

# NAVAIDS TESTING RISKS AND THEIR MITIGATION

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## ABSTRACT

Aircrews have several methods available to them to determine the status of nav aids, including NOTAMs, broadcast messages (e.g., Automatic Terminal Information Service or ATIS), and communications with Air Traffic Control (ATC) personnel. However, some testing activities on these facilities can confuse or mislead aircrews, or even result in radiating *hazardously misleading information* (HMI) which is not detected by monitoring systems onboard aircraft. Given the possibility of these conditions, additional precautions are necessary to ensure that aircrews do not use the misleading signals, and to minimize the number and duration of such conditions.

This paper identifies the testing activities that are known to result in HMI, and reviews anecdotal evidence of inadvertent use of testing signals by aircraft making normal revenue flights. It presents an analysis of the risks, and describes current activities carried out within the International Civil Aviation Organization (ICAO) and by the U.S. Federal Aviation Administration (FAA) to mitigate the risks of such testing.

## DISCLAIMER

NOTE: This paper is a summary 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.

## INTRODUCTION

Some ground and airborne testing activities on radio navigational aids cause the facility to temporarily radiate signals which are not, or may not be, safe to use. Under these conditions, the signals are referred to as *hazardously misleading information* (HMI). In most cases, these activities may require only a few tens of minutes to

accomplish, but on infrequent occasions, HMI may be radiated for several hours.

Because these testing activities are necessary, and because cockpit receivers and indicators cannot detect the condition, some procedural means is required to ensure that users do not rely on the signals during this time. For many years, the publication of NOTAMs, advising that a particular facility is "unavailable" or "out of service" during the testing, has been the method used. Recently, however, there have been a number of documented occasions during which aircraft have apparently inappropriately coupled to or used navigational-aid signals that not only should have been unusable, but were also deceptive. Fortunately, these conditions were discovered prior to an accident having occurred. These incidents have been labeled as "*near-controlled flight into terrain*" (NCFIT) incidents.

## BACKGROUND

### Initial Incident and Reaction

In August, 1999, a large aircraft manufacturer contacted FAA's National Resource Engineer (NRE) for Navigation, to inquire about glide path signal generation and maintenance activities. This contact arose from a February, 1999, flight conducted in visual meteorological conditions (VMC) in another country, during which a coupled Instrument Landing System (ILS) descent to a large airport resulted in the aircraft being abnormally close to the ground at some distance from the airport. The flight crew had reported that the autopilot and glidepath indications were normal until a warning from the airplane's Enhanced Ground Proximity Warning System (EGPWS) resulted in a missed approach and subsequent uneventful landing. After studies resulting from inquiries to the avionics manufacturers could find no reasonable explanation for this apparent descent guidance failure, the airframe manufacturer studied its systems architecture, also finding no apparent explanation, and the FAA was contacted

to learn more about the ground facility and its maintenance.

As a result, the new information about glide path signals and their required testing activities which produce periods of “normally occurring” HMI was factored into the manufacturer’s Mishap Event-Sequence Analysis<sup>[1]</sup>. The manufacturer modified its flight manuals to include additional procedural redundancy and more explicit warnings about the need for cross-checking cockpit indications, to guard against using navigation signals containing HMI. In February, 2000, the manufacturer sent a letter<sup>[2]</sup> to the FAA and to ICAO, defining its concerns and suggesting potential actions for consideration. Both the FAA and ICAO began internal discussions and meetings on this topic shortly thereafter.

### **Multiple Following Incidents and Reactions**

During August, 2000, The Boeing Company (Boeing) advised FAA’s NRE of a similar incident in another country. As a result of the incident, the regulatory authority for the involved airline conducted a test on the subject aircraft type in a

third country, by placing the glide path facility in several testing configurations, to confirm that the avionics would couple to the inappropriate signals. During this testing, despite a NOTAM advertising of the status of the facility, it was confirmed that aircraft would couple to the inappropriate signals.

On 11-12 October, 2000, the FAA and Boeing employees met to review these NCFIT incidents and the procedures normally used to mitigate the risk of ILS maintenance practices that result in radiating HMI. Detailed analyses of possible fault trees resulted in a set of recommendations for the FAA and the industry. As a result, the FAA immediately issued a Maintenance Alert<sup>[3]</sup>, see Figure 1, to heighten the awareness of its ILS technicians to HMI from maintenance practices. In November, 2000, the FAA’s National Airspace System Policy Division published a report<sup>[4]</sup> documenting the mitigations discussed in the October meeting, and recommending specific actions for the FAA. These actions will be presented in the DISCUSSION section of this paper.

