Australian Government
Civil Aviation Safety Authority

ADVISORY CIRCULAR

AC 21-36
Global Navigation Satellite Systems (GNSS) Equipment: Airworthiness Guidelines

v2.2 – November 2014
Project Number: CS 12/16

Advisory Circulars are intended to provide advice and guidance to illustrate a means, but not necessarily the only means, of complying with the Regulations, or to explain certain regulatory requirements by providing informative, interpretative and explanatory material.

Advisory Circulars should always be read in conjunction with the relevant regulations.

Audience

This Advisory Circular (AC) applies to:

- Subpart 21.M authorised persons
- Subpart 21.J approved design organisations.

Purpose

The purpose of this AC is to provide guidance information on design, development and subsequent airworthiness approval of Global Navigation Satellite Systems equipment installations.

For further information

For further information on this AC, contact CASA's Airworthiness and Engineering Standards Branch (telephone 131 757).

Unless specified otherwise, all subregulations, regulations, divisions, subparts and parts referenced in this AC are references to the *Civil Aviation Safety Regulations 1998 (CASR)*.

Status

Version	Date	Details
2.2	Nov 2014	Error corrected in Table 3 to match RTCA/DO-229D
2.1	July 2014	Updated reference to FAA AC 20-138D and clarification of requirements
(1)	Jan 2013	Updated reference to FAA AC 20-138C and updated diagrams
(0)	April 2005	Initial release of the AC

Contents

1 Reference material

1.1 Acronyms

The acronyms and abbreviations used in this AC are listed in the table below.

Acronym	Description
ABAS	Aircraft Based Augmentation System
AC	Advisory Circular
ADS-B	Automatic Dependent Surveillance Broadcasting
AFM	Aircraft Flight Manual
AFM Supp	Aircraft Flight Manual Supplement
AI	Attitude Indicator
ALT	Altitude
AR	All revisions
CAO	Civil Aviation Order
CASA	Civil Aviation Safety Authority
CASR	*Civil Aviation Safety Regulations 1998*
CDI	Course Deviation Indicator
CDU	*Control Display Unit*
CFR	US Government *Code of Federal Regulations*
dBm	Decibel milliwatt
DO	Document (RTCA Inc)
EASA	European Aviation Safety Agency
EFIS	Electronic Flight Instrument System
ETSO	European Technical Standard Order
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FDE	Fault Detection and Exclusion
FOV	Field Of View
FRT	Fixed Radius Transitions
FTE	Flight Technical Error
GBAS	Ground Based Augmentation System
GLS	*GBAS* Positioning Landing System

Acronym	Description
GNSS	Global Navigation Satellite Systems
GPS	Global Positioning System
HFOM	Horizontal Figure Of Merit
HSI	Horizontal Situation Indicator
Hz	Hertz
ICA	Instructions for Continuing Airworthiness
IFR	Instrument Flight Rules
ILS	Instrument Landing System
INTEG	Integrity
LAAS	Local Area Augmentation System
LAME	Licenced Aircraft Maintenance Engineer
LNAV	Lateral Deviation
LODA	Letter Of Deviation Authority (FAA)
LOI	Loss Of Integrity
LPV	Localiser Performance with Vertical Guidance
MSG	Message
NAC	Navigation Accuracy Category
NAV	Navigation
NM	Nautical Mile
NPA	Non Precision Approach
NSE	Navigation System Error
OBS	Omni Bearing Selector
PBN	Performance Based Navigation
PVT	Position Velocity Time
RAIM	Receiver Autonomous Integrity Monitoring
RFI	Radio Frequency Interference
RF Legs	Radius to Fix path terminators
RMI	Radio Magnetic Indicator
RNAV	Area Navigation
RNP	Required Navigation Performance
SA	Selective Availability
SBAS	Satellite Based Augmentation System

Acronym	Description
STC	Supplemental Type Certificates
TAS	True Airspeed
TERM	Terminal
TSE	Total System Error
TSO	Technical Standard Order
TSOA	Technical Standard Orders Authorization (FAA)
VFR	Visual Flight Rules
VHF	Very High Frequency
VNAV	Vertical Navigation
VOR	VHF Omni-directional Radio Range
WAAS	Wide Area Augmentation System
WPT	Way-point

1.2 Definitions

Terms that have specific meaning within this AC are defined in the table below.

Term	Definition
Aircraft Based Augmentation System (ABAS)	An augmentation system that augments and/or integrates the information obtained from the other GNSS elements with information available on board the aircraft.
Ground Based Augmentation System (GBAS)	An augmentation system in which the user receives augmentation information directly from a ground-based transmitter.
Satellite Based Augmentation System (SBAS)	A wide coverage augmentation system in which the user receives augmentation information from a satellite-based transmitter.
Local Area Augmentation System (LAAS)	The GBAS provided by the FAA.
Wide Area Augmentation System (WAAS)	The SBAS provided by the FAA and is limited to continental USA only.
Fault Detection and Exclusion (FDE)	A receiver processing scheme that autonomously provides integrity monitoring for the position solution, using redundant range measurements. The FDE consist of two distinct parts: fault detection and fault exclusion. The fault detection part detects the presence of an unacceptably large position error for a given mode of flight. Upon the detection, fault exclusion follows and excludes the source of the unacceptably large position error, thereby allowing navigation to return to normal performance without an interruption in service.

Term	Definition
Galileo	The European Union satellite-based radio navigation system currently under development, which will provide a positioning service anywhere in the world.
Integrity	A measure of the trust that can be placed in the correctness of the information supplied by the total system. Integrity includes the ability of a system to provide timely and valid warnings to the user (alerts).
Global Positioning System (GPS)	The satellite navigation system operated by the United States.
Global Navigation Satellite System (GLONASS)	The satellite navigation system operated by the Russian Federation.
Selective Availability (SA)	Selective Availability is a requirement for the receiver to properly account for satellite range error if it is reflected in the User Range Accuracy index (commonly referred to as being “Selective Availability aware”).

1.3 References

Regulations

Regulations are available on the ComLaw website http://www.comlaw.gov.au/Home

Document	Title
Part 21 of CASR	Certification and airworthiness requirements for aircraft and parts
Part 23 of CASR	Airworthiness standards for aeroplanes in the normal, utility, acrobatic or commuter category
Part 25 of CASR	Airworthiness standards for aeroplanes in the transport category
Part 26 of CASR	Airworthiness standards for aircraft in the primary category or intermediate category
Part 27 of CASR	Airworthiness standards for rotorcraft in the normal category
Part 29 of CASR	Airworthiness standards for rotorcraft in the transport category
MOS Subpart 91.U	Manual of Standards Subpart 91.U Instrument 2005 — navigation authorisations
CASA 80/14	Instructions – use of Global Navigation Satellite System (GNSS)
CAO 20.18	Part B of Appendix XI - ADS-B transmitting equipment — standard for approval
CAO 20.91	Instructions and directions for performance-based navigation

Advisory material

CASA's advisory material is available at http://www.casa.gov.au/scripts/nc.dll?WCMS:STANDARD::pc=PC_90902

Document	Title
AC 21-37	Airworthiness Approval of Navigation or Flight Management Systems Integrating Multiple Navigation Sensors
AC 21-38	Aircraft Electrical Load Analysis and Power Source Capacity
AC 21-99	Aircraft Wiring and Bonding
AC 91U-2	Required Navigation Performance 10 (RNP 10) Operational Authorisation
AC 91U-3	Required Navigation Performance 4 (RNP 4) Operational Authorisation
AC 91U-II-B-2	Navigation Authorisations – RNAV 5
AC 91U-II-B-3	Navigation Authorisations – RNAV 1 & 2
AC 91U-II-C-2	Navigation Authorisations – RNP 2
AC 91U-II-C-3	Navigation Authorisations – RNP 1
AC 91U-II-C-5	Navigation Authorisations – RNP APCH

Guidance material

Document	Title
AN10-V1	Volume 1 - Radio Navigation Aids of Annex 10 Aeronautical Telecommunications, of the Chicago Convention
ICAO Doc 9613 v4	Performance-Based Navigation Manual
FAA AC 20-138D	Airworthiness Approval of Positioning and Navigation Systems
FAA AC 23-1311-1C	Installation of Electronic Displays in Part 23 Airplanes
PSACE100-2001-004	FAA Public Statement Number PSACE100- 2001-004 on Guidance for Reviewing Certification Plans to Address Human Factors for Certification of Part 23 Small Airplanes
TC 523-008	Transport Canada Policy Letter 523-008, "Design Guidelines and Human Factors Considerations for Installation of IFR GPS/GNSS Receivers
RTCA DO-208	Minimum Operational Performance Standards for Airborne Supplemental Navigation Equipment Using Global Positioning System (GPS)
RTCA DO-229D	Minimum Operational Performance Standards for Global Positioning System/Wide Area Augmentation System Airborne Equipment
RTCA DO-253C	Minimum Operational Performance Standards for GPS Local Area Augmentation System Airborne Equipment
RTCA DO-316	Minimum Operational Performance Standards for Global Positioning System/Aircraft Base Augmentation System

2 GNSS usage

2.1 Operational uses of GNSS

2.1.1 GNSS installations

2.1.1.1 This AC is designed to expand on installation requirements of GNSS equipment in conjunction with FAA AC 20-138D. This equipment may be either of the following:

- GNSS stand-alone equipment that provides deviations (steering commands) for en-route, terminal or approach operations (including Localizer Performance with Vertical Guidance (LPV))
- GNSS sensors integrated into a multi-sensor navigation or flight management system.

