



## ***Policy Letter (PL)***

### **Design Guidelines and Human Factors Considerations for Installation of IFR GPS/GNSS Receivers**

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<b>1.0</b>	<b>INTRODUCTION.....</b>	<b>2</b>
1.1	Purpose.....	2
1.2	Guidance Applicability.....	2
1.3	Description of Changes.....	2
1.4	Termination .....	2
<b>2.0</b>	<b>REFERENCES.....</b>	<b>2</b>
2.1	Reference Documents .....	2
2.2	Cancelled Documents.....	2
<b>3.0</b>	<b>BACKGROUND.....</b>	<b>2</b>
<b>4.0</b>	<b>FAA ADVISORY CIRCULAR AC 20-138A.....</b>	<b>3</b>
<b>5.0</b>	<b>GENERAL DESIGN CONSIDERATIONS.....</b>	<b>3</b>
5.1	Course Deviation Indicator.....	3
5.2	Remote Annunciators – History & Background .....	4
5.3	Application of AC 20-138A – What is a “Center Radio Stack” .....	5
5.4	Installations without Remote Annunciators – Dimensional Constraints.....	6
5.5	Installations with Remote Annunciators – At Applicant’s Discretion.....	8
5.6	Installations that Require Remote Annunciators – What is Required.....	8
5.6.1	Nav Source Annunciator .....	8
5.6.2	Message Annunciator .....	8
5.6.3	Waypoint Annunciator & Distance-to-Go Indicator .....	8
5.6.4	Integrity or RAIM Annunciators .....	9
5.6.5	Approach/Terminal, or Approach Arm/Activate Annunciators .....	9
5.6.6	Other Annunciators .....	9
5.7	Installations not in the Instrument Panel.....	9
5.8	Installations in EFIS-Equipped Aircraft .....	9
5.9	Installations in Aircraft Operated by Two Crew.....	9
<b>6.0</b>	<b>SUMMARY.....</b>	<b>10</b>
<b>7.0</b>	<b>HEADQUARTERS CONTACT .....</b>	<b>10</b>

## **1.0 INTRODUCTION**

### **1.1 Purpose**

The purpose of this Policy Letter is to provide clarification, in response to requests from industry, on specific issues regarding the installation of GPS/GNSS receivers, and in particular, on application of various guidance material.

### **1.2 Guidance Applicability**

This document is applicable to all Transport Canada personnel, delegates and industry.

### **1.3 Description of Changes**

This document, formerly Transport Canada Aircraft Certification Flight Test Working Note No.33, is reissued as a PL. With the exception of minor editorial changes, the content is unaltered.

### **1.4 Termination**

This document does not have a terminating action. It will however, be reviewed periodically for suitability of content.

## **2.0 REFERENCES**

### **2.1 Reference Documents**

It is intended that the following reference materials be used in conjunction with this document:

- (a) Part V Subpart 23 of the Canadian Aviation Regulations (CAR)—*Normal, Utility, Aerobatic and Commuter Category Aeroplanes*
- (b) Chapter 523 of the Airworthiness Manual (AWM)—*Normal, Utility, Aerobatic and Commuter Category Aeroplanes*
- (c) Federal Aviation Administration Advisory Circular (FAA AC) 20-138A—*Airworthiness Approval of Global Navigation Satellite System (GNSS) Equipment*

### **2.2 Cancelled Documents**

As of the effective date of this document, Transport Canada Aircraft Certification Flight Test Working Note No.33 is cancelled.

## **3.0 BACKGROUND**

Global Positioning System (GPS) receivers, or as they are now known, Global Navigation Satellite System (GNSS) receivers, have been installed in aircraft since the early 1990s. Concerns have been expressed, both by the aviation industry, and by Design Approval Representatives (DARs) and engineers within Transport Canada, that there is insufficient and conflicting guidance material with respect to the human factors considerations of GPS/GNSS receiver installations. This PL will attempt to define in practical terms acceptable locations for IFR installations of GPS/GNSS receivers installed without remote annunciators, the acceptable location of the associated course deviation indicators (CDIs), and, when required, the remote annunciators and/or indicators that must be installed. The goal is to ensure an efficient and concise instrument scan. This PL is applicable to installations on normal category Part 23 airplanes; Part 23 Commuter and Transport category airplanes are excluded, as are rotorcraft.

