

# GNSS Radio Frequency Interference in the Eastern Kinshasa FIR: Safety Impacts, Regulatory Gaps, and a Resilience Framework for Civil Aviation in the Democratic Republic of the Congo

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**ABSTRACT:** Global Navigation Satellite System (GNSS) radio frequency interference (RFI) has become a growing operational threat to civil aviation, especially in and around conflict-affected regions. This article develops a publication-ready case study of the Democratic Republic of the Congo (DRC), focusing on repeated GNSS jamming and spoofing events reported in the eastern portion of the Kinshasa Flight Information Region (FIR) between May 2024 and January 2025. The study is based on a structured documentary analysis of the DRC national presentation delivered during the ACAO/ICAO Radio Navigation Workshop in Rabat in February 2025, complemented by current ICAO, ITU, EASA, and IATA guidance and policy documents. The findings show that the affected areas - notably Goma, Butembo, Beni, and Lubero - experienced recurrent signal loss from the surface up to at least FL210, affecting multiple aircraft categories, including transport aircraft, regional aircraft, unmanned aircraft, United Nations flights, and military flights. Operational effects included re-routing, visual continuations, temporary suspension of GNSS-based instrument flight procedures and drone operations, elevated operator risk assessments under safety management systems, and rising economic and passenger-service burdens. The article argues that the DRC case is significant because it illustrates the asymmetry between rapidly increasing dependence on satellite-based CNS and the limited enforceability of civil aviation rules when military or extraterritorial interference is involved. It proposes a resilience framework built on five pillars: threat monitoring, risk assessment, contingency navigation, civil-military coordination, and harmonized reporting. The article concludes that States exposed to conflict-proximate interference should preserve a minimum operational network of conventional navigation aids, standardize GNSS RFI NOTAM practices, integrate spectrum regulators into aviation safety governance, and strengthen regional escalation mechanisms through ICAO and ITU.

**KEYWORDS:** GNSS; radio frequency interference; jamming; spoofing; air navigation safety; Kinshasa FIR; Democratic Republic of the Congo; CNS resilience.

## 1 INTRODUCTION

GNSS has become deeply embedded in modern civil aviation. It supports area navigation, performance-based navigation, surveillance, time synchronization, aircraft situational awareness, and an increasing number of airport and unmanned aircraft operations. ICAO has warned that GNSS jamming and possible spoofing have intensified in areas surrounding conflict zones and that the resulting degradation can adversely affect air traffic management (ATM) and air traffic control (ATC) operations. ICAO's mitigation approach, embedded in the GNSS Manual, is based on a continuous cycle of threat monitoring, risk assessment, and deployment of mitigation measures. This issue is no longer theoretical: operational agencies and international regulators are now treating GNSS RFI as a systemic resilience problem rather than an isolated technical anomaly.

The international concern has sharpened further since 2024. EASA has reported that jamming and spoofing events have increased in severity, intensity, and sophistication, especially near conflict zones. In 2025, ITU, ICAO, and IMO jointly warned that harmful interference in the form of jamming and spoofing is increasing and called on Member States to protect the radio

navigation satellite service, reinforce resilience, retain conventional navigation infrastructure for contingency support, and improve cross-sector coordination. EASA and IATA also stated in 2025 that GPS signal loss events increased by 220% between 2021 and 2024 according to IATA data. Together, these developments confirm that GNSS RFI is a global operational hazard with direct local consequences for States whose airspace lies close to insecurity or military activity.

The DRC provides an important case study because the eastern part of the Kinshasa FIR has recently experienced repeated GNSS interference events affecting flight operations in and around Goma and adjacent sectors. The national presentation submitted by the DRC to the ACAO/ICAO Radio Navigation Workshop framed the issue as an operational safety challenge linked to military activity outside national borders and highlighted the difficulty of protecting civil aviation when interference originates beyond the effective reach of the affected ANSP. The presentation recorded incidents from May 2024 through January 2025, the affected aircraft types, flight levels, operational consequences, mitigation measures already implemented, and the challenges encountered by the DRC authorities. These elements make the DRC case suitable for an analytically grounded case study that can inform international discussions on aviation resilience in Africa and other exposed regions.

This article has three objectives. First, it documents the pattern and operational consequences of GNSS RFI incidents reported in the eastern Kinshasa FIR. Second, it analyses the case through contemporary international regulatory and safety guidance. Third, it proposes a practical resilience framework for States and ANSPs facing recurrent GNSS disruption in conflict-proximate airspace.