2.1.1.2 The GNSS equipment may be used in the following situations:

- Navigation under the Visual Flight Rules (VFR):
  - Visual Navigation and
  - Night VFR Area Navigation
- Navigation under the Instrument Flight Rules (IFR):
  - Dead Reckoning (DR) Substitute
- Performance Based Navigation (PBN):
  - RNAV 10 (authorised as RNP 10)
  - RNAV 5
  - RNAV 1 and RNAV 2
  - RNP 4 (dual independent systems required)
  - RNP 2
  - RNP 1
  - RNP 0.3 (primarily for helicopter operations)
  - RNP APCH (LNAV,LNAV/VNAC, LP and LPV)
  - RNP AR APCH and
  - APV Baro-VNAV
- Supplemental Performance-Based Navigation specifications:
  - APV Baro-VNAV
  - Radius to Fix path terminators (RF Legs)
  - Fixed Radius Transitions
  - Oceanic area navigation outside RNP 10 and RNP 4 designated airspace
  - North Atlantic Minimum Navigation Performance Specification and
  - GBAS Landing System (GLS).

3 Equipment standards

3.1 Introduction

3.1.1 Since the initial approval of GNSS in Australia (1993) as an en-route supplemental means of navigation, ongoing developments to receiver design, and improved accuracy guarantee together with the gathering of an extensive knowledge base has increased the applicability and acceptance of GNSS navigation. This includes the development and deployment of augmentation systems that enhance the accuracy and availability of GNSS navigation data.

3.2 TSO-C129(AR)

3.2.1 Equipment cancellation

3.2.1.1 TSO-C129(AR) Class A equipment is a sensor/navigation computer combination. The provision of pressure altitude data from an approved source (i.e. barometric aiding) is a mandatory requirement for approval of the installation of TSO-129a A1 or A2 based GNSS equipment intended for IFR area navigation operations as detailed in CAO 20.91.

3.2.1.2 TSO-C129a has been cancelled, but this does not affect existing equipment. Equipment produced under FAA TSO-C129(AR) is still eligible for installation in accordance with the guidance in this AC. For further information on alternatives to TSO-C129 equipment see paragraph 3.3.2 of this AC.

3.2.1.3 There are no re-use or replacement possibilities for antennae certified under TSO-C129/C129a.

	Equipment Characteristics					Equipment Capability		
Class	**Stand Alone**	**Multi-Sensor**	**Auto Pilot Req[1]**	**RAIM**	**RAIM Equiv[2]**	**Enroute**	**Terminal**	**Non Precision Approach**
A1	✓			✓		✓	✓	✓
A2	✓			✓		✓	✓	
B1		✓		✓		✓	✓	✓
B2		✓		✓		✓	✓	
B3		✓			✓	✓	✓	✓
B4		✓			✓	✓	✓	
C1		✓	✓	✓		✓	✓	✓
C2		✓	✓	✓		✓	✓	
C3		✓	✓		✓	✓	✓	✓
C4		✓	✓		✓	✓	✓	

Table 1 - TSO-C129(AR) - Equipment Classes

Notes:

1. Intended to provide data to an integrated navigation system which provides enhanced guidance to an autopilot/flight director to reduce flight technical error and limited to CASR Part 121 aircraft.
2. Requirement for the integrated navigation system to provide a level of GNSS integrity equivalent to Receiver Autonomous Integrity Monitor (RAIM).

3.2.2 Effective Noise Density

3.2.2.1 Equipment not meeting the effective noise density e.g. TSO-C129(AR) may experience performance degradation as more GNSS satellites are launched. Equipment intended for use beyond 2020 in applications such as Automatic Dependent Surveillance Broadcasting (ADS-B) should be qualified using the effective noise density as below in Table 2 below.

Receiver Function	**Effective Noise Density**
Initial Acquisition (GPS Only)	-172.2 (dBm/Hz)
GPS Tracking and Re-acquisition	-171.9 (dBm/Hz)
SBAS Tracking and Re-acquisition	-172.8 (dBm/Hz)

Table 2 - Effective Noise Density

3.3 TSO-C145(AR)/TSO-C146(AR)

3.3.1 TSO-C145c defines an acceptable standard for Airborne Navigation Sensors using GPS augmentation by WAAS. TSO-C146c defines an acceptable standard for Stand-Alone Airborne Navigation Equipment using GPS augmentation by WAAS. There are no equipment performance limitations for GPS/SBAS equipped aircraft to have other positioning and navigation systems on-board. There are no plans to withdraw authorisations for TSO-C145a/C146a or TSO-C145b/C146b equipment.

3.3.2 TSO-C129 equipment alternatives

3.3.3 TSO-C129a was cancelled effective 21 November 2011 as it did not provide sufficient performance for all operational applications. Airborne navigation equipment previously approved under all revisions of TSO-Cl29(AR) may still be installed under the provisions of their original approval.

3.3.4 GPS/SBAS TSO-C146(AR) Class Gamma equipment is considered the direct replacement for a Class A sensor/navigation computer combination certified to TSO-C129(AR). Additionally, TSO-C145(AR) equipment can also replace TSO-C129(AR) Class B & C sensors.

3.3.5 Applicants will have to establish sensor/antenna compatibility when replacing TSO-C129(AR) sensors with TSO-C145(AR) sensors.

3.3.6 The items of equipment listed in Table 3 meet the functional Class Gamma or Class Delta of FAA TSO-C145/145c.

Class											
Functional	**Operational**	**Domestic Enroute**	**Oceanic Enroute**	**Terminal**	**Departure**	**NPA**	**LNAV/ NAV**	**Approach(LP and LPV)**	**ILS**	**Integrated sensor**	**Stand alone**
Beta	1	✓	✓	✓	✓					✓	
Beta	2	✓	✓	✓	✓	✓	✓			✓	
Beta	3	✓	✓	✓	✓	✓	✓	✓		✓	
Gamma	1	✓	✓	✓	✓						✓
Gamma	2	✓	✓	✓	✓	✓	✓				✓
Gamma	3	✓	✓	✓	✓	✓	✓	✓			✓
Delta	4							✓	✓		

Table 3 - TSO-C145(AR) and TSO-C146(AR) - Equipment Classes

3.4 TSO-C161a/C162a(AR)

3.4.1 TSO-C161a defines an acceptable standard for GPS/GBAS that provides precision approach capability and Position, Velocity and Time (PVT) information. TSO-C162a defines an acceptable standard for GPS/GBAS equipment designed to receive Very High Frequency (VHF) data broadcast.

3.5 TSO-C196(AR)

3.5.1 TSO-C196b defines an acceptable standard for an Airborne Navigation Sensor using GPS equipment without ground-based or space-based augmentation. TSO-C196a will remain effective for new equipment manufactured until 20 June 2015.

3.5.2 The TSO has been updated to revision “b” to allow applicants to optionally use TSO-C206 GPS Circuit Card Assembly (CCA) (see FAA TSO-C196b for further details). TSO-C196(AR) GPS sensors are intended for use in multi-sensor navigation systems (refer to Table 4). TSO-C196a equipment is intended as a direct replacement for Class B & C sensors certified to TSO-C129(AR). The basis for this TSO is Class Beta 1 without SBAS requirements.

Class		Domestic Enroute	Oceanic Enroute	Terminal	Departure	NPA	LNAV/ NAV	Precision	ILS	Integrated sensor	Stand alone
Functional	Operational										
Beta	1	✓	✓	✓	✓	✓	✓			✓	

Table 4 - TSO-C196 Equipment Class

3.5.3 Improvements with TSO-C196 are:

- Selective Availability aware
- fault detection and exclusion
- improve interference rejection
- ensure no degradation due to other satellite systems.