This PL will not detail the full process for obtaining approval of a GPS/GNSS installation, nor will it address other issues, such as the electrical requirements, not related to human factors considerations of these installations.

This PL assumes that full IFR certification is sought, including approval for approach operations. In the past, some approvals have been restricted to enroute approval, either because the receiver itself was not approved for approach operations, or because there was something lacking in the

installation. There are now no new receivers that are approved for enroute-only operations, and approval with such restrictions will not be addressed herein.

Installations meeting the guidelines contained within this PL do not need a Flight Test review of the human factors considerations of the installation. Other installations may require an assessment by a Transport Canada Flight Test specialist.

#### **4.0 FAA ADVISORY CIRCULAR AC 20-138A**

Advisory Circular 20-138A, "Airworthiness Approval of Global Navigation Satellite System (GNSS) Equipment" was issued by the FAA December 22, 2003. This AC addresses the implementation of Wide Area Augmentation System (WAAS) and Local Area Augmentation System (LAAS) receivers, but also attempts to address many of the shortcomings of the original version of AC 20-138, issued in 1994. Reference will be made throughout this PL to AC 20-138A.

While other Advisory Circulars may address certain aspects of a GPS installation, AC 20-138A is considered to take precedence over other ACs when addressing human factors considerations of GPS/GNSS installations. For example, AC 23.1311-1A, "Installation of Electronic Displays in Part 23 Airplanes", provides a definition of "Primary Field of View" (PFOV). However, the definition of PFOV in AC 20-138A takes precedence over AC 23.1311-1A, insofar as GPS/GNSS installations are concerned.

#### **5.0 GENERAL DESIGN CONSIDERATIONS**

In planning an IFR GPS/GNSS installation in an existing aircraft, there are a number of inter-related design considerations, all of which are dependent on the existing panel of the aircraft in question. The following paragraphs discuss some of these design considerations, and the background and logic behind Transport Canada's position.

##### **5.1 Course Deviation Indicator**

Installation of a GPS/GNSS receiver certified for IFR operations requires that the GPS/GNSS be connected to a remote Course Deviation Indicator (CDI) or Horizontal Situation Indicator (HSI), either conventional or electronic. This CDI must be part of the pilot's primary instrument scan during approach and other IFR operations, and thus should be located to ensure an efficient and concise scan.

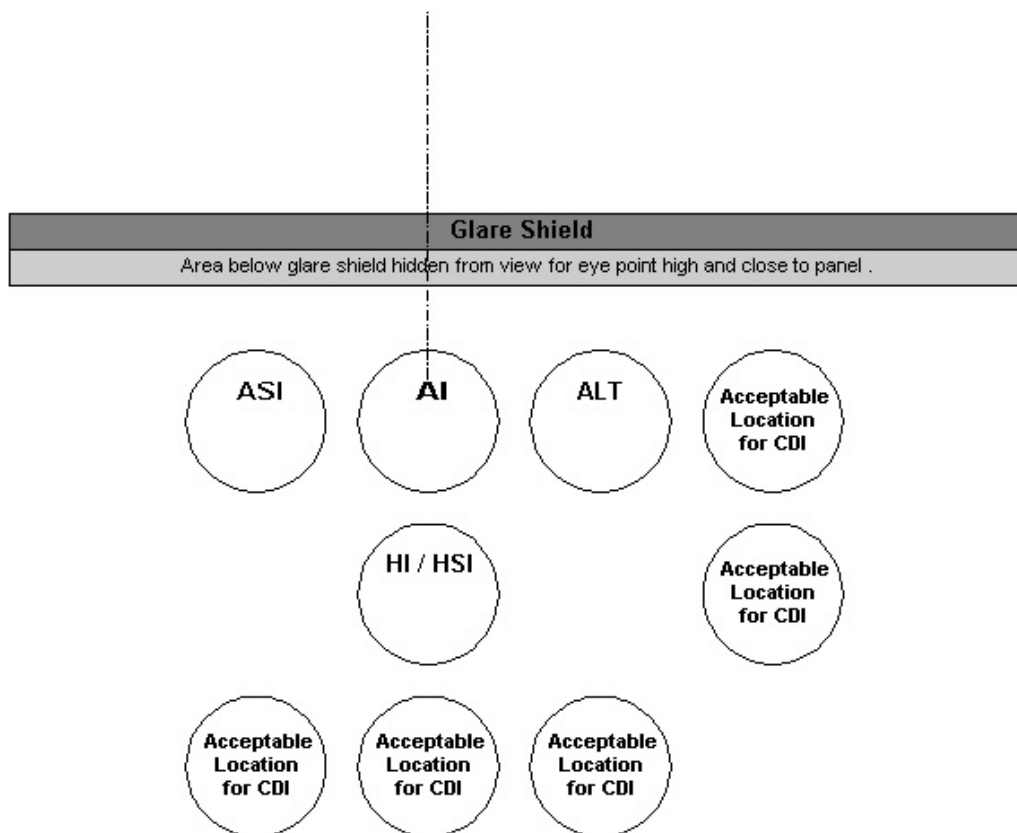
AC 20-138A requires that the CDI connected to a GPS/GNSS receiver be within the pilot's primary field of view<sup>1</sup>, which the AC defines as within 15 degrees of the pilot's primary line of sight. Taken literally, this would mean that the CDI would need to be within roughly a 6½" radius of the center of the Attitude Indicator (AI) on most aircraft<sup>2</sup>. The only means to achieve this on most conventional instrument panels would be to use an HSI. However, it is presumed that the intention of AC 20-138A was not to mandate an HSI in every GPS/GNSS equipped aircraft, as experience has shown that CDIs external to the basic "T" may be acceptable.