## **2 MATERIALS AND METHODS**

The study uses qualitative documentary analysis. The primary case source is the DRC presentation entitled 'GNSS RFI Experienced in the Democratic Republic of the Congo and its Impact on Safety of Civil Air Navigation,' presented at the ACAO/ICAO Radio Navigation Workshop held in Rabat, Morocco, 24-26 February 2025. The presentation provides the chronology of incidents, affected areas, aircraft categories, altitude bands, identified consequences, and mitigation steps already taken. To strengthen interpretation, the article cross-references this case material with current primary or quasi-primary sources: ICAO working papers and conference outputs on GNSS interference, the Convention on International Civil Aviation, ITU statements on harmful interference, EASA safety information, and IATA/EASA mitigation communications. The analysis is therefore interpretive rather than statistical. It does not claim access to raw flight data recorder files, radar tracks, or confidential operator safety reports. Instead, it aims to convert an operational presentation into a structured scientific article suitable for academic and policy readership.

## **3 REGULATORY AND CONCEPTUAL FRAMEWORK**

The legal and institutional framework relevant to the DRC case is multi-layered. At national level, radiofrequency spectrum management is framed by DRC Law No. 20/017 of 25 November 2020 on telecommunications and information and communication technologies, while ARPTC acts as the national telecommunications regulator. The DRC presentation also notes the existence of an ARPTC-CAA memorandum of understanding for coordination. At international level, the ITU Radio Regulations require stations to be established and operated so as not to cause harmful interference and recognize that safety-related radionavigation services require special protection. ICAO Annex 10 and the GNSS Manual provide the aviation-specific framework for preserving operational continuity and mitigating interference. However, the DRC case also highlights an institutional limitation: under Article 3 of the Chicago Convention, the Convention applies only to civil aircraft, while military, customs, and police aircraft are deemed to be State aircraft. This does not remove the obligation to have due regard for civil aviation safety, but it complicates the enforceability of purely civil mechanisms when defense-related emitters are involved. The result is a governance gap between spectrum protection norms and operational enforcement in conflict-linked environments.

## **4 RESULTS: PATTERN OF GNSS RFI IN THE EASTERN KINSHASA FIR**

According to the DRC presentation, the first detection of GNSS RFI in the country was reported through an official release dated 29 May 2024 by the Head of the Aviation Safety Department of MONUSCO. The presentation states that the event involved GPS jamming detected by a crew at 12,500 feet, on heading 330°, at 26 NM from Goma airport, and that many cases of GPS spoofing were later observed. Following investigation by ARPTC, the source of the interference was reportedly determined to be outside DRC national borders and linked to military activity. This is a crucial feature of the case because it

transforms the problem from a purely domestic spectrum-management issue into a transboundary air navigation resilience issue.

The initial phase of reported incidents covered May to July 2024. The affected areas included Goma, Butembo, Beni, and Lubero. Aircraft types mentioned in the presentation include B737, ATR72, unmanned aircraft, Do228, F50, and B762, including United Nations and military flights. Signal loss was observed mainly between FL65 and FL180. Operationally, the presentation reports effects on navigation and landings, including re-routings, with several incidents occurring early in the morning. After a relative break in August, jamming resumed in December 2024 and continued into January 2025. On 22 December 2024, signal losses were reported en route about 75 NM from Goma and inside the Goma control zone, affecting aircraft such as a B767, Let410, AT72, and D228, with some crews continuing visually. On 26 December 2024, additional aircraft were affected in the Goma TMA at different altitudes. On 27 December 2024, two aircraft lost signal in Beni at FL170 and FL190, while another aircraft was affected near IPULI at FL180 and between BKV and ZIRUD at FL210. On 3 January 2025, jamming was reported on the ground in Goma, and on 4 January 2025 multiple aircraft were reportedly affected from the surface up to FL160, including spoofing cases. The reported vertical extent from the ground to FL210 indicates that the phenomenon was not limited to a narrow altitude layer and had the potential to affect both arrival/departure and en-route phases.

