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NavIC's IRNSS-1F Atomic Clock Failure — India's Indigenous Navigation System Under Strain

17 March 2026

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NavIC's IRNSS-1F Atomic Clock Failure — India's Indigenous Navigation System Under Strain

17 March 2026 · 8 min read ·

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WHY IN NEWS

The last functioning atomic clock aboard India's navigation satellite IRNSS-1F ceased operation on March 13, 2026, after the satellite completed its 10-year design life, raising questions about the reliability and future of India's NavIC regional navigation system.

WHAT IS NAVIC?

NavIC (Navigation with Indian Constellation) — formerly known as **IRNSS (Indian Regional Navigation Satellite System)** — is India's indigenous satellite-based navigation system, developed by **ISRO (Indian Space Research Organisation)**.

Approved by the Indian government in 2006 and operational since **2018**, NavIC is designed to provide:

Position accuracy of better than 20 metres in the primary service area

Timing accuracy of better than 50 nanoseconds

Coverage over **India and up to 1,500 km beyond India's borders** — a region of strategic importance covering South Asia, the Arabian Sea, and the Bay of Bengal

NavIC is India's answer to:

GPS (USA) — Global Positioning System

GLONASS (Russia) — Global Navigation Satellite System

Galileo (EU) — European satellite navigation system

BeiDou/BDS (China) — Chinese navigation system

QZSS (Japan) — Quasi-Zenith Satellite System

NavIC and QZSS are **regional** systems; GPS, GLONASS, Galileo, and BeiDou are **global** constellations.

THE SATELLITE CONSTELLATION

ISRO launched 9 first-generation IRNSS satellites and 2 second-generation NVS satellites. Here is the current status:

Satellite	Orbit Type	Launch Date	Status
IRNSS-1A	GSO (55°E)	July 2013	All 3 atomic clocks failed (2016-17); defunct for navigation
IRNSS-1B	GSO (55°E)	April 2014	**Operational** (beyond 10-year design life)
IRNSS-1C	GEO (83°E)	October 2014	All clocks failed; defunct for navigation
IRNSS-1D	GSO (111.75°E)	March 2015	All clocks failed; defunct for navigation
IRNSS-1E	GSO (111.75°E)	January 2016	Partially operational (1 clock remaining)
IRNSS-1F	**GEO (32.5°E)**	**March 2016**	**Last atomic clock failed (March 13, 2026); defunct for navigation**
IRNSS-1G	GEO (131.5°E)	April 2016	Messaging services only; clocks failed
IRNSS-1H	—	August 2017	**Launch failure** (payload fairing did not separate)
IRNSS-1I	GSO (55°E)	April 2018	**Operational** (replacement for 1A)
NVS-01	GEO	May 2023	**Operational** (first 2nd-gen satellite; indigenous atomic clock)
NVS-02	—	January 2025	**Failed to reach orbit** (pyro-valve malfunction)

As of March 2026, only 3 satellites (IRNSS-1B, IRNSS-1I, NVS-01) provide full Positioning, Navigation, and Timing (PNT) services — below the minimum of 4 required for accurate positioning. Five first-generation satellites are completely defunct for navigation due to atomic clock failures across all their clocks.

Two orbit types used by NavIC:

> **GEO (Geostationary Orbit):** Satellites remain stationary over the equator at ~36,000 km altitude — always visible from the same point on Earth. NavIC places 3 GEO satellites at longitudes 32.5°E, 83°E, and 131.5°E.
>
> **GSO (Geosynchronous Orbit):** Satellites orbit at the same altitude but with a 29° inclination, tracing a figure-8 pattern across the sky. NavIC uses 4 GSO satellites — two crossing the equator at 55°E and two at 111.75°E.

This combination ensures continuous visibility of multiple NavIC satellites from anywhere in India at any time.

WHAT IS AN ATOMIC CLOCK — AND WHY DOES IT MATTER?