## **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.

#### **Alert:**

Recently, the FAA has been advised of instances wherein pilots reported the GS useable although the system had been NOTAM'd 'out of service'. This alert is a reminder to ILS specialists that during phasing procedures, when the facility is radiating in quadrature, the radiated signal will look like an 'on-path' signal to the pilot regardless of the position of the aircraft, i.e., above or below the glide path. ATC should also be aware of this and notify all aircraft in the approach landing airspace of this fact. In accordance with the ILS Handbook, Order 6750.49A, a facility shutdown is required whenever performing system phasing. It is the responsibility of the specialist to ensure a facility shutdown has been requested, coordinated, and approved through the appropriate channels. Furthermore, it is good maintenance practice to ensure Air Traffic Control is fully aware of the shutdown and the Notice to Airmen (NOTAM) has been issued before performing maintenance. Procedures are being investigated in an effort to reduce the number of possible coordination link failures. The FAA has assembled a small team to evaluate our coordination system for single points of failure and to improve the content of maintenance handbook warnings. Until such time further guidance is distributed, abide by any and all standard operating procedures when coordinating shutdowns. If you have any questions or concerns, please contact Mickey Lindecker, AOS-241, at (405) 954-5197.

**OPI:**  
AOS

**AOP-100:**  
B. Wilson

**ATT:**

**Serial #:** 100600



**Figure 1, FAA Maintenance Alert**

In February, 2001, ICAO convened its Testing of Radio Navigation Aids Study Group (TRNSG). Part of the agenda was dedicated to discussion of the NCFIT issue, and how ICAO Document 8071, Testing of Radio Navigation Aids<sup>[5]</sup>, might be embellished to reduce the risk of inadvertent use of signals containing HMI. The group developed its proposals, and in May, 2001, ICAO issued a State letter<sup>[6]</sup> recommending actions to be considered by aviation regulatory authorities.

### **Most Recent Incident**

In September, 2001, Boeing advised FAA's NRE that another possible NCFIT incident had occurred in Europe. At the time of preparation of this paper, the details are not yet sufficiently well known to be certain that this incident relates to radiating HMI during facility testing activities.

## **DISCUSSION**

### **Testing Requirements Resulting in HMI**

Several types of ground and airborne testing of navigational aids (Nav aids) require radiating signals containing HMI. In general, the most common of these tests are those that place ILS space modulation components in phase quadrature with the carrier modulation, i.e., phasing of localizers (LOC) and glide slopes (GS) (or glide path (GP) as per ICAO terminology). However, other ILS tests, such as adjusting modulation balance (radiating carrier signals without the separate sidebands) or establishing proper localizer antenna pair nulls using standard modulated carrier signals, also create HMI. Testing requirements for Very High Frequency (VHF) OmniRange (VOR) facilities do not generally create HMI conditions, although unintended error conditions such as swapping the sideband feedlines on a conventional VOR (which is not a typical or required test) can create HMI.

During these testing procedures, an aircraft's course deflection indicator remains centered (or its average position is centered), regardless of the position of the aircraft within the service volume of the ground facility. Thus the receiver's flag warning circuits will not detect and indicate the potential HMI, because the normally required navigation tones are still being transmitted by the carrier signal.

### **Existing Mitigations and Potential Weaknesses**

**LOC and VOR Facilities.** Several methods are commonly available to warn aircrews of nav aid testing conditions, primarily the publication of NOTAMs and removal of the Morse code identification from VHF aids during maintenance activities. Additional methods exist at some locations, such as an Automated Terminal Information Service (ATIS) broadcast. Fortunately, those LOC and VOR maintenance activities that create HMI and must be performed on a periodic

basis, such as phasing, can usually be effected quickly. For most types of LOC antenna arrays, the carrier and separate sidebands appear on most or all antenna feedlines, allowing one person to accomplish the task without leaving the electronics shelter or its vicinity. In addition, aircrews have a ready crosscheck for azimuth errors from the magnetic compass and any more advanced avionics.

