# GPS L5 FREQUENCY INTERFERENCE

## URGENT REGULATORY ACTION REQUIRED

***Critical Infrastructure Conflict Threatening Aviation Safety***

CNS/SG14
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KAVEH PARTO/ IRAN

# Executive Summary

- 16 DME channels operate directly within GPS L5 protected spectrum (1164.45-1188.45 MHz)
- 487 DME facilities worldwide affected across all major aviation regions
- High-power terrestrial navigation aids effectively jamming next-generation satellite signals
- **Power disparity: DME signals 10^13 (130 dB) stronger than GPS L5**
- Threatens entire GPS modernization program and safety-of-life applications
- Requires immediate coordinated international action

**URGENT: Window for proactive resolution is rapidly closing**

# The Problem: Frequency Overlap

## GPS L5 Signal Spectrum

- Center Frequency: 1176.45 MHz
- Bandwidth: ±12 MHz
- Protected Band: 1164.45-1188.45 MHz
- ITU-designated for ARNS
- Designed for safety-of-life operations

## DME Conflicting Channels

- Channels 60X-75X: 1173-1188 MHz
- 16 channels in GPS L5 band
- **Channel 63X (1176 MHz): Only 0.45 MHz offset**
- Channel 64X (1177 MHz): IKIA case
- 487 facilities globally on these channels

**CRITICAL: Fundamental incompatibility - not a simple coexistence issue**

# FUNDAMENTAL REGULATORY CONTRADICTION

## ICAO Annex 10 Volume I Contains Conflicting Standards:

Chapter 3.7.3.1.1.8.3 (GPS L5):"L5 signal power shall be contained within ±12 MHz bands centred on 1176.45 MHz: 1164.45-1188.45 MHz"VERSUSChapter 3.5, Table A (DME):Authorizes 16 channels (60X-75X) operating at 1173-1188 MHz.

## RESULT

Same ICAO standard both:
✓ Protects 1164.45-1188.45 MHz for GPS L5 (Chapter 3.7)
✗ Authorizes DME in 1173-1188 MHz (Chapter 3.5)
Most Critical:
DME Channel 63X (1176 MHz) is only 0.45 MHz from GPS L5 carrier defined in paragraph 3.7.3.1.1.8.2

**This is not operational incompatibility - this is a regulatory gap within ICAO's own standards requiring immediate amendment**

# Technical Background: GPS L5 Signal

## Key Technical Specifications

- Carrier Frequency: 1176.45 MHz (L5 band)
- Minimum Received Power: -157.9 dBW at Earth's surface
- Signal Power: 3 dB stronger than L1/L2 legacy signals
- Bandwidth: 24 MHz (±12 MHz from carrier)
- Chipping Rate: 10.23 Mcps (10× faster than C/A code)
- Dual-Channel Architecture: I5 (data) + Q5 (pilot channel)
- Forward Error Correction: Enhanced robustness
- **Design Intent: Safety-of-life aviation operations**

# Technical Background: DME System

## Pulse Pair Characteristics

- Pulse interval: 12 µs
- Pulse width: 3.5 µs (half-amplitude)
- Rise time: < 3 µs
- **Peak power: 50W to 1000W**
- Rate: Up to 2700 pulse pairs/second
- Duty cycle: 4.32% (at peak)
- Location: Ground-based transponders

## Antenna Pattern

- Peak Gain: +9.5 dBi
- Maximum at 4° elevation
- 3 dB beamwidth: 6° elevation
- Omnidirectional in azimuth
- Vertical linear polarization

# Signal Power Disparity: The Core Problem

## Power Level Comparison


- **Power Difference: ~117 dB (Factor of 10^13)**
- Result: Receiver AGC desensitization
- GPS L5 signal buried below receiver sensitivity
- Complete loss of tracking in strong DME environments

# Case Study:
# Imam Khomeini International Airport

## Investigation (Jan-Mar 2024)

- Authority: Iran CAOPurpose: GBAS certificationEquipment: R&S FSW43 analyzerMethod: Systematic facility shutdown & signal correlation

## Findings

- Interference: 1177 MHzPower: -65 to -42 dBm**Threshold exceeded: -111 dBm**Source: DVOR/DME Channel 64X