Depending on the layout of other instruments and indicators that must also be included in the scan, including the GPS/GNSS receiver that is normally installed in the center radio stack, an external CDI is usually best located at the top of the instrument panel, as close as possible to the altimeter. Based on experience, however, the following locations for an external CDI may be considered acceptable.

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<sup>1</sup> Paragraph 18d(1) states "The horizontal (and vertical) deviation(s) display(s) and failure annunciation should be located within the pilot's primary field of view, as should any indication requiring immediate aircrew action. For the purpose of this AC, the primary field of view is within 15 degrees of the pilot's primary line of sight."

<sup>2</sup> Assuming an eye-to-panel distance of 24", as a typical minimum distance from the instrument panel, 15° equates to 6.4".



The above acceptable locations are considered appropriate for aircraft that do not have an HSI. Aircraft that use an HSI to show track deviation for a VOR/ILS should also show GNSS track deviation on the same HSI, for the primary GNSS receiver. Course deviation indicators for a secondary GNSS receiver, or a back-up indicator for the primary GNSS receiver, do not need to meet the above constraints.

The CDI shall also be visible and unobstructed from the pilot's view with the pilot's hands on the control column, regardless of the pilot's sitting position. If movement of the upper torso, from a normal seated position, is required to see the CDI, its location is not acceptable.

## 5.2 Remote Annunciators – History & Background

In the early days of GPS IFR approvals, it was generally accepted that certain remote annunciators were required for an IFR approach approval. Foremost amongst these was a requirement that the navigation source driving a CDI/HSI must be annunciated on or near the CDI/HSI, when it was possible to display navigation information from more than one source on the same CDI/HSI<sup>3</sup>. Remote annunciators were also common for MSG, WPT, GPS Approach ARM/ACT and OBS/LEG, though the requirement for these annunciators was somewhat open to interpretation<sup>4</sup>.

<sup>3</sup> It was, and still is, possible to connect an IFR approved GPS/GNSS receiver to a dedicated CDI, but that was not common, and is becoming even less common.

<sup>4</sup> Aircraft Certification Policy Letter (ACPL) No.11, *Selection & Annunciation of Multiple Navigation Sources*, and FAA AC 20-138 clearly required nav source annunciation, but the need for other annunciators came from the following wording in AC 20-138: "Each display element (i.e., the cross track deviation display (CDI), horizontal situation indicator (HSI), map display, etc.), used as a primary flight instrument in the guidance and control of the aircraft, for maneuver anticipation, or for failure/status/integrity annunciation, shall be located where it is visible to the pilot (in the

With the introduction of integrated GPS/VOR/ILS boxes<sup>5</sup>, an external switch was no longer required for a GPS and VOR/ILS to share a common CDI/HSI, as this switching, and its annunciation, were handled internally by the integrated box. In approving the initial installation of the Garmin GNS-430, the FAA found that many approvals of the GNS-430 could be completed without any remote annunciators<sup>6</sup>. The FAA approval of the GNS-430 set a precedent that led to the approval of thousands of installations without any remote annunciators, though the constraints on such installations were never well defined. In Canada, installations were generally not allowed on commuter and transport category aircraft without remote annunciators, but were allowed on many smaller Part 23 aircraft. The decision as to when remote annunciators were required, and which annunciators, was generally decided by the individual DAR or Regional Engineer, with little guidance other than that provided by Garmin and the FAA.