The operational consequences described by the DRC are consistent with international safety warnings on GNSS disruption. The presentation reports increased safety risk in the affected area, temporary suspension of GNSS-based instrument flight procedures and drone operations, lost aircraft in the airspace, cancelled, delayed or deviated flights, and situations in which some flights shifted from IFR to VFR. Additional impacts included extra expenses for operators and disruption for passengers. From a systems perspective, these effects can be grouped into four categories. First, there are direct navigation impacts: degraded position awareness, loss of lateral guidance integrity, reduced confidence in avionics outputs, and greater ATC workload. Second, there are procedural impacts: cancellation of GNSS-dependent procedures, increased use of visual continuation or reversionary techniques, and operational restrictions on UAV activity. Third, there are capacity impacts: re-routings, spacing penalties, and reduced predictability of arrivals and departures. Fourth, there are socio-economic impacts: costs of delays, diversions, fuel burn, crew disruption, passenger dissatisfaction, and the reputational risk of a corridor perceived as operationally fragile.

**Table 1. Summary of reported GNSS RFI events and operational effects in the DRC case**

Period / Date	Area	Reported effect	Operational significance
29 May 2024 (first detection)	Near Goma	GPS jamming reported by crew at 12,500 ft, 26 NM from Goma; later spoofing cases noted	Initial operational detection of a transboundary safety problem
May-Jul 2024	Goma, Butembo, Beni, Lubero	Signal loss mainly between FL65 and FL180 affecting B737, ATR72, UAV, Do228, F50, B762, UN and military flights	Demonstrates multi-aircraft, multi-sector exposure
22 Dec 2024	En route 75 NM from Goma and Goma CTR	B767, Let410, AT72, D228 affected; some continued visually	Shows impact on both en-route and terminal operations
26 Dec 2024	Goma TMA	Additional aircraft affected at different altitudes	Suggests persistence of the hazard in terminal airspace
27 Dec 2024	Beni / IPULI / BKV-ZIRUD	Aircraft affected at FL170, FL180, FL190 and FL210	Confirms extended vertical and route-level exposure
3-4 Jan 2025	Goma, including ground operations	Jamming on the ground; multiple aircraft affected from surface to FL160; spoofing cases reported	Indicates that the hazard can disrupt the full operation chain from surface to airborne phases

## **5 DISCUSSION**

The DRC case confirms three broader analytical points. The first is that GNSS dependence creates asymmetric vulnerability. The more ANSPs and operators modernize around satellite-based CNS and PBN, the more they gain efficiency under normal conditions, but the greater the operational disruption when GNSS becomes unavailable or misleading. This does not mean modernization is mistaken. It means modernization must be accompanied by resilience planning. ICAO and the 2025 joint ITU-ICAO-IMO statement explicitly recognize this by calling for the retention of sufficient conventional navigation infrastructure and the development of mitigation techniques for outages and misleading signals. In the DRC case, the challenge is heightened by terrain and meteorological realities in the Goma area, where scarce VMC conditions, mountains, and Lake Kivu constrain purely visual fallback options.

The second point is that transboundary and conflict-linked interference cannot be handled adequately by the aviation authority alone. In the DRC presentation, the source was reported as being outside national territory. That finding immediately places the issue at the interface of aviation safety governance, telecommunications regulation, diplomacy, and security coordination. ITU emphasizes that Member States must prevent harmful interference and act when harmful interference affecting safety services is brought to their attention. ICAO Assembly policy likewise urges close collaboration among aviation authorities, military authorities, service providers, radio regulators, and spectrum-enforcement authorities, and calls on States to refrain from jamming or spoofing affecting civil aviation. Therefore, the relevant institutional response is not merely technical troubleshooting by the ANSP; it is multi-agency governance with international escalation mechanisms.

The third point is that reporting and notification remain weak links in global resilience. ICAO's 2025 recommendations note the absence of standardized NOTAM coding for GNSS RFI and the practical difficulty faced by operators when different States use different Q-codes and free-text expressions. This matters in the DRC case because timely, unambiguous operational awareness is essential for dispatch, route planning, ATC contingency management, and pilot decision-making. The DRC authorities issued NOTAMs and airlines activated SMS GO/NO-GO procedures for Goma, which were appropriate reactive steps. Yet the broader lesson is that inconsistent reporting taxonomies reduce the usefulness of otherwise correct warnings. Harmonized terminology - for example distinguishing 'GNSS may be unreliable' from 'GNSS may be misleading' - is operationally important because spoofing can present more severe consequences than simple loss of signal.