3.5.4 It is acceptable for TSO-C145b/c sensors to simply disable GPS/SBAS tracking loops to qualify as a TSO-C196a.

3.5.5 TSO-C196 equipment still requires other navigation equipment to be available unless operating in oceanic and remote areas, provided the operator obtains a Fault Detection and Exclusion (FDE) prediction program. These limitations must be documented in the installation/instruction manual.

3.5.6 Applicants will have to establish sensor/antenna compatibility when replacing TSO-129(AR) sensors with TSO-C196 sensors. See paragraph 5-5.4 of FAA AC 20-138D for antenna compatibility.

3.6 TSO-C115(AR)

3.6.1 TSO-C115c defines an acceptable standard for Flight Management System (FMS) using Multi-Sensor inputs. It is not acceptable to use systems certified to TSO-C115 revisions for GNSS sensor integration, unless they are at revision “b” or later.

3.6.2 There are no plans to withdraw TSO-C115b or earlier versions. For more information on TSO-C115(AR) see FAA AC 20-138(AR).

4 Design, Development and approval of modifications

4.1 Application of guidance material

4.1.1 FAA AC 20-138D is endorsed by CASA as appropriate guidance material for the design, development and approval of modifications intended for Australian registered aircraft involving the installation of GNSS equipment. Copies of this AC may be obtained from the FAA website at http://rgl.faa.gov/

4.1.2 References to the FAA procedures, documentation and regulatory requirements contained in FAA AC 20-138D are not applicable to Australian registered aircraft. All modifications to Australian registered aircraft must comply with Australian regulations.

4.1.3 CASA related ACs - AC 21-38 – *Aircraft Electrical Load Analysis and Power Source Capacity* and AC 21-99 – *Aircraft Wiring and Bonding* provide additional guidance material for consideration during design and installation.

5 Human Factors considerations

5.1 Human factors guidance

5.1.1 Concerns have been expressed that there is insufficient and sometimes conflicting guidance material with respect to the human factors issues of GNSS receiver installations. This section is intended to provide guidance, in practical terms, in identifying acceptable locations for IFR installations of GNSS receivers installed without remote annunciators, the associated Course Deviation Indicators (CDI) and when required, the remote annunciators and/or indicators that are to be installed.

5.1.2 The goal is to ensure an efficient and concise instrument scan. The principles explained below, whilst primarily aimed at installations into normal category aircraft, may be applied to other aircraft.

5.1.3 For further information on human factors considerations refer to:

- FAA AC 20-138D Section 12-11- *General Human Factors Considerations*
- FAA Public Statement Number PSACE100-2001-004 on *Guidance for Reviewing Certification Plans to Address Human Factors for Certification of Part 23 Small Airplanes*.

6 General design considerations

6.1 PBN

6.1.1 In planning an IFR GNSS installation in an existing aircraft, there are a number of inter-related design considerations, all of which are dependent on the existing instrument panel of the aircraft in question. The PBN requirements are in addition to the other airworthiness installation requirements. The PBN requirements are detailed in the relevant CASA ACs that are listed in the References section of this AC.

6.2 Deviations from the Basic T configuration

6.2.1 Deviations from the basic T-configuration (14 CFR 23.1321) have been approved for individual instrument arrangements if the droop angle (angle below the 14 CFR 23.1321(d) position) is 15° or less, or if the elevated angle is 10° or less, see Figure 1: *Basic T configuration -horizontal reference line.* These angles are measured from a horizontal reference line that passes through the centre of the attitude reference data with lines passing through the centre of the airspeed and altitude data.

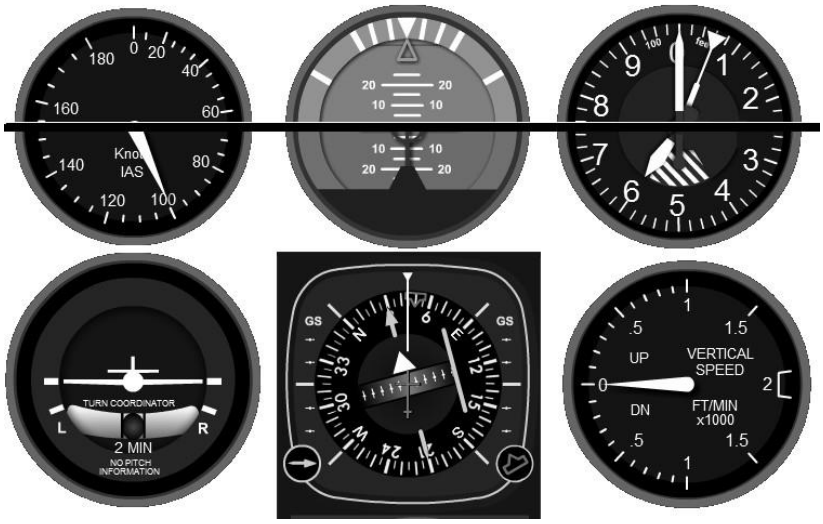

Figure 1 - Basic T configuration - horizontal reference line

6.3 Pilot field of view

6.3.1 The pilot should be able to use all the required instruments with “minimum head and eye movement". Primary optimum (Field Of View) (FOV) is based on the vertical and horizontal visual fields from the design eye reference point that can be accommodated with eye rotation only.

6.3.2 With the normal line-of-sight established at 15° below the horizontal plane, the values for the vertical and horizontal (relative to normal line-of-sight forward of the aircraft) are ±15°, as shown in Figure 2. This area is normally reserved for primary flight information and high priority alerts.

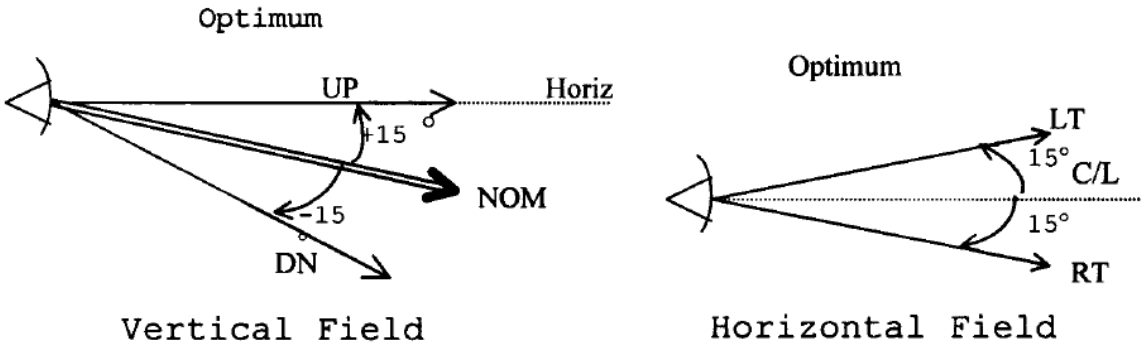

Figure 2 - Optimum FOV

6.4 Course deviation indicator

6.4.1 Installation of a GNSS receiver certified for IFR operations requires that the GNSS be connected to a remote CDI or Horizontal Situation Indicator (HSI), either conventional or electronic. This CDI/HSI is to 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.

6.4.2 Paragraph 12-11b. (1) - *General Human Factors Considerations* - of FAA AC 20-138D, requires each display element (including the CDI) be located clearly visible to the pilot. The CDI connected to a GNSS receiver to be within the pilot's primary FOV.

6.4.3 By assuming a typical minimum eye-to-instrument panel distance of 600 mm, the 15° FOV figure equates to a circle with a radius of approximately 160 mm. This would mean that the CDI would need to be within approximately a 160 mm radius of the centre of the Attitude Indicator (AI) on most aircraft. 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 FAA AC 20-138D was not to mandate a HSI in every GNSS equipped aircraft, as experience has shown that a CDI external to the basic "T" may be acceptable.

6.4.4 Depending on the layout of other instruments and indicators that are to be included in the scan, including the GNSS receiver that is normally installed in the centre 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 locations identified in Figure 3 for an external CDI may be considered acceptable.

6.4.5 The acceptable locations identified in Figure 3 are considered appropriate for aircraft that do not have a HSI. Aircraft that use a HSI to show track deviation for a *VHF Omni-directional Radio Range/ Instrument Landing System* VOR/ILS should also show GNSS track deviation on the same HSI, for the primary GNSS receiver. CDI for a secondary GNSS receiver, or a back-up indicator for the primary GNSS receiver, does not need to meet the constraints described in this section.