Technical Standard Orders (TSOs) are based on standards produced by RTCA Inc; DO-229 is the standard for GPS/WAAS Airborne Equipment<sup>7</sup>. The original wording of DO-229 included wording similar to AC 20-138<sup>8</sup>, suggesting remote annunciators were required in the pilot's primary field of view. However, in 1998, RTCA published DO-229A and introduced the concept of a "normal field of view", making it clear that many annunciations previously required in the pilot's primary field of view did not have to be so prominent<sup>9</sup>. In essence, those annunciations not normally provided on the CDI/HSI, could, per DO-229A, be provided anywhere between the airspeed indicator on the left, and the center radio stack on the right. Identical wording was incorporated into AC 20-138A in December 2003.

In summary, applicants have been faced with confusing and conflicting information as to when remote annunciators are required, and if required, what annunciators must be installed.

### **5.3 Application of AC 20-138A – What is a “Center Radio Stack”**

AC 20-138A is focused on smaller Part 23 aircraft, and presumably the authors were thinking of typical single engine Part 23 aircraft when they developed the definition of “normal field of view”. Transport Canada accepts that many installations may be done without remote annunciators, per AC 20-138A, but the term “center radio stack” must be constrained. In fact, in the majority of smaller single engine aircraft, the radio stack is displaced to the right of center; in some cases it is so far to the right that it is directly in front of the right seat pilot/passenger (e.g. older Beech Bonanzas and Barons). Some of these cannot be considered “center radio stacks”. Further, on larger aircraft, the distance from the attitude indicator to the “center radio stack” may be much more than what was envisioned when this wording was developed.

On most single engine Part 23 aircraft, the distance from the attitude indicator (AI) to the center of the instrument panel is 10”-14”. Since it is really the proximity of the radio stack to the attitude indicator that is of concern, Transport Canada will accept that any radio stack that is centered

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pilot's primary field of view) with the least practicable deviation from the pilot's normal position and line of vision when looking forward along the flight path.”

<sup>5</sup> The Garmin GNS-430, introduced in 1997, was the first such integrated GPS/VOR/ILS/COM.

<sup>6</sup> See Installation Memo from Garmin, dated 25 January 1999, and letter from FAA Small Airplane Directorate, also dated 25 January 1999. These are included in Appendix B of Garmin GNS-430 Installation manual at Rev H and later.