**GS Facilities.** Although NOTAMs (and optionally, ATIS broadcasts) are published for GS maintenance activities, GS signals do not provide Morse code identification signals that can be removed during maintenance. Further, pressure may exist to leave a LOC in service with normal Morse code identification signals during GS maintenance, because the LOC still provides a procedural benefit in marginal weather conditions by supporting a Localizer-only approach. Although it is typically a rare occurrence to conduct GS tests producing HMI during poor weather conditions, it may still occur following corrective maintenance, or following routine maintenance if not specifically prohibited.

**All Navaid Facilities.** Remote nav aids status indicators are typically located in an ATC facility such as a control tower cab. Maintenance actions producing HMI typically require, as a matter of good practice, at least temporarily turning a nav aid transmitter off to establish the test condition, and this will produce a visual and audible warning on the status indicator. This warning provides a redundant method of ensuring that ATC personnel are aware of the maintenance activity. However, modern nav aids allow for the maintenance actions to be conducted without turning the transmitter on and off to make temporary connections of antennas and cables. This may encourage the technician to proceed for expediency without turning the transmitter off, which would eliminate the redundant warning. Further, the remote warning at the control point can be defeated with good intentions to save the ATC personnel from suffering and responding to numerous warnings.

### **Contributors to Undetected or Lengthy Periods of HMI.**

**Notification System Design.** Although remote status indicators can provide a redundant path to other HMI mitigation methods, recent trends in some countries may defeat the advantage of the redundancy. For example, in one country the maintenance program is being structured around the concept of a small number of Facility Control Centers, each having a large geographical area of coverage. In some cases, remote status indicators for nav aids facilities are being relocated away from ATC personnel and into the control centers.

As a result, telephonic or other communications are required to coordinate with ATC personnel and ensure their awareness of facility outages. This may be contrary to the intent of an ICAO requirement found in Annex 10<sup>[7]</sup> about the timeliness of operational status awareness. The requirement text is found in Volume 1, Chapter 2, General Provisions for Radio Navigation Aids, and states:

## **2.8 Provision of information on the operational status of radio navigation aids**

*2.8.1 Aerodrome control towers and units providing approach control service shall be provided without delay with information on the operational status of radio navigation aids essential for approach, landing and take-off at the aerodrome(s) with which they are concerned.*

**Glide Slopes.** GS HMI is particularly troublesome, because there is no Morse code identification to remove and because of the procedural benefit of leaving a LOC in service during GS maintenance. To make matters worse, three additional considerations increase the risk of unsuccessfully warning aircrews of GS maintenance that may create HMI.

(1) Phasing of GS signals typically requires making measurements in the far-field of the antenna system, often near or outside the typical airport boundary. At large airports, accessing the phasing location may require up to several tens of minutes, due to the need to cross active runways and taxiways, and passing through security gates. If only one technician is available for the measurement, the GS must be left radiating HMI for a significant amount of time.

(2) ATC personnel may issue an approach clearance, even with the GS out of service, using "Cleared for the ILS" or similar phrasing, while relying on the NOTAM or ATIS broadcast to advise aircrews that the GS is out of service. In this case, the approach clearance does not provide any redundancy to the NOTAM or ATIS broadcast.

(3) It is difficult for an aircrew to detect an incorrect descent angle without advanced avionics.

**NOTAMs.** Even though other mitigations are available (e.g. removing Morse code identification and ATIS broadcast), a NOTAM is generally considered the primary method of ensuring that aircrews are aware of abnormal navaid situations. However, at most locations *all three* of these methods (i.e., NOTAM, ID removal, and ATIS broadcast) are initiated by the (same) facility maintenance person, creating an obvious

potential single point of failure for the procedural notification of possible HMI. Further, in most countries the maintaining technician merely *requests* that a NOTAM be issued, and one or more additional persons are involved in actually *issuing* the NOTAM. Therefore, the NOTAM issuing process at most locations is subject to multiple single points of (human) failure.

Other factors also contribute to potential use of nav aids during periods of HMI. It is common for NOTAMs on scheduled outages of nav aids to advertise longer outage times than actually used, and normal signals are frequently restored prior to the scheduled end time. Therefore pilots are used to facilities being usable, even though NOTAMs are still in effect. In addition, most NOTAM systems exhibit some latency, possibly resulting in facilities being restored to service prior to NOTAM cancellation.

