes the atoms to transition between energy states at a precise frequency. This frequency is used to measure time with extraordinary accuracy.
- Atomic clocks are the most accurate clocks ever developed. Modern atomic clocks can measure time so precisely that they would lose or gain less than a second over millions of years.

Importance of Atomic Clocks

- Atomic clocks play a critical role in several modern technologies and scientific applications.
- **Satellite Navigation Systems:** Global navigation systems such as GPS (United States), GLONASS (Russia), Galileo (European Union), and BeiDou (China) rely on atomic clocks to determine accurate positioning.
- **Precise Timekeeping:** Atomic clocks define the international standard of time known as **Coordinated Universal Time (UTC)**.
- **Telecommunication Networks:** Accurate time synchronisation is essential for mobile networks, internet communication, and financial transactions.
- **Scientific Research:** Atomic clocks are used in space science, physics experiments, and deep-space navigation.
- Because satellite navigation depends on measuring the time taken for signals to travel from satellites to receivers, even a tiny error in time can translate into large positional errors. Therefore, atomic clocks are essential for maintaining accurate navigation services.

Role of Atomic Clocks in Satellite Navigation

- Satellite navigation systems work by transmitting signals from satellites to receivers on Earth. These signals contain the precise time at which the signal was sent.
- The receiver calculates its position by measuring the time difference between signal transmission and reception. Since signals travel at the speed of light, extremely accurate timing is required.
- Even a time error of **one nanosecond (one billionth of a second)** can lead to positional errors of several centimetres. Therefore, atomic clocks installed on navigation satellites ensure that time measurements remain extremely precise.
- Each satellite typically carries multiple atomic clocks as backup systems to ensure uninterrupted functioning.

News Summary

- According to ISRO, the atomic clock onboard the IRNSS-1F satellite stopped functioning in March 2026. This development has significant implications for India's NavIC system.
- **Impact on Navigation Capability**
 - Atomic clocks are critical components of navigation satellites because they ensure precise timing for navigation signals.
 - With the failure of the IRNSS-1F clock, the number of satellites with functioning clocks has fallen further. At least four operational satellites are required to provide reliable navigation services, but the number has now been reduced to three.
 - This situation weakens the reliability of India's indigenous navigation system.
- **Status of NavIC Satellite Constellation**
 - Since 2013, nine IRNSS satellites have been launched, out of which eight reached their intended orbit.
 - However, several satellites in the constellation have experienced failures in their onboard atomic clocks. Earlier reports indicated that multiple satellites had lost all three of their atomic clocks.

- The IRNSS-1F satellite, launched in March 2016, had already completed its designed mission life of ten years in March 2026 when the clock failure occurred.
- Although the satellite will continue operating in orbit, it can now provide only limited services such as one-way broadcast messaging.

Efforts to Strengthen NavIC

- To address the challenges posed by ageing satellites and clock failures, ISRO has begun deploying improved navigation satellites.
- For future missions, ISRO plans to use indigenously developed rubidium atomic clocks instead of imported ones.
- Previously, the atomic clocks used in NavIC satellites were imported from a Swiss manufacturer, SpectraTime.
- Recent developments include:
 - **NVS-01 satellite (launched in 2023)** carrying an indigenous rubidium atomic clock.
 - **NVS-02 satellite (launched in 2025)**, which unfortunately failed to reach its intended orbit.
- ISRO has also announced plans to launch three new replacement satellites by the end of 2026 to replace ageing and malfunctioning satellites in the NavIC constellation.

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