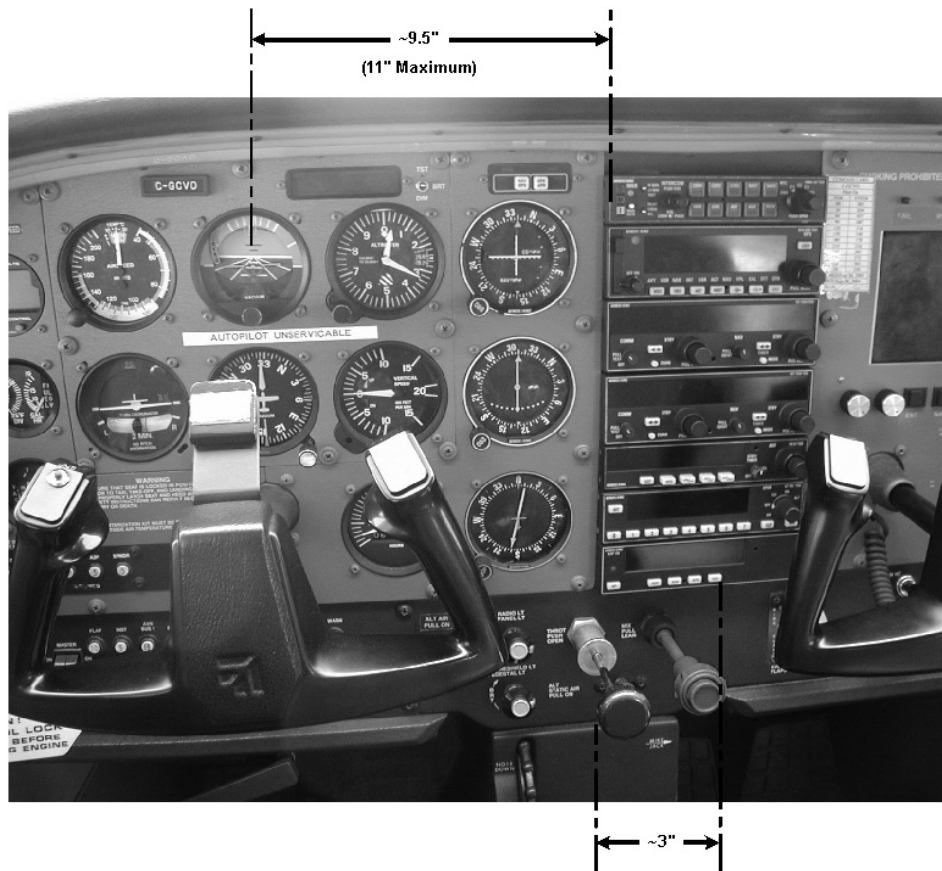
<sup>7</sup> RTCA, Inc., a not-for-profit corporation, publishes DO-229, titled “Minimum Operational Performance Standards For Global Positioning System/Wide Area Augmentation System Airborne Equipment”. DO-229, now at Rev C (DO-229C) is an internationally harmonized industry standard, referenced by TSO-C145a.

<sup>8</sup> DO-229 originally stated “The horizontal deviation display, displays used for failure annunciation, maneuver anticipation, and automatic mode switching shall be located within the pilot's primary field of view (i.e., within 15 degrees of the pilot's primary line of sight), as shall any indication requiring immediate aircrew action.”

<sup>9</sup> DO-229A (same wording remains in DO-229C) states, in paragraph 3.3.1.1.1: “The horizontal (and vertical) deviation(s) display(s) and failure annunciation shall be located within the pilot's primary field of view (i.e., within 15 degrees of the pilot's primary line of sight), as shall any indication requiring immediate aircrew action. “Displays used for loss of integrity monitoring, waypoint sequencing, start of a turn, turn anticipation, TO/FROM indication, approach mode annunciation, and automatic mode switching shall be located within the pilot's normal field of view. If the box is located in the center radio stack, the lateral normal field of view is from the center of the airspeed indicator to and including the box.”

within 14" of the centerline of the AI qualifies as a "center radio stack", per AC 20-138A, regardless of whether the radio stack is in the center of the instrument panel or not. Considering newer radios are a standard 6.25" wide, this means that if the AI centerline is within 11" of the closest edge of the radio stack, that radio stack qualifies as a "center radio stack".

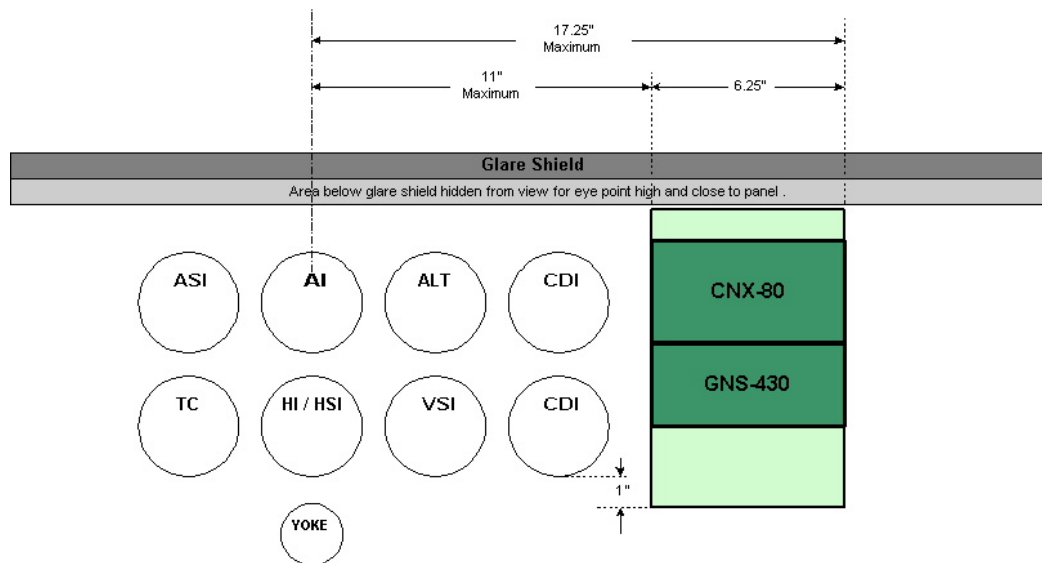
As an example, on most later model C-172s, the center radio stack is displaced about 3" to the right of center, but the distance from the AI to the edge of the radio stack is ~10". Thus this would qualify as a "center radio stack".