**Cockpit and Avionics Issues.** Pilots may not always monitor and decode the Morse code identification, at least in part because newer avionics accomplish this task on an automated basis. Some flight management systems may not display the actual decoded identification (although this is increasingly rare), and if an incorrect ILS frequency is selected (e.g., a parallel runway situation), a lack of ILS Morse code identification on the desired LOC may not be detected. Obviously pilots cannot detect the absence of GS Morse code, since ILS was not designed to provide facility identification on a GS channel. Further, pilots are taught repeatedly to "rely on your instruments". Some experienced pilots have stated that this training is so effective that if cockpit indications look normal, pilots will use the indications in spite of NOTAMs to the contrary. Since most HMI conditions do not provide a visible cockpit indication, this will result in inappropriate use of HMI signals.

**Ground Maintenance Personnel.** Many nav aids technicians may have very little insight into the HMI issue. Training programs may not cover avionics design well or at all. As a result, it is common for technicians to mistakenly think that the cockpit warning flag will appear during ILS phasing activities. Maintenance documents and procedures may not contain the characteristics of well-designed warnings about the potential hazards of HMI-producing activities. Many technicians consider an out-of-service facility to be a "safe" facility if a NOTAM has been requested, and therefore may not minimize the time duration of HMI conditions. Finally, some technicians might consider the NOTAM requesting procedures to be overly burdensome or lengthy, and "quick" adjustments may be effected without requesting a NOTAM.

**Notification System Integrity.** During U.S. discussions on this topic, it has been noted

that there is no published requirement for the integrity of any notification system dealing with HMI. ICAO's Annex 10<sup>[7]</sup> defines integrity requirements for nav aids monitor systems, which endeavor to ensure that faulty signals are removed or made unusable, when the signals are intended to be correct. Annex 10, Volume 1, Chapter 3, contains the following provisions for ILS:

**3.1.3.12 Integrity and continuity of service requirements**

3.1.3.12.1 The probability of not radiating false guidance signals shall not be less than  $1 - 0.5 \times 10^{-9}$  in any one landing for Facility Performance Categories II and III localizers.

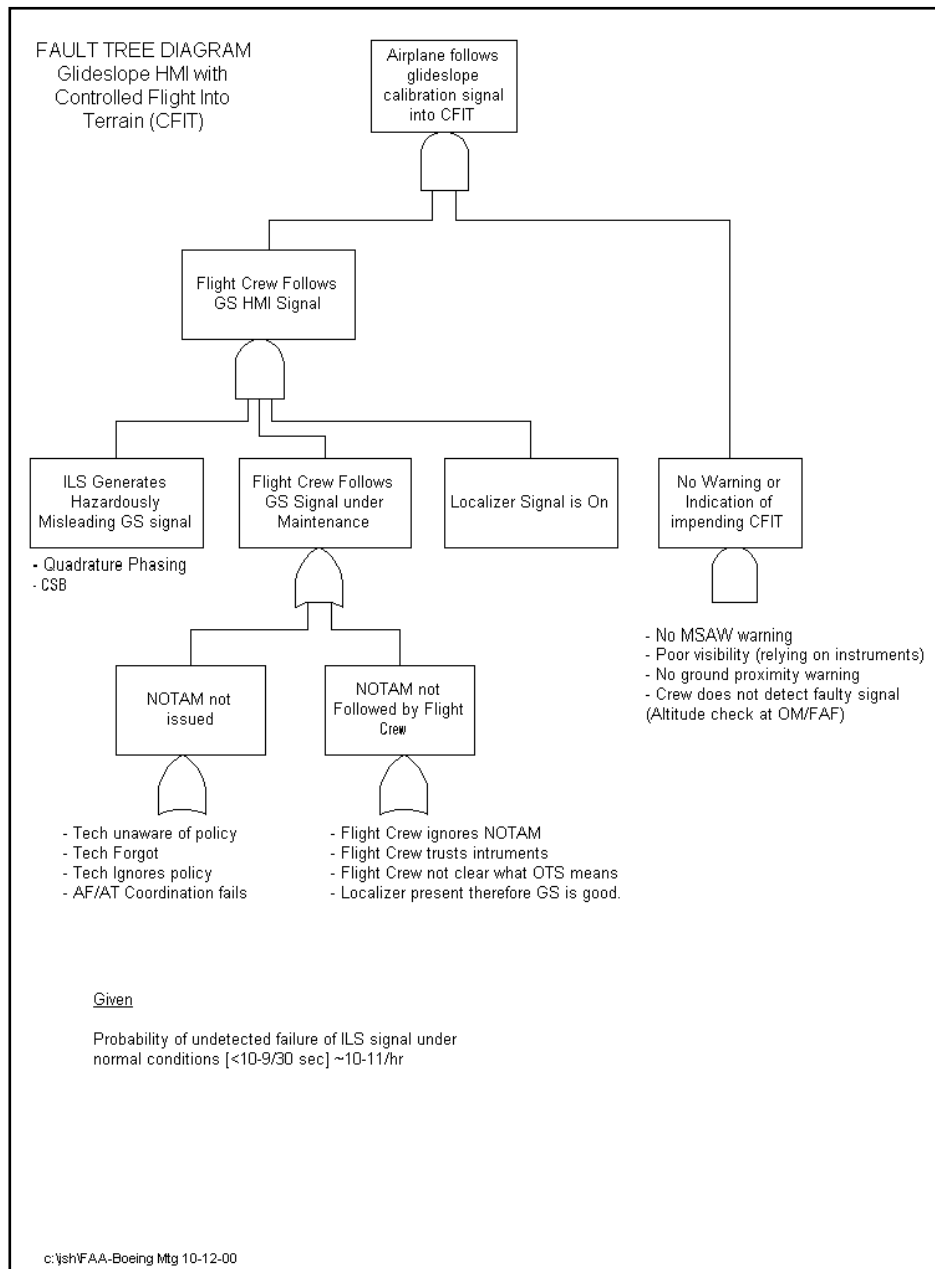
3.1.3.12.2 Recommendation.- The probability of not radiating false guidance signals should not

