Navaids Testing Risks and their Mitigation

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Disclaimer

- This paper and presentation are summaries of recent meetings and discussions involving many offices, companies, and organizations.
- The views expressed in this paper do not necessarily represent the views of the Federal Aviation Administration or the United States.

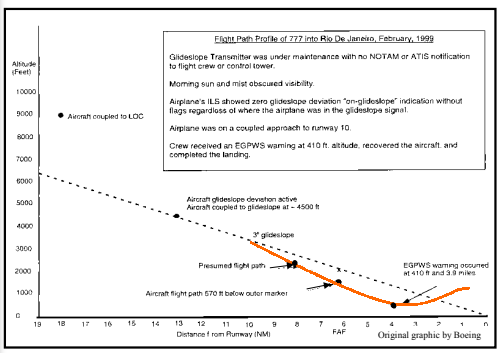
HMI

- Some ground and airborne testing activities on navaids temporarily cause the facility to radiate signals which are not, or may not be, safe to use.
- These signals are termed Hazardously Misleading Information **(HMI).**
- Since the testing is necessary, procedural means are required to ensure users do not rely on the signals.
  - NOTAMs
  - ATIS if present
  - Morse identification off

First Documented NCFIT Event

- Aircraft have apparently coupled to, or used, navaid signals which:
  - Should have been unusable, and…
  - Also were deceptive.
- These events are called Near Controlled Flight into Terrain **(NCFIT)**
- First known case -- Rio, February 1999
  - Boeing 747, VFR, Sun in eyes
  - Autopilot coupled to ILS
  - EGPWS caught premature descent

Rio HMI/NCFIT Event



Boeing Response

- Convened Safety Review Board
- Contacted NRE to discuss maintenance activities on ILS
- Prepared Mishap Event-Sequence Analysis
- Modified flight manuals to...
  - Include additional procedural redundancy
  - Add more explicit cross-checking warnings
- February 2000, wrote to FAA and ICAO suggesting potential actions for consideration

Additional NCFIT Events & FAA Response

- Multiple international cases; none known in U.S. yet
  - August 2000, New Zealand
    - Auckland autopilot tests
  - September 2001, Europe (?)
- October 2000, FAA/Boeing meeting developed recommendations
- FAA issued Maintenance Alert #100600, October 2000
- AOP-300 published report recommending FAA actions

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FAA Maintenance Alert (Excerpt)

ATS Maintenance Alert

National Operations Division (AOP-100)

10/17/00

Glide Slope System Phasing

Facility: GS
Summary:
This document emphasizes the importance of a facility shutdown and the related coordination procedures when performing Glide Slope (GS) system phasing. During this periodic maintenance procedure, there is a portion of time when the radiated signal will indicate to a pilot that the GS is operational and, worse yet, give the pilot a false indication that the aircraft is on the correct glide angle, regardless of the position of the aircraft….

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ICAO Actions

- February 2001, convened Testing of Radio Navigation Aids Study Group (TRNSG/4)
- Proposals developed for modifications to ICAO Document 8071
- May 2001, ICAO State Letter
  - Recommended actions for consideration by aviation regulatory authorities.
  - Requests national accident investigation authorities, per Annex 13, advise ICAO of incidents with potential for CFIT.

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Sources of HMI

- Periodic Maintenance (typical)
  - Phasing of LOC/GS
  - Setting of Modulation Balance for LOC/GS
  - Some (infrequent) other sources for ILS
- Aperiodic
  - Phasing LOC/GS
  - Reverse ground checks on VOR
  - Some (rare) other activities
- See paper for details, existing mitigations, potential weaknesses

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Phasing GS Facilities

- Most insidious source of HMI
- Fly up/down indications centered regardless of aircraft position
- No Morse code identification to remove (LOC Morse may remain on for procedural benefit of LOC-only approaches)
- Normal modulation components present
  - No flag action in cockpit

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Contributors to Undetected or Lengthy Periods of HMI

- Notification system design
  - NOTAM procedures -- several single points of failure exist
  - Remote status indicators provide redundancy to NOTAM system by notifying ATC of abnormal facility status; however, indicators being relocated away from ATC in some cases
- Glide Slopes
  - Depending on airport, HMI may last for tens of minutes if only one specialist
  - ATC issues approach clearance for LOC-only approaches as “Cleared for the ILS”, relying on NOTAM or ATIS broadcast to advise crew of GS outage
  - Difficult for crew to detect without sophisticated avionics (e.g., FMS)

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Contributors to Undetected or Lengthy Periods of HMI (Cont'd)

- Exisiting Mitigations (NOTAMs, ATIS if present, removing Morse code identification) weak
  - All 3 mitigations rely on SAME person to initiate
  - Initiator may only REQUEST, rather than CONFIRM, that NOTAM has been issued
  - NOTAM systems often exhibit latency
  - Latency of NOTAM cancellation
    - Causes pilots to frequently see signals usable before NOTAM expires
    - Pilots may begin to increasingly expect this

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Contributors to Undetected or Lengthy Periods of HMI (Cont'd)

- Cockpit & Avionics issues
  - Pilots may not always monitor AND DECODE the Morse code identification
    - Newer avionics accomplish this task
    - Some FMSs may not display actual decoded ident (increasingly rare);
    - If incorrect ILS selected (parallel runways), lack of Morse code may not be detected
  - Pilots taught to "trust your instruments" -- if indications appear normal, guidance may/will be used, especially vertical guidance