#### **5.4 Installations without Remote Annunciators – Dimensional Constraints**

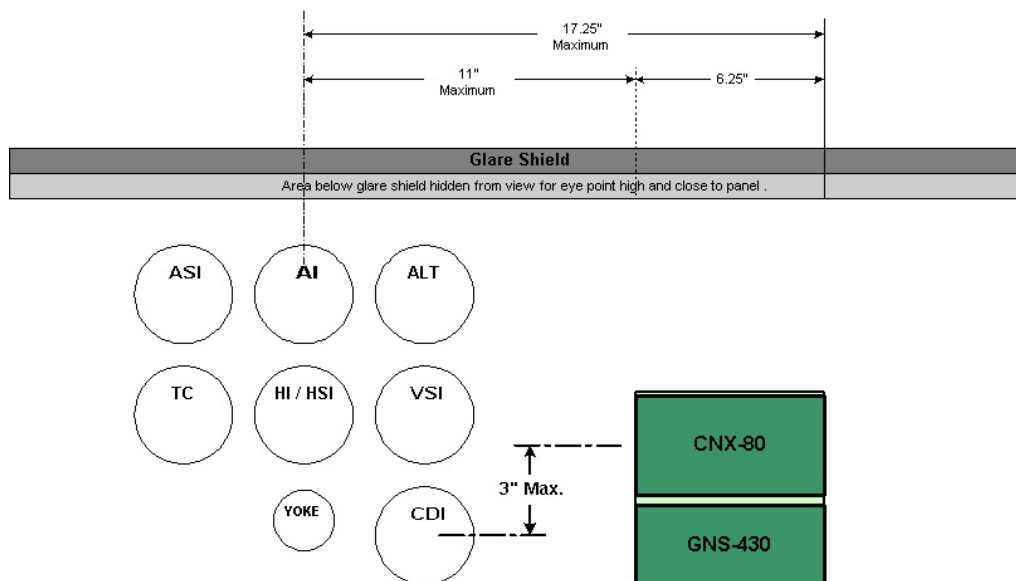
For GPS/GNSS receivers installed in the center radio stack, as constrained above, Transport Canada will accept the installations without remote annunciators, in accordance with AC 20-138A, provided certain conditions are met, as outlined in this section. The GPS/GNSS receiver must provide all required annunciations on the front of the receiver and must be intended for installation without remote annunciators<sup>10</sup>. The entire GPS/GNSS receiver and display must also be visible and unobstructed from the pilot's view, regardless of the pilot's sitting position. If movement of the upper torso, from a normal seated position, is required to see all or part of the receiver or display, its location is not acceptable. To facilitate an effective scan, the GPS/GNSS receiver should also be located at roughly the same height as the CDI/HSI that it is driving. If the CDI/HSI is level with the directional gyro, the receiver shall not be more than 1" below the CDI/HSI.

<sup>10</sup> This is the case for recently certified GPS/GNSS receivers such as the GNS-430/530, KLN-94, and CNX-80, but may not be true of some older receivers.



**CDIs to Right**  
Receiver shall not be >1\" below CDI.

If the CDI/HSI is below the directional gyro, the receiver shall not be below the CDI/HSI, as shown below.



**CDI to Lower Right**  
Receiver shall not be below CDI.

The center of the receiver should also be within 3\" vertically of the center of the CDI/HSI that it is driving.