The core technology of any satellite navigation system is **precise timekeeping**. Here is why:

Your GPS/NavIC receiver calculates its position by measuring the **time delay** between when a signal was sent from a satellite and when it was received. Since radio waves travel at the speed of light (~3×10^8 m/s), even a **1 microsecond (0.000001 second) error** translates to a **300 metre positioning error**.

Atomic clocks achieve accuracy of **1 second of error in 300 million years** — roughly **100,000 times more accurate** than the best quartz crystal oscillator.

NavIC satellites use **Rubidium atomic clocks** — the same type used in GPS satellites. Each satellite carries multiple atomic clocks for redundancy, but when all fail, the satellite loses its primary navigation function.

IRNSS-1A experienced the first atomic clock failure in July 2016, with all three clocks failing by 2017 — India's first major NavIC setback. IRNSS-1I was launched on April 12, 2018 specifically as a replacement. By July 2025, an RTI response revealed that **five IRNSS satellites were completely defunct**, with all their clocks having failed. IRNSS-1F's failure in March 2026 reduced the constellation to just 3 operational navigation satellites. The failing clocks were all internationally procured from **SpectraTime** (Switzerland) — the same supplier whose clocks also affected Europe's Galileo constellation.

IMPACT AND INDIA'S RESPONSE

With IRNSS-1F's clock non-functional:

> The satellite can no longer contribute to **positioning and timing signals**
>
> It will continue to function for **one-way broadcast messaging services**

- Only **3 satellites remain operational** for navigation (IRNSS-1B, IRNSS-1I, NVS-01) — below the **minimum of 4** required for accurate positioning
- The system has fallen below its operational threshold, a critical situation for India's navigation independence

The atomic clock problem is not unique to India — the internationally procured SpectraTime rubidium atomic clocks have also caused failures in Europe's Galileo constellation, pointing to a systemic issue with these components.

ISRO has been working on **NavIC's second-generation (NavIC-2)** satellites with improved atomic clocks and longer design lives. On **May 29, 2023**, ISRO launched **NVS-01** (NavIC Voyage Satellite-01) — the first next-generation NavIC satellite — with an **indigenous Rubidium Atomic Frequency Standard (IRAFS)** developed in India, marking a critical step toward self-reliance. NVS-01's indigenous clock outperforms the first-generation imported clocks. However, **NVS-02** (launched January 2025) failed to reach its designated orbit due to a pyro-valve malfunction. ISRO plans to launch NVS-03, NVS-04, and NVS-05 before the end of 2026 to restore the constellation.

NAVIC'S STRATEGIC AND CIVIL APPLICATIONS

Civil applications:

- Vehicle tracking and fleet management (mandatory for commercial vehicles in India since 2019 — **AIS-140 standard**)
- Fishermen navigation aids — NavIC-enabled devices distributed to fishing communities along India's coasts
- Precision agriculture — soil moisture mapping, drone navigation
- Disaster management — position tracking during floods, earthquakes

Strategic applications:

- Indian Armed Forces' navigation systems
- Missile guidance systems (NavIC enables guidance in denied-GPS environments)
- Border surveillance

NavIC's strategic value is precisely that it operates **independently of US GPS** — India cannot be cut off from navigation services during a conflict or political dispute, unlike countries that solely rely on GPS.

NAVIC IN YOUR PHONE

In 2019, **Qualcomm** became the first chipmaker to include NavIC support in its Snapdragon processors. From 2019 onwards, high-end Android phones (Samsung, OnePlus, Realme) sold in India include **NavIC receivers**. Apple's **iPhone 15 Pro and iPhone 15 Pro Max** (September 2023) were the first iPhones to

support NavIC — the standard iPhone 15 and iPhone 15 Plus do not include NavIC support. As of 2026, NavIC support is mainstream in smartphones sold in India.