6.4.6 The CDI is to 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.

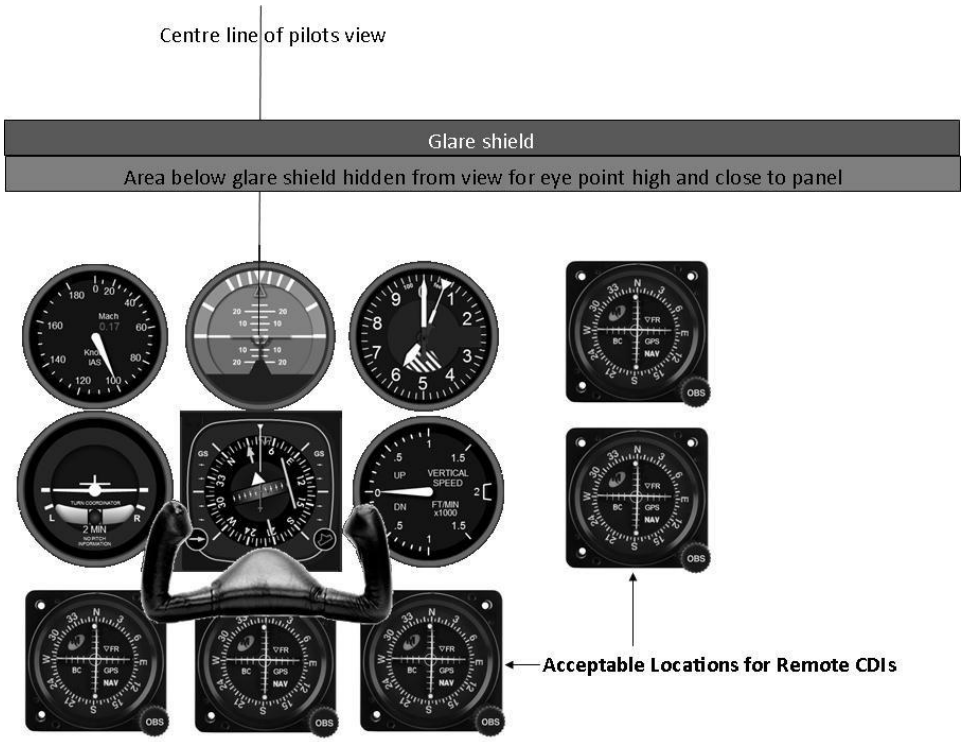

Figure 3 - Acceptable locations for remote CDI

Note: As some manufacturers do not recommend that their receivers be installed without remote CDIs, the designer should consider this fact and justify any deviation.

6.5 Remote annunciators

6.5.1 In the early days of GNSS IFR approvals, it was generally accepted that certain remote annunciators were required for an IFR approach approval.

6.5.2 Foremost amongst these was a requirement that when it was possible to display navigation information from more than one source on the same CDI/HSI, the navigation source driving that CDI/HSI was to be annunciated.

Note: See paragraph 14.3a - Navigation Source Selection of FAA AC 20-138D.

6.5.3 Remote annunciators were also common for Message (MSG), Way-point (WPT), GNSS Approach ARM/ACT and Omni Bearing Selector OBS/LEG, though the requirement for these annunciators was somewhat open to interpretation. Paragraph 12-11b - General Human Factors Considerations - Display Visibility of FAA AC 20-138D, clearly required navigation source annunciation, but there is also a requirement for failure annunciation to be located within the pilot's primary FOV.

6.5.4 Since all annunciators must be clearly visible under all lighting conditions, some annunciators incorporated into GNSS equipment may not meet the requirements. It is recommended that remote annunciators be installed within the primary FOV.

6.5.5 In the early development of GNSS in Australia, the design of an installation that featured automatic override of the GNSS navigation source by ILS data was not recommended. This was due in part to the possible differences between the published ILS and GNSS approaches. As the deactivation of this feature could only be done at the hardware level and involved wiring changes, it was considered prudent to have the installation designed with this consideration in mind.

6.5.6 However, some examples of modern equipment have this feature available as an internal function and which may be capable of being set by the aircrew. An example is that with the introduction of these integrated GNSS/VOR/ILS systems (e.g. Garmin GNS-430), an external switch is no longer required for a GNSS and VOR/ILS to share a common CDI/HSI, as the switching and annunciations are handled internally. 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.

Note: Installation Memo from Garmin, dated 25 January 1999, and letter from FAA Small Airplane Directorate, also dated 25 January 1999 provide further information. These are included in Appendix B of Garmin GNS-430 Installation Manual at Rev H and later.

6.5.7 This guidance is still applicable, however the design may incorporate the automatic override feature providing sufficient indication is provided to the pilot, together with appropriate procedures in the AFM Supp, to ensure an unambiguous notification of the source of the displayed navigation data. This would be especially important for autopilot/flight director coupled systems.

6.5.8 RTCA, Inc. document, DO-208, titled "Minimum Operational Performance Standards for Airborne Supplemental Navigation Equipment using Global Positioning System (GPS)" is the standard that defines the performance and functional requirements for TSO 129 and 129a equipment. TSO-129a has been cancelled, but this does not affect equipment with existing TSOA/LODA approvals.

6.5.9 RTCA, Inc. document, DO-229, titled "Minimum Operational Performance Standards for Global Positioning System/Wide Area Augmentation System Airborne Equipment", now at Revision D, is the standard that defines the performance and functional requirements TSO-C145, TSO-C146 and TSO-C196 equipment.

6.5.10 RTCA/DO-229 originally stated:

> "The horizontal deviation display, displays used for failure annunciation, manoeuvre anticipation, and automatic mode switching shall be located within the pilot's primary field of view (i.e., within 15° of the pilot's primary line of sight), as shall any indication requiring immediate aircrew action."

6.5.11 RTCA/DO-229A was issued in 1998 and introduced the concept of a "normal field of view", making it clear that many annunciations previously required in the pilot's primary FOV did not have to be so prominent.

6.5.12 Location of loss of integrity (LOI) monitoring & other annunciations

6.5.12.1 Displays used for way-point sequencing, start of a turn, turn anticipation, active way-point, distance to active way-point, desired track and track (or track angle error), and automatic mode switching should be located within the pilot's primary FOV, or, on a readily accessible display page.

6.5.12.2 Displays used for LOI monitoring, TO/FROM indication, approach mode annunciation should be located within the pilots' primary FOV.

6.5.12.3 Traditionally, 14 CFR Part 23 airplanes with "classic" analog instrumentation in the "basic T" arrangement have included the centre radio stack within the allowable FOV to satisfy this guidance.

6.5.12.4 In essence, those annunciations not normally provided on the CDI/HSI, could, per FAA AC 20-138D, be provided anywhere between the airspeed indicator on the left, and the centre radio stack on the right.

> "The primary field of view definition should be broad enough to include the centre radio stack on FAR Part 23 airplanes with "classic", analog basic 'T'"

6.5.12.5 Operational experience has shown that systems with the system annunciators on the front panel and installed in the radio stack are often not observed by pilots and consideration should be given to optimising the location of these annunciators. Bright cockpit light conditions, particularly with direct sunlight, aggravate the condition. It is therefore strongly recommended that system annunciators are located in the primary FOV for each required pilot.

6.5.13 Definition of centre radio stack

6.5.13.1 FAA AC 20-138D is focused on smaller normal category aircraft, and that fact presumably influenced the development of the definition of "optimum field of view". CASA accepts that many installations are installed without remote annunciators, per FAA AC 20-138D, but the term "centre radio stack" needs constraining.

6.5.13.2 In fact, in the majority of smaller single engine aircraft, the radio stack is displaced to the right of centre; 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 "centre radio stacks". Further, on larger aircraft, the distance from the AI to the "centre radio stack" may be much more than what was envisioned when this wording was developed.

6.5.13.3 On most single engine normal category aircraft, the distance from the AI to the centre of the instrument panel is 250–350 mm. Since it is really the proximity of the radio stack to the AI that is of concern, CASA will accept that any radio stack that is centred within 350 mm of the centreline of the AI qualifies as a "centre radio stack", per FAA AC 20-138D, regardless of whether the radio stack is in the centre of the instrument panel or not. Considering newer radios are a standard 6.25" (~160 mm) wide, this means that if the AI centreline is within 280 mm of the closest edge of the radio stack, that radio stack qualifies as a "centre radio stack".