The above guidance applies to the primary GPS/GNSS receiver and the primary CDI/HSI. It does not apply to an independent VOR/ILS, since there is no need to scan the receiver while flying an ILS approach. For aircraft in which two GPS/GNSS receivers are installed, it is recommended that the receivers be installed at roughly the same height as the CDIs that they are driving,

though it may not be possible to meet the 3" constraint. Generally, the primary receiver, which would normally drive the HSI, should be mounted above the secondary receiver.

## **5.5 Installations with Remote Annunciators – At Applicant's Discretion**

Even when the constraints of subsection 5.4 are met, remote annunciators can significantly improve a pilot's scan and reduce workload. For that reason, an applicant may choose to install remote annunciators in the pilot's primary field of view. In such a case, the guidelines below are recommended.

## **5.6 Installations that Require Remote Annunciators – What is Required**

In other installations, it may not be possible to meet the above dimensional constraints for locating the receiver. In such situations, remote annunciators and/or indicators will be required for an IFR approval. Note that the installed location of the GPS/GNSS receiver must still meet the requirements of 23.1321, regardless of whether remote annunciators are used. "Head movement" as used in 23.1321, is interpreted, in the context of an IFR GPS/GNSS receiver approval, to mean movement of the head without movement of the upper torso. If the installed location of the receiver requires a pilot to reposition his/her upper torso, from the normal piloting position, in order to read part of the display, or adjust a control, that location is not acceptable for installation of an IFR GPS/GNSS receiver.

AC 20-138A does not address what remote annunciators/indicators are required when the receiver cannot be located to preclude the need for such remote annunciators, so the following is provided as Transport Canada's position. Note that remote annunciators are considered any annunciators external to the GPS/GNSS receiver. They may be grouped on an annunciator control unit (e.g. MD-41), they may be individual annunciators, they may be integral to the CDI/HSI, or they may be displayed on an EFIS display.

### **5.6.1 Nav Source Annunciator**

Annunciation of nav source on or next to the affected CDI/HSI has long been considered a requirement, as the consequences of the pilot not knowing the navigation source could be hazardous. Thus an annunciation of nav source shall be included in the pilot's primary field of view, or immediately adjacent to the CDI/HSI that the GPS is driving, if remote annunciators are required. This annunciator is typically "NAV/GPS", "VLOC/GPS" or "VOR/GPS", and is typically green, cyan and/or white in colour.

### **5.6.2 Message Annunciator**

All newer GPS/GNSS receivers provide an array of messages for the pilot's information. If the constraints of subsection 5.4 cannot be met, a remote "message" annunciator is required to draw the pilot's attention to the existence of such a message. This annunciator is typically "MSG" or "GPS MSG", and is typically amber in colour.

### **5.6.3 Waypoint Annunciator & Distance-to-Go Indicator**

All GPS navigation is predicated on flying to waypoints, and pilots will regularly scan the distance-to-go indication to assist themselves with their situational awareness. If the distance-to-go indication is not within the pilot's normal scan, the head movement required to observe the distance-to-go indication can significantly disrupt an instrument scan. Furthermore, on some displays, there can be a lot of information presented on a small display, and distance to next waypoint may not be prominent on a cluttered display.

It is thus strongly recommended that if the constraints of subsection 5.4 cannot be met, a distance-to-go indicator should be provided within the pilot's primary field of view. Even if the constraints of subsection 5.4 can be met, it is recommended that consideration be given to providing distance-to-go indication within the pilot's primary field of view.

Unfortunately, often it may not be possible or practical to provide such a distance-to-go indicator within the pilot's primary field of view. While a waypoint annunciator does not provide the same information, nor will it obviate completely the need to scan the GPS/GNSS receiver, it may reduce



the frequency with which the receiver must be scanned, and will alert the pilot upon waypoint arrival. Even if distance-to-go is within the pilot's primary field of view, a waypoint annunciator provides a prominent and timely reminder of waypoint arrival. Thus, when the constraints of subsection 5.4 cannot be met, as a minimum, a waypoint annunciator is required within the pilot's primary field of view. This annunciator is typically "WPT" or "GPS WPT", and is typically amber in colour.