UPSC RELEVANCE

NavIC = Navigation with Indian Constellation; IRNSS = Indian Regional Navigation Satellite System; operational since 2018; 7 original satellites; GEO (3) + GSO (4) orbits; coverage up to 1,500 km beyond India; position accuracy < 20 m; IRNSS-1F GEO satellite clock failed March 13, 2026; only 3 satellites operational for navigation (IRNSS-1B, IRNSS-1I, NVS-01); IRNSS-1A clocks failed 2016-17; NVS-01 launched May 29, 2023 (first NavIC 2G satellite, indigenous IRAFS atomic clock); NVS-02 failed to reach orbit (Jan 2025); Rubidium atomic clocks; AIS-140 standard (vehicle tracking); SpectraTime (Swiss) supplied first-gen clocks.

MAINS GS3:

India’s space technology indigenisation; strategic importance of independent navigation systems; dual-use (civil + military) technology; ISRO’s role in India’s strategic autonomy; comparison with GPS, GLONASS, BeiDou; systemic atomic clock failures and lessons for indigenous development.

📌 FACTS CORNER — KNOWLEDGEPEDIA

NAVIC — CORE DATA:

Full name: **Navigation with Indian Constellation**

Earlier name: **IRNSS** (Indian Regional Navigation Satellite System)

Developed by: ISRO; renamed NavIC by PM Modi in 2016

Government approval: 2006 | Operational: **2018**

Original constellation: 7 satellites; 11 launched total (9 first-gen + 2 second-gen)

Orbit types: **3 GEO** (Geostationary, ~36,000 km, at 32.5°E, 83°E, 131.5°E) + **4 GSO** (Geosynchronous, 29° inclination, at 55°E and 111.75°E)

Coverage: India + **1,500 km beyond India's borders**

Position accuracy: **< 20 metres**

Timing accuracy: **< 50 nanoseconds**

Operational satellites (March 2026): only **3** — IRNSS-1B, IRNSS-1I, NVS-01

IRNSS-1F FAILURE:

Orbit: **GEO (Geostationary)** at 32.5°E longitude

Launched: **March 10, 2016**; design life completed **March 10, 2026**

Failure date: **March 13, 2026** — last functioning atomic clock ceased operation

Clock supplier: **SpectraTime** (Switzerland) — same supplier whose clocks failed on other IRNSS and Galileo satellites

Earlier failure: IRNSS-1A — first clock failed **July 2016**, all 3 failed by **2017**

IRNSS-1I launched **April 12, 2018** (PSLV-C41) as replacement for IRNSS-1A

ATOMIC CLOCK TECHNOLOGY:

First-gen NavIC clock type: **Rubidium atomic clocks** (imported from SpectraTime, Switzerland)

Accuracy: ~1 second error in **300 million years**

Why critical: 1 microsecond timing error = **300 metre** position error

NVS-01 (launched **May 29, 2023**): first NavIC satellite with **indigenous Rubidium Atomic Frequency Standard (IRAFS)**

NVS-02 (launched **January 29, 2025**): failed to reach orbit (pyro-valve malfunction)

NVS-03, NVS-04, NVS-05: planned for launch before end of 2026

NAVIC COMPARED TO OTHER SYSTEMS:

GPS (USA): global, 31 satellites, accuracy ~3–5 m (civilian)

GLONASS (Russia): global, ~24 satellites

Galileo (EU): global, 30 satellites

BeiDou/BDS (China): global

NavIC (India): **regional** (South Asia coverage)

QZSS (Japan): regional (Japan + Oceania)

OTHER RELEVANT FACTS:

AIS-140 standard (2019): mandates NavIC in all commercial vehicles in India for real-time tracking

Qualcomm Snapdragon: first chipmaker to support NavIC (2019)

Apple iPhone 15 Pro / Pro Max (September 2023): first iPhones with NavIC support (standard iPhone 15 does NOT support NavIC)

NavIC fishermen devices: ISRO/Department of Fisheries distribute to coastal fishing communities

NavIC strategic value: functions **independently of GPS** — ensures navigation during conflict/GPS denial scenarios

Sources: ISRO , Department of Space , PIB , GPS World

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