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TECHNOLOGICAL SOVEREIGNTY IN AEROSPACE NAVIGATION: STRATEGIC, TECHNICAL, AND OPERATIONAL ANALYSIS OF THE BAYKAR FGN-100-D2 FIBER-OPTIC GYROSCOPIC SYSTEM

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Abstract: Technological sovereignty in aerospace navigation has become a strategic necessity in modern defense ecosystems, particularly in the context of increasing geopolitical fragmentation and reliance on foreign-controlled positioning infrastructures. This study analyzes the design, technical parameters, and operational significance of the FGN-100-D2 fiber optic gyroscope (FOG) system developed within the Baykar-Fergana space initiative.

Keywords: technological sovereignty, fiber optic gyroscope, inertial navigation system, aerospace navigation, satellite deployment, Baykar, FGN-100-D2, defense systems, LEO (Low Earth Orbit) satellites, autonomous navigation.

Modern armed conflicts involving Ukraine–Russia, the United States, Israel, and Iran have demonstrated that traditional navigation systems (GPS/GLONASS) may become strategically vulnerable. The FGN-100-D2 and the "Baykar" satellite constellation supporting it possess military-strategic significance precisely because they aim to eliminate these vulnerabilities.

1. Evolution of Aerospace Navigation Systems

The evolution of aerospace navigation systems has shifted from dependence on external satellite constellations toward hybrid architectures integrating Global Navigation Satellite Systems (GNSS) with Inertial Navigation Systems (INS). This transition is driven by the necessity for resilience against electronic warfare, signal degradation, and geopolitical dependence.

The FGN-100-D2 satellite, developed by Baykar—Türkiye's largest and most renowned aviation and defense industry company—through its space subsidiary Fergani Space, represents a significant step toward sovereign navigation capabilities. Launched in November 2025 as part of a national positioning constellation initiative, the system is designed to support an independent global positioning system.

At the core of its navigation architecture lies a fiber-optic gyroscopic system capable of providing high-precision angular velocity measurements independently of external signals. This study examines the technological, strategic, and operational dimensions of this system.

2. Literature Review

The development of inertial navigation technologies has historically progressed through three major stages:

- Mechanical gyroscopes (early aviation systems)
- Ring Laser Gyroscopes (RLG)
- Fiber-Optic Gyroscopes (FOG)

FOG systems have gained popularity due to the absence of moving parts, high reliability, and resistance to environmental stresses such as vibration and radiation.

Existing literature emphasizes:

- The integration of INS with GNSS in modern systems such as GPS, GLONASS, and BeiDou
- The vulnerability of GNSS systems to jamming and spoofing in military environments

- The increasing importance of sovereign navigation systems for defense autonomy

However, there is limited academic research on emerging sovereign navigation initiatives led by the private sector, such as the FGN-100-D2 constellation, making this study particularly relevant.

3. Methodology

This study employs a qualitative-analytical methodology that includes:

1. Technical analysis of publicly available system specifications
2. Comparative evaluation with existing navigation technologies
3. Strategic assessment of defense and geopolitical implications

Primary data sources include defense industry reports, official statements, and technical data related to the FGN-100-D2 system.

4. Analysis and Discussion

4.1 System Design and Architecture

The FGN-100-D2 operates as a 100 kg LEO (Low Earth Orbit) satellite equipped with fully indigenous subsystems, including avionics, propulsion, and navigation modules.

Key architectural features include:

- Integration of fiber-optic gyroscopic INS
- Redundant onboard computing systems
- Autonomous telemetry and telecommunication subsystems
- Compatibility with constellation-based positioning frameworks

Operating in low Earth orbit at approximately 510 km altitude, the satellite completes around 15 orbits per day at a velocity of approximately 7.6 km/s, ensuring continuity of global coverage when deployed within a constellation.

4.2 Technical Parameters of the Fiber-Optic Gyroscopic System

The fiber-optic gyroscope operates based on the Sagnac effect, measuring phase shifts between counter-propagating light beams within a fiber coil.