be less than  $1 - 1.0 \times 10^{-7}$  in any one landing for Facility Performance Category I localizers.

It appears reasonable to expect that the integrity of 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.**

During the October, 2000, Boeing/FAA meeting, participants analyzed the NCFIT problem from differing viewpoints, and composed fault tree diagrams to assist in assessing the potential value of additional mitigations. One of the fault trees is shown in Figure 2, showing the contributing conditions that result in CFIT during a GS phasing test.



**Figure 2, CFIT Fault Tree for GS HMI**

Depending on the probabilities assigned to each condition or event, the top-level probability of CFIT is approximately  $2 \times 10^{-6}$ , prior to implementing any additional mitigations. This is approximately five times worse than the recommended integrity of a Facility Performance Category I GS, and approximately 500 times worse than the required integrity of a Facility Performance Category II/III GS.

### **Potential New Mitigations**

Also during the October, 2000, Boeing/FAA meeting, a brainstorming session resulted in a list of 14 possible methods of reducing the risk of NCFIT due to facility testing. The list of options is shown in Table 1, including brief statements of advantages, disadvantages, implementation costs, and timeframes. For some options, a rough order-of-magnitude estimate of the improvement factor is given.

### **ICAO ACTIONS**

At the February, 2001, meeting of the TRNSG, the participants drafted language for an amendment to Volume 1 of Document 8071. In general, the text addressed coordination and publication of HMI-producing maintenance activities, and emphasized that initial and recurrent training programs for navigation aid technicians should include detailed explanation of maintenance procedures and their effect on the integrity of the radiated signal. The text also identified a number of recommended protective measures.

Pending publication of a revised Volume 1 to Document 8071, ICAO issued in May, 2001, a State letter<sup>6</sup> defining the NCFIT problem, and requesting a review of current practices and procedures. The letter stated in part:

*However, full prevention of the type of incidents in question involves a combination of measures which would protect the system from single points of failure. ....[R]eview current practices and procedures as necessary to ensure that ILS will not be used for normal flight operations when test signals are being radiated or the executive monitoring function of the facility is inhibited for testing/maintenance purposes.*

*It is highly desirable to eliminate the possibility for any operational use to be made of the ILS guidance during the testing by administratively removing (e.g., by a NOTAM) the localizer and the glide path from service simultaneously. If this is not feasible for operational reasons, a deferral of testing should be considered. However, in case the localizer needs to remain in service while the glide path undergoes testing and the testing cannot be delayed,*

*sufficient measures should be implemented to ensure that users are aware of the potential for false indications from the glide path facility.*

*In all cases, the basic protective measures should include as a minimum: [see Figure 3 for the full text of the basic measures]....Additional protective measures may be appropriate....[see Figure 4 for the full text of the additional measures]*

*In addition, it is essential to ensure that protective measures (in addition to the coordination and promulgation process) are put in place to guard against single points of failure. One highly desirable measure is the installation of remote ILS status-indicating equipment such that it is visible to the air traffic controller issuing approach clearances.*

.....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;
- 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.