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Contributors to Undetected or Lengthy Periods of HMI (Cont'd)

- Ground maintenance personnel
  - Specialist may have very little insight into HMI, & training programs may not cover avionics design well or at all. Some Specialists may mistakenly think cockpit warning flag will appear during phasing
  - Handbooks and procedures may not contain characteristics of well-designed warnings of HMI occurrences
  - Many specialists consider an out-of-service facility to be a "safe" facility if NOTAM requested, and may not minimize periods of HMI
  - Some may consider NOTAM procedures burdensome, and "quick" adjustments may be effected without requesting a NOTAM

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Notification System Integrity

- There is no published requirement for the integrity of any notification system dealing with HMI.
- ICAO defines integrity requirements for navaids monitor systems
  - Ensure faulty signals removed or made unusable, when signals are INTENDED to be correct.
  - "3.1.3.12.1 The probability of not radiating false guidance signals shall not be less than 1 - 0.5 x 10^{-9} in any one landing for …[Cat] II and III localizers."

[1 - 0.5 x 10^{-9} = 0.999999995]

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Notification System Integrity (Continued)

- It appears reasonable that the notification system advising against the use of test signals, when they are KNOWN to be incorrect or contain HMI, should be at least as demanding.
- Fault tree analysis at Boeing/FAA meeting estimated probability of CFIT with HMI at 2 x 10^{-6}
  - Five times worse that recommended integrity of Facility Performance Category I GS
  - 500 times worse than required integrity of Facility Performance Category II/III GS

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Potential New Mitigations

- Boeing/FAA meeting documented 14 additional measures with varying merits
  - See paper for details, including advantages, disadvantages, implementation comments, and some numerical assessments of improvement factors
- Some already routinely in use in some countries
- Draft ICAO Document 8071 text and State Letter include some of these.

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ICAO State Letter Recommendations

"…In all circumstances, the **basic protective measures** should include as a minimum:

a) NOTAM phraseology that is specific about the possibility of false indications to the flight crew from the radiated test signals and clearly prohibits their use (suggested NOTAM wording – "RUNWAY XYZ ILS NOT AVBL DUE MAINTENANCE (or TESTING); DO NOT USE; FALSE INDICATIONS POSSIBLE");

b) confirmation by maintenance personnel that such a NOTAM has been issued by the Aeronautical Information Services before the testing procedures begin;"

(Continued)

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ICAO State Letter Recommendations

ICAO **basic protective measures** (Continued)

"c) prior to beginning the tests, suspension or alteration to an unusual tone/sequence of the transmission of the unique Morse Code facility identification on the localizer, if the localizer should radiate solely for testing purposes, and

d) a requirement that ATC advise, by automatic terminal information service (ATIS) and/or by a voice advisory, each pilot on an approach to the affected runway, emphasizing the possibility of false indications."

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ICAO State Letter Additional Protective Measures

"Additional protective measures may be appropriate, especially during phasing and modulation balance conditions for the localizer or the glide path….Accordingly, when the phasing and modulation balance tests are being performed the following options may be exercised:

a) when the tests are being performed on the localizer, remove the glide path from service by turning the signals off (to provide a glide path flag indication to the pilot); and..."

(Continued)

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ICAO State Letter Additional Protective Measures

ICAO additional protective measures (Continued)

b) ...when the tests are being performed on the glide path, remove the localizer from service by turning the signals off (to provide a localizer flag indication to the pilot).

c) Note. – If the b) option is exercised, the ATC voice advisories required….above [in basic protective measures] become redundant."

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Current FAA Actions

- FAA has assigned four actions for the short term:
  - Modify Order 6000.15, General Maintenance Handbook, to define HMI, increase emphasis on HMI situations, and require confirmation that a NOTAM has been issued prior to HMI testing.
  - Modify Order 6750.49, ILS Maintenance Handbook, to require shutting down LOC during GS HMI, and to redesign appearance and content of procedures text
  - Develop new NOTAM wording using ICAO guidelines
  - Formally define requirement for ATC to monitor ILS status displays
- Additional actions being considered

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Conclusions

- If cockpit indications appear normal, pilots may feel compelled to integrate those indications into their activities, despite the existence of NOTAMs
- Removal of localizer Morse code identification is not sufficient to ensure that facilities under test will not be operationally used.
- GS tests that produce HMI should not be conducted in marginal or poor weather conditions unless LOC signals are turned off.

(Continued)

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Conclusions (Cont'd)

- Language of ATC LOC-only approach clearances should be revised, especially for GS HMI conditions, to be noticeably distinct from a full ILS clearance.
- Visible cockpit indications during HMI may be the only reasonably sure way to ensure HMI signals are not operationally used.
- It is extremely difficult to provide the same integrity for a notification system that warns of HMI testing, as is required for normal ILS-based operations. An international standard or recommendation is needed.

(Continued)

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Conclusions (Cont'd)

- Ground and airborne testing communities for navaids need to become more aware of the HMI/NCFIT issue, and minimize the number and duration of its potential occurrences.

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End

- Acknowledgements
  - The Boeing Company
  - FAA's National Airspace System Policy Division
  - Participants in October 2000, Boeing/FAA meeting
  - ICAO's TRNSG

- Q&A

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