#### **5.6.4 Integrity or RAIM Annunciators**

GPS/GNSS receivers must be capable of annunciating when they should not be used for navigation, either because of some failure or because of poor satellite coverage. In some cases, the NAV flag will appear on the CDI/HSI, and course guidance will be removed, but in other situations, the indication may be subtler. A dedicated annunciator to indicate that the pilot should not rely on GPS navigation would provide the pilot with unambiguous information. Such annunciator is typically "INTEG", "GPS INTEG", "RAIM", or "LOI" (Loss of Integrity) and is typically amber in colour. However, if this annunciation is available on the receiver, and would also cause the message annunciator to illuminate, inclusion of a dedicated remote annunciator is optional.

#### **5.6.5 Approach/Terminal, or Approach Arm/Activate Annunciators**

GPS/GNSS receivers must annunciate when they are in Terminal or Approach mode. A dedicated annunciator to indicate the mode of operation would provide the pilot with unambiguous information. Such an annunciator typically consists of two segments, either one or no segments being illuminated at any given time. The segments are typically either "TERM/APR", or "GPS APR: ARM/ACT", and are typically green in colour. During normal approach operations, the mode of operation will change from Terminal to Approach at 2 Nm back from the FAF, and will then change back to Terminal mode when the missed approach is selected. The only time that the mode of operation might change unexpectedly would be following some other event (e.g. hardware failure, loss of satellite coverage), but such an event would be annunciated by a message light or other indication. Thus, if annunciation of mode of operation is available on the receiver, inclusion of a dedicated annunciator is optional.

#### **5.6.6 Other Annunciators**

The use of other remote annunciators, such as to indicate OBS/LEG, MAN/AUTO waypoint sequencing, Parallel Track, etc., are optional if these annunciations are readily available on the receiver.

#### **5.7 Installations not in the Instrument Panel**

Installations of GPS/GNSS receivers in locations other than the instrument panel (e.g. in the center pedestal) cannot meet the constraints of subsection 5.4 and must have the required remote annunciators noted in subsection 5.6.

#### **5.8 Installations in EFIS-Equipped Aircraft**

Installations of panel-mounted GPS/GNSS receivers in aircraft equipped with Electronic Flight Instrument Systems (EFIS) require special consideration. Generally, remote annunciations should be provided on the EFIS display, whenever possible. It is assumed that nav source and GPS distance-to-go will always be available on the EFIS display, but some older or simpler EFIS may not allow for annunciation of GPS/GNSS messages and other alerts. In such a situation, it is strongly recommended that, as a minimum, a GPS/GNSS message annunciator be provided in the pilot's primary field of view, even if the constraints of subsection 5.4 are met. If the constraints of subsection 5.4 are not met, then the required remote annunciators noted in subsection 5.6 must be in the pilot's primary field of view.

#### **5.9 Installations in Aircraft Operated by Two Crew**

Installations of panel-mounted GPS/GNSS receivers in aircraft certified for two pilots can be significantly more complex, and are beyond the scope of this PL.

For aircraft certified for single pilot operations, there is no certification requirement to provide any indicators or annunciators on the co-pilot's side. However, an operator may choose to provide GPS/GNSS navigation information on the co-pilot's side, either as back-up information, or to allow the pilot in the co-pilot's seat to perform all flying and navigating duties. If GPS guidance is provided to a CDI/HSI on the co-pilot's side, it is strongly recommended that the required annunciators noted above be installed for the co-pilot, if the constraints of subsection 5.4 cannot be met. Otherwise, a flight manual limitation may be added, requiring that GPS approaches be flown by the pilot in the pilot's seat.

## **6.0 SUMMARY**

This PL has provided guidance on the most common installation issues associated with the human factors considerations of GPS/GNSS installations on normal category airplanes. Acceptable locations have been defined for the CDI and for the GPS/GNSS receiver when no remote annunciators are to be used. The minimum acceptable remote annunciators, and their acceptable location, have also been defined. This position has been rationalized with existing regulations and guidance material, in particular AC 20-138A.

When situations arise that are beyond the scope of the installations discussed in this PL, it will be necessary to seek guidance from the Transport Canada Flight Test Division on the acceptability of the installation. This consultation should take place as early in the design cycle as possible.

## **7.0 HEADQUARTERS CONTACT**

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