**Figure 3, Excerpt re: Basic Protective Measures from ICAO State Letter, 11 May 2001**

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:

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

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).

Note. – If the b) option is exercised, the ATC voice advisories required....above [in Figure 3] become redundant.

**Figure 4, Excerpt re: Additional Protective Measures from ICAO State Letter, 11 May 2001**

### U.S. FAA ACTIONS

In March, 2001, FAA convened National Airspace System Policy Division representatives and navigation aid subject matter experts, to assign four action items resulting from the Boeing/FAA meeting.

#### Changes to General Maintenance Handbook

FAA's Order 6000.15<sup>[8]</sup>, which applies to all facility types, will be amended to increase emphasis on potential HMI situations and to require confirmation that a NOTAM has been issued prior to proceeding with testing activities. Some of the text now in formal coordination includes the following:

*AVIATOR AWARENESS. Aviators have several methods available to determine the operational status of navigational aids (navaids), including NOTAMs, broadcast messages, and communications with ATC personnel. Certain maintenance procedures on navaids, however, produce indications that can confuse or mislead aviators. Additional precautions may be required to ensure aviators do not use these signals...*

*Hazardously Misleading Information (HMI). Certain maintenance practices may require intentional radiation of HMI. Such occurrences shall be minimized in both number and duration when practical. Methods to accomplish this include using more than one specialist to eliminate access time to far-field measurement areas, and using additional or specialized test equipment and procedures as a substitute for*

*radiating HMI. Risk Management techniques shall be used to mitigate the remaining risk.*

*INTERRUPTION COORDINATION. System Specialists shall confirm that a NOTAM has been issued prior to removing any navaid from service if HMI will be radiated. This may be accomplished by a variety of methods, including but not limited to calling the servicing [flight service station], coordinating with [airway facility] control center or ATC personnel, or monitoring the applicable ATIS.*

#### Changes to ILS Maintenance Handbook

FAA's Order 6750.49<sup>[9]</sup> will be amended in several ways, some of which are already in formal coordination. During GS phasing, a Localizer shutdown will be required unless alternate phasing procedures that avoid radiation of HMI are used. One possible procedure to accomplish this will require a vector voltmeter and a hang-on probe for the GS antennas, and the establishment of reference phase readings corresponding to a thorough flight inspection. Other changes will redesign the appearance and content of procedural text to better educate the technician on the potential for HMI and the potential outcomes if procedures are not rigorously followed.

#### Other Changes

NOTAM wording will be developed, using ICAO guidelines, to enhance understanding and awareness of maintenance-induced HMI. The requirement for ATC to monitor ILS status displays will be formally defined to Integrated Product Teams responsible for deployment and positioning of equipment.

### CONCLUSIONS

Although some aviation industry and regulatory entities have already initiated responses to the HMI and NCFIT issue, more awareness and discussion is needed. Some high-level conclusions from the discussions to date include the following:

a. If cockpit indications appear normal, pilots may feel compelled to integrate those indications into their activities, despite the existence of NOTAMs declaring navaids, particularly GS facilities, out of service.

b. Due to a number of avionics and human-factors considerations, removal of the localizer Morse code identification signal is not sufficient to ensure that LOC and GS facilities under test will not be operationally used.

c. Due to the troublesome nature of preventing operational use of GS signals which appear normal in the cockpit:

(1) GS tests that produce HMI should not be conducted in marginal or poor weather conditions unless the LOC signals are turned off, and ...

(2) The language of ATC LOC-only approach clearances should be revised as necessary, particularly when the GS is undergoing testing that can produce HMI, to be noticeably distinct from a full ILS approach clearance.

d. A visible cockpit indication during the radiation of HMI may be the only reasonably sure way to ensure that navaid signals containing HMI are not operationally used. While this may not be feasible to achieve by modifying avionics already in use, some options exist for implementation by ground personnel to either eliminate the HMI or cause warning flags to appear in the cockpit.

e. It is extremely difficult, using any method proposed to date, to decrease the probability of operational use of ILS signals containing HMI to match the ICAO integrity requirements applicable to normal ILS-based operations. An international standard or recommendation on the integrity of aircrew notification systems, particularly with respect to HMI, would promote standardization of analysis and implementation of notification systems.

f. The ground and airborne testing communities for nav aids need to become more aware of the HMI/NCFIT issue, and minimize the number and duration of its potential occurrences.

