

## Machine-Based Navigation Accuracy Table

This document summarizes the evolution of machine-based navigation systems, their accuracy, methods, and reliability across different eras—from early mechanical devices like the Antikythera Mechanism, to modern digital and space-based systems.

Navigation System / Device	Era / Date	Accuracy (Range / Precision)	Method Used	Notes on Reliability & Errors
Antikythera Mechanism	~100 BCE (Ancient Greece)	Days–weeks (planetary & lunar cycles)	Mechanical gears + cosmic cycles	Remarkably advanced; required manual calibration; accuracy degraded without adjustments.
Magnetic Compass	~1100s CE (China → global by 1200s–1300s)	5–15°	Earth’s magnetic field	Simple, reliable; subject to local magnetic anomalies and variation.
Marine Chronometer	1700s CE (Harrison, 1760s)	≈0.1 s/day drift → ~2 nautical miles	Precision clock + celestial navigation	Solved the 'longitude problem'; accuracy limited by mechanical drift and sea conditions.
Sextant	1700s CE – present	1–2 nautical miles	Stellar / solar angular measurement	Depends on operator skill, clear skies, horizon visibility.
Gyroscopic Compass	Early 1900s CE (~1908 Sperry)	0.1–0.5°	Gyroscopic inertia	Independent of magnetism; drift accumulates over time, needs correction.
Inertial Navigation System (INS)	1950s CE – present	0.6–1.8 nm/hour drift (unaided)	Accelerometers + gyroscopes	Highly precise short-term; drifts without GPS/stellar updates.
LORAN (Long Range Navigation)	1940s (WWII) – 2000s (retired in most regions)	0.25–0.5 nautical miles	Radio signal timing	Widely used before GPS; limited by signal range and station geometry.

GPS (Global Positioning System)	First launch 1978; fully operational 1995 – present	3–10 m (civilian); <1 m (military/augmented)	Satellite signals + atomic clocks	Highly accurate, but vulnerable to jamming/spoofing; backbone of global navigation.
Atomic Clock Navigation	1960s CE – present	Nanosecond precision (~30 cm spatial)	Atomic resonance timing	Foundation of GPS and deep-space navigation; highly reliable.
AI / Quantum Navigation	2020s – emerging	Predicted <1 cm	Quantum sensors, AI-enhanced INS, cosmic background mapping	Still experimental; could bypass GPS dependency; potential for deep-space resilience.