## **6 PROPOSED RESILIENCE FRAMEWORK**

Based on the DRC case and current international guidance, this article proposes a five-pillar resilience framework for conflict-proximate GNSS environments. Pillar 1 is threat monitoring. States should establish a recurrent process for collecting pilot reports, operator reports, ATC observations, maintenance findings, and regulator spectrum analyses in a common operational picture. Pillar 2 is risk assessment. Incident zones should be mapped by phase of flight, altitude band, severity, and probability, with explicit links to safety management systems, dispatch procedures, and aerodrome accessibility criteria. Pillar 3 is contingency navigation. ANSPs should preserve a minimum operational network of conventional navigation aids, maintain timely flight inspection, validate reversionary procedures, and ensure controller and pilot training for operations under GNSS degradation. Pillar 4 is civil-military and cross-sector coordination. Aviation authorities, spectrum regulators, defense actors, and foreign affairs institutions should share protocols for notification, deconfliction, escalation, and post-incident investigation. Pillar 5 is harmonized reporting and international escalation. GNSS RFI NOTAM practices should follow evolving ICAO guidance, and cases with international significance should be reported through the appropriate ICAO-ITU channels to support analysis, attribution, and diplomatic action.

Pillar	Core operational content
1. Threat monitoring	Integrate pilot reports, operator reports, ATC observations, NOTAM review, and telecommunications regulator analyses in one operational picture.
2. Risk assessment	Map exposure by route, phase of flight, altitude band, terrain, weather fallback, and procedure dependency; link outputs to SMS decisions.
3. Contingency navigation	Preserve and inspect conventional aids, validate reversion procedures, and train crews/controllers for GNSS-unreliable and GNSS-misleading scenarios.
4. Cross-sector coordination	Institutionalize coordination among ANSP, CAA, spectrum regulator, defense actors, foreign affairs bodies, and neighboring States.
5. Harmonized reporting	Standardize NOTAM language and escalate internationally significant events through ICAO/ITU mechanisms.

**7 POLICY IMPLICATIONS FOR THE DRC AND SIMILAR STATES**

For the DRC specifically, several practical priorities emerge. First, the eastern Kinshasa FIR should be treated as a persistent vulnerability zone, not as a temporary anomaly. Second, conventional aid resilience around Goma and adjacent corridors requires renewed attention, including regular flight inspection of VOR/DME and ILS where applicable, because deferred maintenance of terrestrial aids increases strategic dependence on the very systems most exposed to disruption. Third, operator and ATC training should include spoofing recognition and operational cross-checking, since misleading position information may be more dangerous than complete signal loss. Fourth, national procedures should institutionalize coordination between RVA, the CAA, ARPTC, security actors, and neighboring States when cross-border attribution is suspected. Fifth, the DRC should continue using ICAO regional and headquarters channels to push for stronger international norms concerning the protection of RNSS near international air routes and airports.

**8 LIMITATIONS**

This study has limitations. It relies primarily on a national technical presentation rather than a full anonymized safety database. Incident counts, durations, and exact geographic footprints could not be independently validated from raw surveillance or avionics records. The analysis is therefore best read as an evidence-informed case study, not as a definitive statistical measurement of interference intensity. Nevertheless, the consistency between the DRC account and current ICAO, ITU, EASA, and IATA warnings strengthens the plausibility and relevance of the findings.

**9 CONCLUSION**

GNSS RFI in the eastern Kinshasa FIR is a concrete safety and resilience challenge with implications that extend beyond the DRC. The reported sequence of jamming and spoofing events between May 2024 and January 2025 demonstrates how rapidly a localized signal problem can cascade into navigation uncertainty, procedural restrictions, delays, diversions, and wider confidence costs for civil aviation. The case also shows that States close to conflict zones face a double vulnerability: strong operational dependence on satellite-based CNS and weak direct control over extraterritorial or military sources of interference. In this context, the appropriate strategy is not to retreat from modernization but to modernize with resilience. That means monitoring threats continuously, assessing risk explicitly, retaining contingency navigation capability, coordinating across sectors, and improving the quality of operational reporting and international escalation. The DRC case should therefore be understood not only as a national incident record, but as an instructive African case study for the global debate on secure and resilient air navigation in the age of pervasive GNSS dependence.

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This manuscript was developed from the DRC presentation prepared by Billy DIABASENGA for the ACAO/ICAO Radio Navigation Workshop in Rabat in February 2025 and expands that operational material into an academic case study format.

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