## References

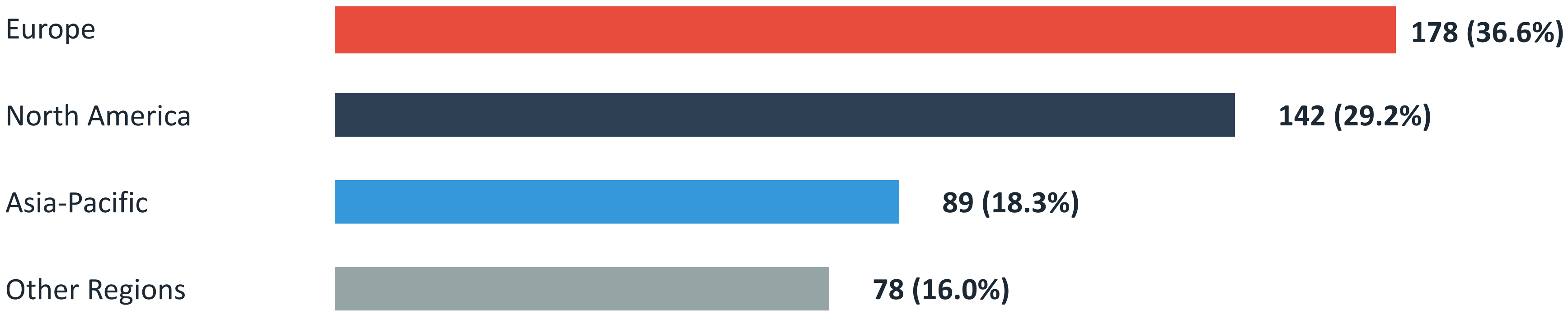
- RTCA DO-229E: GPS/SBAS MOPSICAO Annex 10 Vol I Chapter 3.5Working Paper Section 3.1

### Key Finding:

Definitive identification of DME as interference source through controlled testing methodology

# Global Distribution of Affected DME Facilities

## 487 Facilities Operating on Conflicting Channels (60X-75X)




- Major hubs affected where GPS L5 benefits most critical
- Multiple overlapping interference zones in metro airspace
- Recent infrastructure investments require premature replacement

# Interference Mitigation: Current Limitations

## Pulse Blanking

**Advantages:**

- Simple implementation
- Fast processing

**Limitations:**

- Removes GPS + DME
- 20-40% accuracy loss
- Leaves pulse tails

## Notch Filtering

**Advantages:**

- Filters frequency channels
- Better than blanking

**Limitations:**

- Removes GPS at DME freq
- Still lossy

## Hybrid Method

**Advantages:**

- Time + freq domain
- Preserves more data

**Limitations:**

- Complex
- Still causes data loss

**All traditional methods eliminate interference by removing data → GPS signal loss**

# Advanced Mitigation: Nonlinear Least Squares (NLS) Method

## Novel Approach: Reconstruct & Subtract

- Treats DME as 'signal of interest'
- Estimates parameters under NLS criterion:
  - Doppler frequency shift - Complex amplitude
- Reconstructs DME signal from parameters
- Subtracts estimated interference

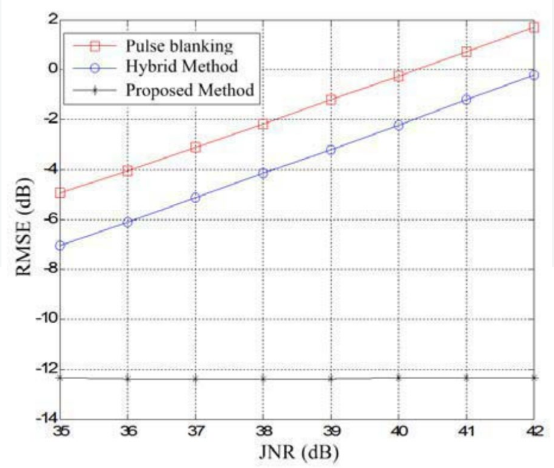
**Result: Preserves more GPS data**

## Performance Advantage

Lower RMSE than traditional methods across all JNR levels

Significantly outperforms:

- Pulse blanking
- Notch filtering
- Hybrid methods




**✓ Maintains useful satellite data → Better receiver performance**

# Impact on Aviation Modernization Programs

## PBN Initiatives

- RNP AR approaches with vertical guidance compromised
- Trajectory-based operations require reliable dual-freq

## GBAS CAT II/III Operations

- Precision autoland systems degraded
- Ionospheric correction unavailable

## A-SMGCS Low-Visibility Operations

- Surface navigation unreliable at DME-equipped airports
- Enhanced multipath mitigation unavailable