### **ACKNOWLEDGEMENTS**

This paper is a summary of the contributions to the paper's topic by a number of people. The author acknowledges and appreciates the efforts by Boeing and other FAA personnel, and by the members of ICAO's TRNSG, in advancing the NCFIT issue. Any content errors, omissions, or misrepresentations are solely those of the author.

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OPTION	ADVANTAGES	DISADVANTAGES	IMPLEMENTATION	IMPROVEMENT
1. Outer Marker/Final Approach Fix. Reemphasize altitude check procedure in the aircraft operations manual.	An independent check. No equipment modification.		Medium implementation time. Manufacturer printing cost for procedure changes (in some cases).	5.00E-01
2. Issue Maintenance Alerts	Alerts system specialist to the possibility of problem.	Not directive in nature.	Printing Cost.	
3. Turn off localizer when glideslope is out-of-service.	Positive Crew Indication that ILS not available (ident & signal). AT will not issue ILS approach. Independent of NOTAM issue. No equipment modification.	Loss of LOC Availability (delays TBD). Additional scheduling problems for full ILS outage, additional outage time if no remote control. Some computer/autopilot systems allow GS capture, even if the LOC signal is not captured.	Overtime for additional nighttime (low traffic time) checks by system specialist. Printing Cost for change to maintenance handbook. Union coordination required.	1.00E-03
4. Rephrase NOTAM language. State the nature of the outage in clear terms so pilots will know an apparently good signal may be HMI.	Better pilot comprehension		Long-term implementation time; Printing cost to revise orders.	
5. Ensure approach controller has ILS status information (without delay per ICAO).	Approach controller has independent confirmation of ILS status.	Possible lack of console room for displays.	Medium delay in implementation of handbook changes (TBD; 6750.54; 7110.65).	
6. Require that the technician confirms NOTAM has been issued prior to taking the glideslope OTS.	Can be implemented by system specialist via procedure change in maintenance handbook.	Not a positive check that pilot is aware.	Medium implementation time; Printing Cost.	
7. Add human factors-approved warnings in maintenance handbook.	Increase the system specialist's awareness of the impact of radiating HMI.		Medium implementation time; Printing cost.	

**Table 1, Possible NCFIT Mitigations, from 10/00 Boeing/FAA Meeting (Continued next page)**

Note: This table was originally prepared by M. Lindecker of FAA; some minor editing was done by this paper's author.

<b>OPTION</b>	<b>ADVANTAGES</b>	<b>DISADVANTAGES</b>	<b>IMPLEMENTATION</b>	<b>IMPROVEMENT</b>
8. Glideslope on/off switching during HMI periods (greater than 10 seconds: TBD by avionics performance characteristics)	Less likely that aircraft can couple to signal.	Doesn't guarantee that flight director/autopilot doesn't fly.	Expensive & Long Lead time to design and implement.	
9. One Frequency phasing procedure	Aircraft cannot couple to signal.	Training and possible problem for specialist to perform procedure.	Medium implementation time; printing cost for change to maintenance handbook procedure.	2.00E-08
10. 60/20%(or other % TBD) modulation during phasing procedure.	Selected so that aircraft receives only fly up signal.	Specialist training and/or modification to equipment.	Medium to long-term implementation time. Medium to high cost.	2.00E-08
11. Permanently bias modulation percentage to a non-DDM on carrier signal.	Presents a small fly-up signal to the aircraft during performance of phasing procedure.	Would require a one-time or during periodic flight check. Aircraft could still couple to a misleading signal. Slight possibility of pitch up of aircraft to stall (amount must be determined).	Medium implementation time; printing cost for change to maintenance handbook procedure.	1.00E-07
12. Require two technicians to perform glideslope phasing procedure.	Reduction of amount of time abnormal signal is radiated. Second specialist to oversee procedure.	Two system specialists required.	Medium implementation time; Printing cost.	1.00E-02
13. Avionics detection of glideslope quadrature condition during phasing procedure.	Automatic detection by aircraft equipment.	Possible elimination of a "good" signal.	Expensive & Long Lead time to implement - May only get to limited number of receiver types/aircraft.	
14. Issue NOTAM earlier.	Increase the likelihood that crews associated with longer flights have this information at dispatch.		Medium implementation time; Printing cost.	

**Table 1 (Continued), Possible NCFIT Mitigations, from 10/00 Boeing/FAA Meeting**