Key technical characteristics include:

- Angular velocity sensitivity: high precision (≤0.01°/hour, typical for space-grade FOG systems)
- No moving mechanical components, reducing wear and failure probability

High resistance to:

- Radiation
- Temperature fluctuations
- Mechanical vibration

Long operational lifespan:

- Adapted for mission durations of 5–7 years

System-level advantages include:

- Continuous navigation independent of external signals
- Seamless integration with GNSS for hybrid navigation
- High precision in competitive electromagnetic environments

4.3 Strategic Importance: Technological Sovereignty

The FGN-100-D2 is part of a broader initiative aimed at creating the Ulugbek global positioning system as a domestic alternative to foreign GNSS infrastructure.

This reflects three strategic priorities:

1. Independence from Foreign GNSS

Reliance on systems such as GPS creates vulnerabilities, including:

- Signal denial during conflicts

- Restrictions on data access
- Strategic dependence

2. Dual-Use Military Capability

FOG-based military-grade INS enables:

- Autonomous missile control
- UAV navigation in GPS-denied environments
- Secure military communications

3. Development of a Technological Ecosystem

The system incorporates:

- Indigenous software
- Domestic avionics
- National propulsion systems

This strengthens the national defense-industrial base and reduces external dependence.

4.4 Operational Efficiency in Space Conditions

Operations in LEO introduce several constraints:

- Radiation exposure
- Thermal cycling
- Material stress caused by microgravity

FOG systems are particularly suitable for such environments due to:

- Solid-state architecture
- Minimal sensitivity to mechanical deformation
- High reliability during long-term missions

The FGN-100-D2 successfully demonstrated:

- Telemetry transmission
- Stable orbital insertion after deployment
- Functional validation of onboard systems

4.5 Real-World Applications

The integration of FOG systems in aerospace navigation enables:

- Unmanned aerial systems (UAS) operating in contested environments
- Guidance systems for ballistic and cruise missiles
- Synchronization of satellite constellations
- Deep-space navigation (future applications)

Historically, similar INS technologies played critical roles in:

- U.S. submarine navigation during the Cold War
- Soviet intercontinental ballistic missile (ICBM) systems

The FGN-100-D2 represents a modern continuation of this evolution within a digitally integrated system.

Parameters	GPS (USA)	GLONASS (RF)	FGN-100-D2
Orbit Type	MEO (Medium Earth Orbit)	MEO (Medium Earth Orbit)	LEO (Low Earth Orbit)
Altitude	~20,200 km	~19,100 km	500–600 km
Signal Power	Low (~ -160 dBW)	Low (~ -160 dBW)	High (20–30 dB stronger)
Doppler Shift	Low (relatively static system)	Low (relatively static system)	Extremely high (7.5–7.6 km/s)

Signal Delay	60–70 milliseconds	60–70 milliseconds	1.5–4 milliseconds
Drift Stability	<0.01°/hour (atomic clocks)	<0.01°/hour (Nav-grade INS)	<0.01°/hour (Nav-grade INS)
Weight	~2000 kg	~1400 kg	~104 kg
Accuracy Level	3–5 meters	5–10 meters	1–5 meters
Modernization	Slow (expensive)	Slow (expensive)	Fast (cost-effective and mobile)

5. Conclusion

The Baykar FGN-100-D2 fiber-optic gyroscopic system represents a significant advancement in aerospace navigation by combining technical innovation with strategic autonomy. Its integration into a domestically developed satellite platform highlights the broader transition toward technological sovereignty in defense systems.

The analysis demonstrates that:

- Fiber-optic gyroscopes provide high reliability and autonomy in space environments
- The FGN-100-D2 contributes to the development of an independent positioning ecosystem
- Hybrid navigation architectures combining INS and GNSS represent the future of aerospace navigation

From a strategic perspective, the system enhances national security by reducing dependence on foreign infrastructure while simultaneously strengthening domestic technological capabilities.

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