6.5.13.4 As an example, on most later model Cessna C-172s (refer Figure 4 - Typical Cessna 172 instrument panel), the centre radio stack is displaced about 75 mm to the right of centre, but the distance from the AI to the edge of the radio stack is ~240 mm. This would qualify as a "centre radio stack".

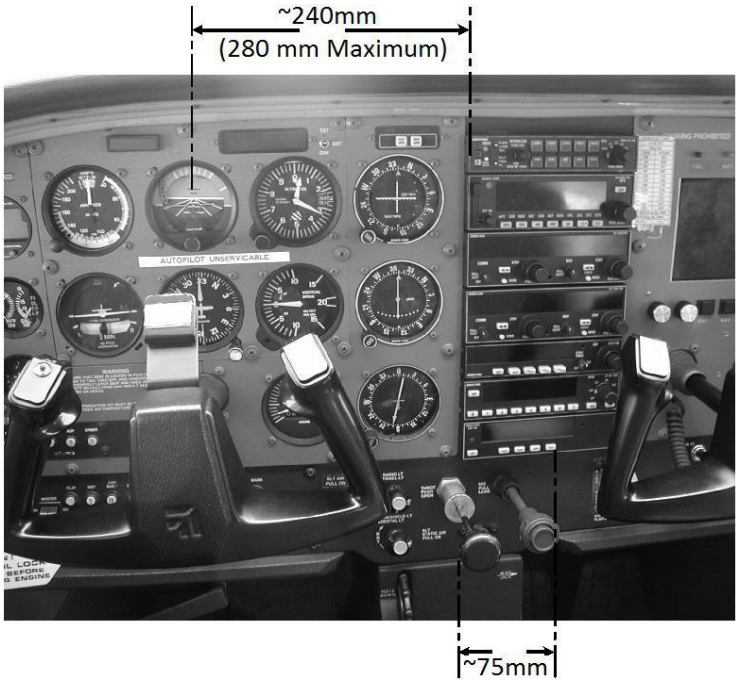

Figure 4 - Typical Cessna 172 instrument panel

6.5.14 Installations without remote annunciators

6.5.14.1 For GNSS receivers installed in the centre radio stack, as constrained above, CASA will accept the installations without remote annunciators, in accordance with FAA AC 20-138D, provided certain conditions are met.

6.5.14.2 The GNSS receiver is to provide all required annunciations on the front of the receiver and is to be intended for installation without remote annunciators. The entire GNSS receiver and display is to be visible and unobstructed from the pilot's view, regardless of the pilot's sitting position. The annunciators must be visible under all lighting conditions.

6.5.14.3 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 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 should not be more than 25 mm below the CDI/HSI as shown in Figure 5.

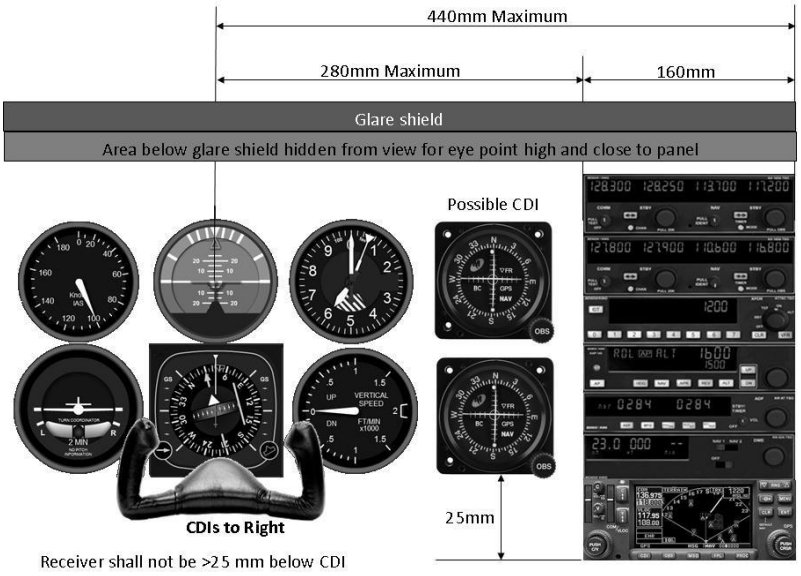

Figure 5 - Location of GNSS receiver - Position 1

6.5.14.4 If the CDI/HSI is below the directional gyro, the receiver should not be below the CDI/HSI, as shown in Figure 6. The centre of the receiver should also be within 75 mm vertically of the centre of the CDI/HSI that it is driving.

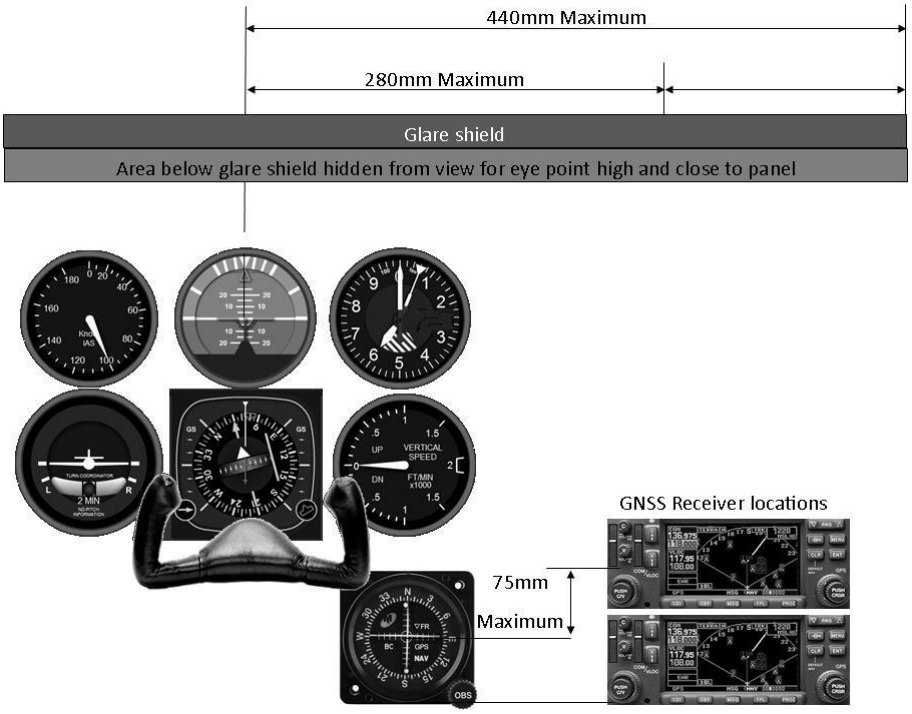

Figure 6 - Location of GNSS receiver - Position 2

6.5.14.5 The above guidance applies to the primary GNSS receiver and the primary CDI/HSI. For aircraft in which two GNSS receivers are installed, it is recommended that the receivers be installed at approximately the same height as the CDIs that they are driving, though it may not be possible to meet the 75 mm constraint. Generally, the primary receiver, which would normally drive the HSI, should be mounted above the secondary receiver.

6.5.15 Installations with Remote Annunciators

6.5.15.1 Even when the constraints of paragraph 6.5.14 Installations without remote annunciators 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 FOV. In such a case, the guidelines below are recommended.

6.5.15.2 If GNSS receivers are installed in a location other than the instrument panel (e.g. in the centre pedestal), then these installations are required to have remote annunciators.

6.5.15.3 For installations containing more than one approach navigation source, the navigation source (for example ILS, GPS/GBAS etc.) selected for the approach requires positive indication in the primary FOV. It is important to consider the overall aircraft-level annunciation philosophy.

Note: Aircraft requiring two pilots must have this annunciation at each pilot station.

6.5.15.4 The approach type (GLS) requires annunciation to the flight crew prior to and throughout the entire approach in the primary FOV.

6.5.16 Requirements for installations with Remote Annunciators

6.5.16.1 In other installations, it may prove problematic to meet dimensional constraints for locating receivers. In such situations, remote annunciators and/or indicators are required for IFR approval. The installed location of the GNSS receiver is still required to meet 14 CFR 23.1321, 25.1321, 27.1321 or 29.1321 regardless of whether remote annunciators are used.

6.5.16.2 "Head movement" as used in 14 CFR Part 23.1321, is interpreted, in the context of an IFR 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 GNSS receiver.

6.5.16.3 The following guidance is provided, as FAA AC 20-138C and 138D does not address what remote annunciators/indicators are required when the receiver cannot be located to preclude the need for such remote annunciators.