**Investment at Risk: Billions in GPS L5 infrastructure and avionics**

# Safety Implications

## Near-Term Risks

- Inconsistent L5 performance creates operational confusion
- No DME interference warnings in current receivers
- Pilot training assumes reliable dual-frequency
- Intermittent interference creates unpredictable performance

## Long-Term Strategic Risks

- 2040 traffic doubling requires enhanced navigation
- Autonomous aircraft depend on multi-frequency GNSS
- Urban air mobility safety case compromised
- Global harmonization requirements

## Critical Operational Scenarios

- CAT II/III approaches: Require stringent accuracy/integrity - DME interference forces single-freq with reduced integrity
- RNP AR procedures: Integrity alerts may force missed approaches, negating PBN benefits
- Low-visibility surface ops: Enhanced multipath mitigation unavailable where most needed

# Economic Analysis

## Resolution Costs

**Global total: $2.5-3.0 billion**

- Equipment procurement: $1.2B
- Installation & commissioning: $400M
- Flight inspection: $150M
- Procedures & databases: $100M
- Management & oversight: $650M

## Opportunity Costs

**GPS L5 investments: $10B+**

- L5-capable avionics: $3B unrealized
- Annual DME maintenance: $30M (487 facilities)

- Efficiency benefits:
- • Reduced flight distances
- • Decreased weather delays
- • Fuel savings

**Net Present Value: Strongly Positive**
**Benefit-Cost Ratio: >5:1 over 20 years**

# Case Studies: Success Stories

## Germany DME Rationalization

- Timeline: 2015-2020 (5 years)
- Decommissioned: 23 DME facilities
- Conflicting channels: 3 facilities

**Result: Confirmed GPS L5 quality improvement**

- Approach: Extensive stakeholder consultation, alternative procedures, phased transition

## Singapore 'GNSS-First' Policy

- Implemented: 2018
- Decommissioned: 4 DME facilities
- Conflicting channels: 2 facilities
- Strategy: Prioritize satellite navigation with minimal ground backup

**Leadership: Strong regulatory mandate + equipage requirements**

Key Lessons:

❑ Long-term planning essential
❑ Stakeholder engagement critical
❑ Leadership drives success

# Recommended Actions: Immediate (0-6 months)

**ICAO State Letter acknowledging DME-GPS L5 incompatibility**

- Freeze new DME installations on channels 60X-75X
- Directive to States: Begin planning for transition

**Publish Interim Operational Mitigations**

- AIPs/NOTAMs: Identify areas with GPS L5 limitations
- Update flight operations manuals and training

**Technical Requirements**

- Mandate DME interference detection in new L5 receivers
- Real-time crew alerting for signal degradation

**State Infrastructure Surveys**

- Identify all facilities on conflicting channels
- Assess operational criticality and develop cost estimates

# Recommended Actions: Short-Term (6-24 months)

## Establish GPS L5 Protection Task Force

- Navigation Systems Panel + GNSS Panel + Frequency Spectrum Management Panel
- Develop comprehensive SARP for DME transition

## Develop New DME Channel Allocations

- Coordinate with ITU for frequencies outside GPS L5 spectrum
- Consider Galileo E5a/b and BeiDou B2a protection

## Priority Channel Relocation: 63X and 64X

- Most critical due to proximity to L5 carrier (1176 MHz)
- Leading states commit to 24-month transition

## Establish Global Navigation Transition Fund

- Initial capitalization: $500M minimum
- Assist developing nations with transition costs

# Recommended Actions: Long-Term (2-5 years)

### Complete Global DME Transition

- All 487 facilities relocated off conflicting channels
- Coordinated regional implementation
- Maintain operational safety throughout transition

### Establish Protected GNSS Frequency Bands

- Prevent future conflicts with new systems
- Proactive spectrum protection philosophy

### New ICAO Standards

- GNSS-DME compatibility testing procedures
- Interference monitoring networks
- Enforcement mechanisms for frequency compliance

### Integration with PBN Modernization

- Align DME transition with broader navigation infrastructure evolution

# Implementation Timeline Overview

**Phase 1: Foundation (0-12 months)**

- Task force
- Surveys
- Interim mitigations
- Draft standards

**Phase 2: Priority (13-36 months)**

- Channels 63X/64X
- 100+ facilities
- Fund establishment
- Regional plans

**Phase 3: Global (37-60 months)**

- All facilities
- Monitoring
- Validation
- FOC declaration

**Success Metrics:**

- **99% L5 availability**
- **Improved approach minima**
- **Fuel savings**
- **Enhanced accuracy**