6.5.16.4 Remote annunciators are defined as annunciators that are external to the GNSS receiver and different configurations are:

- grouped on an annunciator control unit (e.g. MD-41)
- individual annunciators
- integral to the CDI/HSI or
- displayed on an Electronic Flight Instrument System (EFIS) display.

6.5.17 Nav Source Selector

6.5.17.1 Annunciation of the navigation 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.

6.5.17.2 Annunciation of the navigation source requires locating in the pilot's primary FOV, or immediately adjacent to the CDI/HSI that the GNSS is driving, if remote annunciators are required. This annunciator is typically "NAV/GNSS", "VLOC/GNSS" or "VOR/GNSS", and is typically green, cyan and/or white in colour.

6.5.17.3 The navigation source indicator must show the system actually driving the CDI/HSI and not indicate the system selected with the intent of providing the display (displaying selection switch position rather than the actual source selected is potentially a case of misleading information and is not permitted).

6.5.18 Message Annunciator

6.5.18.1 All newer GNSS receivers provide an array of messages for the pilot's information. If meeting the constraints of paragraph 6.5.14 of this AC is not possible, 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 "GNSS MSG", and is typically amber in colour. The pilot's primary FOV is the ideal location for the message annunciator.

6.5.19 Way-point Annunciator & Distance-to-Go Indicator

6.5.19.1 All GNSS navigation is predicated on flying to way-points, and pilots will regularly scan the distance-to-go indicator to assist themselves with their situational awareness. If the distance-to-go indicator 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. Some displays can present a lot of information on a small display, and distance to next way-point is sometimes not prominent on a cluttered display.

6.5.19.2 It is recommended that if it is not possible to meet the constraints of paragraph 6.5.14 of this AC, then it is recommended to install a distance-to-go indicator within the pilot's primary FOV. It is still recommended to consider providing distance-to-go indication within the pilot's primary FOV, even if the constraints of paragraph 6.5.4 of this AC are met.

6.5.19.3 Often it may not be possible or practical to provide such a distance-to-go indicator within the pilot's primary FOV. A way-point annunciator does not provide the same information, nor will it obviate completely the need to scan the GNSS receiver, it may reduce the frequency of scanning the receiver, and will alert the pilot upon arrival.

6.5.19.4 If distance-to-go is within the pilot's primary FOV, a way-point annunciator provides a prominent and timely reminder of way-point arrival. Thus, when it is not possible to meet the constraints of paragraph 6.5.14 of this AC, as a minimum, consider placing a way-point annunciator within the pilot's primary FOV. This annunciator is typically "WPT" or "GNSS WPT", and is typically amber in colour.

6.5.20 Integrity or Receiver Autonomous Integrity Monitor (RAIM) Annunciators

6.5.20.1 GNSS receivers are required to have capability 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 the course guidance is removed, but in other situations, there are subtler indications.

6.5.20.2 A dedicated annunciator to indicate that the pilot should not rely on GNSS navigation would provide the pilot with unambiguous information. Such an annunciator is typically "RAIM", "INTEG", "GNSS INTEG" or "LOI" and is typically amber in colour. If this annunciation is available on the receiver and also causes the message annunciator to illuminate, inclusion of a dedicated remote annunciator is optional. As a minimum, consider placing the integrity or RAIM annunciator in the pilot's primary FOV.

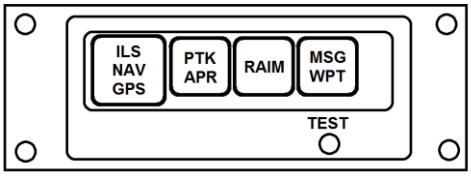

Figure 7 - RAIM annunciator

6.5.21 Approach/Terminal, or Approach Arm/Activate Annunciators

6.5.21.1 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 Terminal/Approach "TERM/APR", or "GNSS APR: ARM/ACT", and are typically green in colour.

6.5.21.2 During normal approach operations, the mode of operation will change from Terminal to Approach at 2 Nm back from the Final Approach Fix (FAF), and will then change back to Terminal mode when the missed approach is selected.

6.5.21.3 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.

6.5.22 Other Annunciators

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

6.6 Installations in Electronic Flight Instrument Systems Equipped Aircraft

6.6.1 Installations of panel-mounted GNSS receivers, in aircraft equipped with EFIS, requires special considerations. Generally, remote annunciations should be provided on the EFIS display, whenever possible.

6.6.2 It is assumed that the navigation source and GNSS distance-to-go are always capable of being available on the EFIS display, but some older or simpler EFIS may not allow for annunciation of GNSS messages and other alerts. In such a situation, it is strongly recommended that, as a minimum, provide a GNSS message annunciator in the pilot's primary FOV, even if the constraints of section paragraph 6.5.4 of this are met. If the constraints of paragraph 6.5.4 of this AC are not met, then include the requirements for remote annunciators, in the pilot's primary FOV as detailed in paragraph 6.5.5 of this AC.

6.7 Multi-Function Displays

6.7.1 Installations that utilise generic multi-function displays that receive and display input from a variety of sources (e.g. combined RMI/TCAS/GPS Track/GPS Moving Map etc.) need evaluation to confirm the priority of display of the various inputs. This is to ensure that necessary flight information is not removed during critical phases of flight.

6.8 Autopilot Interfaces

6.8.1 When a GNSS system is interfaced to an autopilot to provide a navigation steering capability, the aircraft steering function must meet airworthiness criteria. The steering function must allow the aircraft to intercept and capture a flight plan leg, maintain a flight plan leg within the Total System Error limits for the designated performance requirement, transition between flight plan legs using fly-by and fly-over transitions without undue delay or S-turning. To meet these requirements, "roll-steering" is necessary.

6.8.2 To obtain adequate autopilot response, it is not acceptable to change the CDI scaling from the default full scale values (5 NM (TSO-C129 systems) or 2 NM (TSO-C146 systems) en route, 1 NM terminal and 0.3 NM for approach.

6.8.3 Some navigation systems provide a capability to limit bank angle. It is recommended not to use this capability since there is a potential for bank angle limits to cause the aircraft to not comply with the navigation accuracy requirements.

6.9 Installations in Aircraft Operated by Two Crew

6.9.1 For aircraft approved for single pilot operations in the Type Certificate, there is no requirement to provide any indicators or annunciators on the co-pilot's side.

6.9.2 An operator may choose to provide 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.

6.9.3 If GNSS guidance is provided to a CDI/HSI on the co-pilot's side, it is strongly recommended to install the required annunciators noted above for the co-pilot, if the constraints of paragraph 6.5.14 of this AC are difficult to meet. Otherwise, it may require a limitation in the flight, that GNSS approaches flown require the pilot in the pilot's seat.

6.9.4 When an aircraft requires operation by two pilots by the Type Certificate, additional installation requirements apply so that either pilot can operate the system, monitor the systems and provide cross-checking.

6.9.5 When a single system is installed, it is important to locate the control/display for the system where it can be viewed and operated with minimal head movement for either pilot.

6.9.6 The displays required within the pilot's primary FOV require replication for both pilots. To meet the criteria, with the pilot's seat adjusted to the normal flying position with the harness firmly fastened and the shoulder harness locked, the pilot capably operate the furthermost controls without straining and all display areas on the Control Display Unit CDU visible.

6.9.7 Dual independent systems are an acceptable means of meeting the above requirement, but either pilot should be able to select either system to their primary instrument displays. In dual installations, the primary (No. 1 systems) should connect to an electrical power source that is unlikely to fail or shed in the event of an electrical power generations system failure.

6.9.8 For CDU installations to meet acceptable criteria (for both single and dual installations), adjust the pilot's seat to the normal flying position with the harness firmly fastened and the shoulder harness locked; the pilot is required to operate the furthermost controls without straining and all display elements on the CDU visible. For single CDU installations, this criterion is required for both pilots; for dual CDU installations, this criterion is required or the on-side pilot only.

6.10 Alternative Installations

6.10.1 When situations arise that are beyond the scope of the installations discussed in this AC, obtain further guidance from your local CASA Office on the acceptability of the installation.

6.11 Performance-Based Navigation

6.11.1 PBN is being implemented globally; in Australia, PBN will be predicated on GNSS.

6.11.2 CAO 20.91 contains the details for all PBN navigation specifications except for RNAV 10 (RNP 10) and RNP 4, which are in Manual of Standards subpart 91.U. CAO 20.18 specifies the requirements for the installation of GNSS equipment in all IFR aircraft by 4 February 2016. For further information see the applicable AC 91U series.

6.12 Automatic Dependent Surveillance Broadcasting

6.12.1 Position and other flight parameters derived from GNSS are critical to the effective operation of ADS-B. AC 21-45 v2.1 provides the detailed parameters necessary for compliance with ADS-B regulations published in paragraph 9B of CAO 20.18. Refer to FAA AC 20-138D for information on functional testing.

6.12.2 It should be noted that the CAO 20.18 requirements for ADS-B specify TSO-C145a, TSO-C146a or TSO-C196 GNSS but the requirements for GNSS navigation specify TSO-C129, TSO-C145, TSO-C146 or TSO-C196.

6.12.3 The requirements for ADS-B are more stringent than the navigation requirement, so TSO-C145a, TSO-C146a or TSO-C196 are the minimum standards acceptable for IFR aircraft.

7 Aircraft Flight Manual Supplement (AFM Supp)

7.1 AFM Supp requirements

7.1.1 The approved AFM Supp provides the operational capability information and restrictions for the pilot to confirm what operations the aircraft is approved for. Submit an appropriate AFM Supp containing the limitations and referencing the GNSS manufacturer's operating procedures applicable to the equipment, as installed, to CASA or an Authorised Person for approval.

Note: Except for stand-alone GNSS equipment fitted only as a supplemental aid for VFR navigation.

7.1.2 Some imported Supplemental Type Certificates (STC) contain approvals for features or procedures that are available or relevant only within the approving country's airspace. There is no requirement to amend the approved AFM Supp to remove these features.

7.1.3 If the installed GNSS equipment does not have an appropriate TSOA or equivalent, then a limitation placard installed in clear view of, and easily readable, by the pilot is required stating the restrictions detailed in the Australian Aeronautical Information Package (AIP).

7.2 Layout

7.2.1 The layout for an AFM Supp (see Appendix 5 of FAA AC 20-138D) should follow the format of the approved flight manual and include the following:

7.2.2 Section 1 - General

7.2.2.1 This section should contain an appropriate statement to describe the TSO equipment type, capability and the type/s of procedures available e.g. IFR RNAV, Oceanic RNAV etc. See A5-4 in FAA AC 20-138D for further details.

Note: Full technical details of the system installed in the aircraft, including reference to the subpart 21.M or subpart 21.J approval documentation controlling the incorporation, are contained in the aircraft log book.

7.2.3 Section 2 - Limitations

7.2.3.1 Any airworthiness or operational limitations on the use of the system resulting from the design or equipment capability.

7.2.3.2 The limitations section should include:

- part number of equipment and revision date
- software version details
- if equipment TSO-C129(AR) or TSO-C196(AR) is installed, then supply details on other operational, approved navigation equipment installed appropriate to the operation
- TSO-C number and revisions used.

7.2.3.3 The limitations section should also list each of the navigation specifications the aircraft meets, airworthiness requirements and the document used to determine compliance. There must also be a statement that these approvals do not constitute an operational approval to conduct those operations.

7.2.3.4 If the equipment does not have the capability to carry out Radius to Fix legs or Fixed Radius Transitions (FRT), there must be a statement in the Limitations section that states the equipment cannot be used for procedures that include RF legs or FRT.

7.2.4 Section 3 - Emergency/Abnormal Procedures

i. Emergency Procedures: detail of changes to published aircraft emergency procedures introduced with the installation of the new equipment.
ii. Abnormal Procedures: details of procedures to be followed in the event that GNSS derived information are identified as invalid or are no longer available. Procedures detailed in the manufacturer's handbook would be sufficient.

7.2.5 Section 4 - Normal Procedures

7.2.5.1 This section contains either operating procedures in terms of manufacturer's instructions or reference to the manufacturer's operating manual. When the operating instructions refer to the manufacturer's instructions, there must be a flight manual statement stating that the document must be carried in the aircraft and accessible to the flight crew at all times whilst in flight.

7.2.5.2 Details are to be provided explaining all the functions and indications provided by the system annunciators, system switches, pilot's display, flight director/autopilot coupled operation and any other procedure necessary for the efficient and effective operation of the installed equipment.

7.2.6 Section 5 - Performance

7.2.6.1 Any change in performance to the basic Aircraft Flight Manual.

7.2.7 Section 6 - Weight and Balance

7.2.7.1 Revised weight and balance data (if applicable) from the basic Aircraft Flight Manual.

7.2.8 Section 7 - System Description

7.2.8.1 Provide a brief description of the system, its operation, installation and other relevant elements required for description.

7.3 Evaluation of Installed Equipment

7.3.1 A suggested post installation evaluation sheet is attached at Appendix B of this AC and an installation checklist is attached at Appendix C of this AC. The procedure is designed for follow-on installations carried out in accordance with an approved data set

Note: This could be a Subpart 21.M or 21.J of CASR approval or STC.

7.3.2 Variations to the approved data set necessitated by a different aircraft configuration will need evaluation for impact and may require additional approval. This could call for additional inclusion of items to include in the test procedure to evaluate the differences.

7.3.3 First of Type or First of Model GNSS installation may also require a more comprehensive testing procedure to evaluate the GNSS/Aircraft interface.

8 Continued Airworthiness

8.1.1 To obtain a navigation authorisation, the aircraft operator must demonstrate that the aircraft meets the airworthiness requirements for each authorisation sought, and that the aircraft will be maintained compliant with the airworthiness requirements and conforming to its type design.

8.1.2 For GNSS installations, the following aspects require addressing:

- Analyse the aircraft electrical load in accordance with AC 21-38 to meet all regulatory requirements and aircraft manufacturer limits. The ELA is particularly important for older aircraft that were originally equipped with air-driven instruments that have subsequently been replaced with electronic display systems.
- System installation configuration. Most GNSS systems have an extensive configuration capability to enable interfacing to a broad range of aircraft systems. This installation configuration forms part of the type design of the aircraft and require inclusion in the instructions for continuing airworthiness (ICA). For easy reference, it is acceptable to include a copy of the configuration table as an Appendix in the AFM Supp.
- The ICA must provide instructions for the removal and installation of system components, system configuration, system testing and troubleshooting procedures. The installation description must identify the location of all system components. Installation wiring diagrams are required that shows all interface wiring and the interface of the navigation system to other aircraft systems.
- Software configuration management. The configuration of the aircraft software requires management so that it remains current and compliant. The software is managed in accordance with the approved equipment manufacturer's instructions. The same amendment status is required for installed software on multiple installations and this is verified by cross-checking of installed software versions between duplicate systems.
- Navigation databases. Navigation authorisations require the current navigation database in GNSS systems if the aircraft is operated under IFR. Navigation databases are obtained from suppliers that hold a regulatory Letter of Approval.

Executive Manager
Standards Division

November 2014

Appendix A

Approved GNSS equipment

A.1 Approved GNSS equipment

A.1.1 At the present time there are eight Technical Standard Orders (TSO) that are accepted by CASA for airborne GNSS equipment:

- FAA TSO-C129/C129a or EASA ETSO-C129a (Cancelled) Airborne Supplemental Navigation Equipment using the Global Positioning system (GPS). TSO-C129a is cancelled, but this does not affect equipment with an existing TSOA/LODA.
- FAA TSO-C145(AR) or EASA ETSO-C145(AR) Airborne Navigation Sensors Using the Global Positioning System (GPS) Augmented by the Wide Area Augmentation System (WAAS).
- FAA TSO-C146(AR) or EASA ETSO-C146(AR) Stand-alone Airborne Navigation Equipment Using the Global Positioning System (GPS) Augmented by the Wide Area Augmentation System (WAAS).
- FAA TSO-C161(AR) or ETSO-C161(AR) Ground Based Augmentation System Positioning and Navigation Equipment (incorporating TSO C162(AR) or ETSO-C162(AR) Ground Based Augmentation System Very High Frequency Data Broadcast Equipment).
- FAA TSO-C196(AR) or ETSO-C196(AR) Airborne Navigation Sensors for Global Positioning Systems using ABAS.
- FAA TSO-C204(AR) Circuit Card Assembly Functional Sensors using Satellite-Based Augmentation System (SBAS) for Navigation and Non-Navigation Position/Velocity/Time Output
- FAA TSO-C205(AR) Circuit Card Assembly Functional Class Delta Equipment Using The Satellite-Based Augmentation System For Navigation Applications
- FAA TSO-C206(AR) Circuit Card Assembly Functional Sensors using Aircraft-Based Augmentation for Navigation and Non-Navigation Position/Velocity/Time Output

A.1.2 Further detailed information on the minimum performance specifications for individual types of equipment is found in the relevant FAA TSO on the FAA website or EASA website for standards on ETSO equipment.