# Funding Mechanisms

**Innovative Financing Approaches**

## Global Navigation Transition Fund

- ICAO/regional organization administered
- State contributions + industry investments + development financing
- Cost-recovery model: Early adopters receive priority funding

## Public-Private Partnerships

- Private sector finances implementation for long-term contracts
- World Bank & regional development banks support

## Industry Contributions

- Temporary surcharge on L5-capable avionics sales

## Carbon Credit Mechanisms

- GPS L5 efficiency improvements reduce emissions
- Credits sold to offset implementation costs

# Cost Mitigation Strategies

- **~30% of facilities can be decommissioned without replacement**

- **Transition to RNAV procedures instead of DME**
  - VOR-only operations where appropriate
  - Potential savings: $500-700 million globally

- **Regional Bulk Procurement Programs**
  - 20-30% savings through economies of scale
  - Standardized transition packages eliminate redundant engineering

- **Phased Implementation**
  - Prioritize high-traffic areas for early benefits
  - Spread costs over extended periods for affordability

- **Network Optimization Studies**
  - Comprehensive analysis before replacement decisions

# Technical Standards Requirements

## Updated Receiver MOPS

RTCA DO-229F / EUROCAE ED-75E updates

- DME interference tolerance specifications
- Detection algorithms for pulse patterns
- Mandatory crew alerting requirements
- Certification test procedures
- Performance logging for monitoring

## DME Equipment Standards

- Improved spectral containment
  - Advanced pulse shaping & filtering
- Adaptive power control
  - Reduce power for nearby aircraft
- GPS-disciplined timing
  - Synchronized quiet periods
  - Network-wide coordination

## Integrated Navigation System Requirements

- Proper handling of degraded L5 signals in solution algorithms
- Specific DME interference pattern detection beyond traditional RAIM
- EMC testing at operational DME power levels

# Call to Action: What ICAO Must Do

## 1. FORMALLY ACKNOWLEDGE THE CRISIS

- Issue State Letter declaring DME-GPS L5 incompatibility
- Classify as URGENT - SAFETY CRITICAL issue

## 2. PROVIDE STRONG REGULATORY LEADERSHIP

- Establish GPS L5 Protection Task Force immediately
- Set clear requirements and enforceable timelines
- Drive international consensus and coordination

## 3. FACILITATE FUNDING MECHANISMS

- Establish Global Navigation Transition Fund
- Enable PPP models and development financing

## 4. DEVELOP NEW STANDARDS

- Updated receiver MOPS with DME interference tolerance
- DME frequency reallocation outside GNSS protected bands

# Call to Action: What States Must Do

## 1. ACCEPT INFRASTRUCTURE TRANSITION RESPONSIBILITY

- Acknowledge that DME facilities on channels 60X-75X must transition
- Allocate budget resources despite fiscal constraints

## 2. CONDUCT COMPREHENSIVE FACILITY SURVEYS

- Identify all DME installations on conflicting channels
- Assess operational criticality and alternatives
- Develop detailed cost estimates and transition plans

## 3. PRIORITIZE MOST CRITICAL FACILITIES

- Begin with channels 63X and 64X (closest to L5 carrier)
- Focus on major international hubs first

## 4. SHARE IMPLEMENTATION LESSONS

- Document transition process and outcomes
- Share best practices with international community

# The Choice Before Us

**PROACTIVE ACTION**

- Coordinated global transition
- Adequate resources and planning
- Realize GPS L5 benefits
- Enable aviation future

**CONTINUED INACTION**

- Degraded capabilities
- Increased safety risks
- Stranded investments
- Aviation growth constrained

# CONCLUSION

**The technical evidence is conclusive.**

**The solutions are defined.**

**The economic case is compelling.**

**What remains is the WILL TO ACT.**

**487 DME facilities worldwide threaten the GPS modernization program.**

**Every day of delay increases costs and risks.**

**ICAO leadership and State commitment are essential NOW.**

# DISCUSSION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# Key References

## Key Publications:

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- [30] Dekker (2011): Drift into Failure - Complex Systems

## Standards & Regulations:

- [8] ICAO Annex 10 Volume I: Aeronautical Telecommunications (Radio Navigation Aids)
- [4] GPS IS-GPS-705 Rev E: L5 Interface Specification
- [5] ITU Radio Regulations Article 5.328B: ARNS band allocation