A.1.3 It is possible for CASA to accept equipment that does not have a FAA TSO or equivalent approval, provided sufficient data is provided to enable evaluation against the equivalent TSO.

Appendix B

Post installation evaluation sheet

B.1 Post installation evaluation sheet

AIRCRAFT TYPE			
Model			
Registration VH			
GNSS Equipment type			
Model Part Number		**Serial number**	
TSO-C number			
RNP operations			

B.2 Introduction

B.2.1 This document is a suggested ground/flight evaluation procedure designed to confirm the functions and serviceability of the GNSS equipment installed in the aircraft in accordance with the approved technical data.

B.2.2 An appropriately rated LAME/check pilot is to initial the entry identifying the outcome of the evaluation of each item and, when completed, finalise and certify the checklist in the certification box at the bottom of the document.

B.2.3 Types of operation that equipment will be used for should be stated under RNP operations.

Approved data package used in this installation: _____

Check pilot signature (Flight test only):

Licence number: _____

Certification: The GNSS installation has found to

COMPLY ☐

NOT COMPLY ☐

with the functionality requirements of current version of CASA AC 21-36

LAME Signature: _____

Licence number: _____

Certificate of approval: _____

Date: _____

Appendix C

Installation Checks

C.1 Installation Checks Part A – Installation Evaluation: Ground Check

	Test Instructions	Pass	Fail	N/A
C.1.1	Verify that the installation of the equipment is in accordance with the approved drawings and related data, consistent with the type of approval sought (VFR/IFR) and meets the aircraft requirements for the applicable navigation specifications for which a navigation authorisation will be sought.			
C.1.2	System documentation should support maintenance of Flight Technical Error (FTE) (95% of flying time) during straight and curved path segments, for each phase of flight and each autopilot and/or FD mode.			
C.1.3	Provide an electrical load analysis to verify that the total electrical load requirements are within the capabilities of the aircraft's electrical generating system in conjunction with guidance in CASA AC 21-38.			
C.1.4	Evaluate the GNSS installation from the pilot's normal seating position, in accordance with the guidelines detailed in CASA AC 21-36 general design considerations, for: • acceptable location of equipment controls, switches, etc • acceptable location of related annunciators, indicators, displays Note: 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. • correct placarding and identification of all relevant components (if required) • correct switch functions and dimmer operation. If the navigation system is capable of RF legs or FRT, verify that the aircraft is equipped with a map display that depicts the intended aircraft flight path and applicable circuit breakers (labels and accessibility).			
C.1.5	Verify the visibility and operation of the controls, displays, and annunciators relating to the GNSS installation under day and night conditions are consistent with the guidelines detailed in CASA AC 21-36.			
C.1.6	Verify that the night lighting associated with the GNSS equipment is consistent with other cockpit lighting with no distracting cockpit glare or reflections evident.			
C.1.7	Verify that all switching and transfer functions affecting the GNSS equipment installation are assessed. This includes but is not limited to: • electrical bus switching • equipment selector switches and • remote switches including navigation source selector switches.			

	Test Instructions	Pass	Fail	N/A
	Ensure that the expected aircraft system response during switching to all alternate navigation sources is accomplished as expected, and the switching itself does not induce any inaccurate guidance indications.			
C.1.8	Verify that the correct software version is displayed on the relevant data page. Record software version(s): _____ Record software version date(s): _____			
C.1.9	With GNSS derived data displayed on each relevant display, verify proper display of deviations, To/From flags, bearing to way-point, desired track and distance to way-point.			
C.1.10	Verify the various failure modes and associated annunciations, such as: • loss of electrical power • loss of signal reception • GNSS equipment failure • FMS equipment failure • Display equipment failures or other display anomalies • autopilot/flight director response to flags, etc by simulating the appropriate fault condition • loss of barometric-aiding input.			
C.1.11	Confirm the lack of RFI from VHF radio transmissions by tuning each VHF transmitter to the frequencies listed below and transmitting for a period of 35 seconds while observing the signal status of each satellite being received. Note: Degradation of individually received satellite signals below a point where navigation is no longer possible is not acceptable.			
	121.150 MHz			
	121.175 MHz			
	121.175 MHz			
	121.185 MHz (8.33 kHz channel spacing)			
	121.190 MHz (8.33 kHz channel spacing)			
	121.200 MHz			
	130.285 MHz (8.33 kHz channel spacing)			
	131.250 MHz			

	Test Instructions	Pass	Fail	N/A
	131.275 MHz			
	131.290 MHz (8.33 kHz channel spacing)			
	131.300 MHz			
	For installations on rotorcraft, confirm that the rotor blades do not degrade the received GNSS signals sufficiently to affect the GNSS receiver functions. Note: This may require a ground run to confirm			
C.1.12	Confirm correct function of the GNSS equipment by comparing the displayed position with the actual position when the aircraft is located at a known surveyed location. Note: The accuracy of GNSS equipment is not a function of the installation, and need not be evaluated for each installation. The accuracy of the equipment has been demonstrated under the evaluation of the sensor, typically as part of the TSOA.			
C.1.13	Verify that a warning associated with loss of navigation is accompanied by a visible indication within the pilot's primary field of view as defined in CASA AC 21-36.			
C.1.14	Verify the navigation data presented corresponds to that displayed on the flight instruments by reviewing the appropriate GNSS equipment.			
C.1.15	For TSO-C129 or 129a or TSO-C196a certified equipment: • de-select satellites and confirm appropriate annunciation • verify all appropriate warning flags appear on the flight instruments • reselect satellites • verify the warning and flag conditions clear. Note: Shielding of the antenna may be required in order to block the GNSS signals and then observe the displays.			
C.1.16	Fail the GNSS receiver by opening the appropriate system circuit breaker. Verify the flight instrument NAV flags come into view.			
C.1.17	Fail the air data inputs (if fitted) by opening the appropriate system circuit breakers. Monitor the relevant GNSS status pages and verify that True Air Speed (TAS), Indicated Air Speed, and ALT fields (as applicable) are cleared. Enter the data manually. Verify proper manual data entry is achieved.			

	Test Instructions	Pass	Fail	N/A
C.1.18	Verify no objectionable Electromagnetic Interference or RFI exists between the GNSS equipment and the other aircraft systems and vice versa by the conduct of a tailored test sequence. A copy of the test program, including the list of installed equipment tested, should be attached to this Evaluation sheet.			
C.1.19	Verify that operation of the GNSS and the description of the system are accurately presented in the AFM Supp.			
C.1.20	Verify that the RAIM Prediction System, where separate from the receiver, matches the receiver.			
C.1.21	Verify that any equipment fitted to the aircraft that utilises data derived from the new installation functions correctly (eg. FMS, ADS-B etc). Note: A list of all affected equipment should be provided.			

C.2 Installation Checks Part B – Installation Evaluation: Flight Check

	Test Instructions	Pass	Fail	N/A
C.2.1	Verify continuity of navigation data during normal aircraft manoeuvring for the navigation modes to be validated: bank angles of up to 30°, and pitch angles associated with approaches, missed approaches and departures.			
C.2.2	Evaluate the steering response of the autopilot/flight director when coupled to the GNSS equipment. Verify that leg changes do not result in unacceptable over or undershoot conditions.			
C.2.3	Verify the overall operation of the GNSS equipment to include at least the following: • hold at a designated way-point • intercept and track to or from a way-point on a selected course • turn anticipation • way-point sequencing • selection of an approach • Direct To function general presentation of navigational data (depiction of the “TO” way-point, distance to way-point, estimated time of arrival, estimated time en route, ground speed, etc.) and • confirm that the FTE is less than 1 nm during the enroute and approach transition operating modes and, if enabled, 0.25 nm for non- precision approach mode. If the navigation systems is capable of RF legs or FRT, verify that the route is correctly displayed on a map display and that the aircraft can be flown to maintain the route centre-line, as depicted by the navigation displays, in manual flight, using a flight director (if installed) and using an autopilot (if installed). Note: This test may not be necessary if the FTE has been previously established for the aircraft. One acceptable way of assessing FTE is to monitor the measured cross-track deviation using the navigation display provided.			
C.2.4	Verify that, once an approach has been selected, appropriate feedback to the pilot (e.g. display of approach name (including runway), airport and reference path identifier) is given to indicate the approach has been correctly selected.			
C.2.5	If enabled, select and fly an appropriate Non-Precision Approach to confirm the operation of the RAIM prediction function and correct sequencing of modes.			