Republic of the Philippines
CIVIL AVIATION AUTHORITY OF THE PHILIPPINES

MEMORANDUM CIRCULAR NO.: 05-2020

TO	**:**	**ALL CONCERNED**
FROM	**:**	**THE DIRECTOR GENERAL**
SUBJECT	**:**	**AMENDMENT TO PHILIPPINE CIVIL AVIATION REGULATIONS – AIR NAVIGATION SERVICES (CAR-ANS) PART 6 (AERONAUTICAL TELECOMMUNICATIONS GOVERNING RADIO NAVIGATION AIDS) INCORPORATING AMENDMENT 91 TO ANNEX 10 VOLUME 1**

REFERENCE:

1. Philippine Civil Aviation Regulations – Air Navigation Services Part 6 Aeronautical Telecommunications Governing Radio Navigation Aids.
2. ICAO Annex 10 – Volume 1 Amendment 91
3. Regulations Amendment Procedures.
4. Board Resolution No. 2012-054 dated 28 September 2012

Pursuant to the powers vested in me under the Republic Act 9497, otherwise known as the Civil Aviation Authority Act of 2008 and in accordance with the Board Resolution No. 2012 -054 dated 28 September 2012, I hereby approve the incorporation of ICAO Annex 10 Volume 1 Amendment 91 to the Philippine Civil Aviation Regulations Air Navigation Services (CAR-ANS) Part 6.

ORIGINAL REGULATIONS SUBJECT TO AMENDMENT:

CIVIL AVIATION REGULATIONS AIR NAVIGATION SERVICES PART 6

6.2. GENERAL PROVISIONS FOR RADIO NAVIGATION AIDS

6.2.1 Standard radio navigation aids

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6.2.1.4 GNSS-specific provisions

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6.2.1.4.2 A State that approves GNSS-based operations ~~should~~ shall ensure that GNSS data relevant to those operations are recorded.

Note 1.— These recorded data ~~are primarily intended for use in~~ can support accident and incident investigations. They may also support periodic ~~confirmation that accuracy, integrity, continuity and availability are maintained within the limits required for the operations approved~~ analysis to verify the GNSS performance parameters detailed in the relevant Standards in this CAR-ANS.

Note 2.— Guidance material on the recording of GNSS parameters and on GNSS performance assessment is contained in Attachment 6D, 11 and 12.

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6.3. SPECIFICATIONS FOR RADIO NAVIGATION AIDS

Note.— Specifications concerning the siting and construction of equipment and installations on operational areas aimed at reducing the hazard to aircraft to a minimum are contained in CAAP MOS - Aerodromes, Chapter 11.

6.3.1 Specification for ILS

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6.3.1.2 Basic requirements

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6.3.1.2.7.1 At those locations where two separate ILS facilities serve opposite ends of a single runway and where a Facility Performance Category I — ILS is to be used for auto-coupled approaches and landings in visual conditions an interlock ~~should~~ **shall** ensure that only the localizer serving the approach direction in use radiates, providing the other localizer is not required for simultaneous operational use.

*Note.— If both localizers radiate there is a possibility of interference to the localizer signals in the threshold region. Additional guidance material is contained in ~~2.1.9 and 2.13~~ **2.1.8** of Attachment 6C.*

6.3.1.2.7.2 At locations where ILS facilities serving opposite ends of the same runway or different runways at the same airport use the same paired frequencies, an interlock shall ensure that only one facility shall radiate at a time. When switching from one ILS facility to another, radiation from both shall be suppressed for not less than 20 seconds.

Note.— Additional guidance material on the operation of localizers on the same frequency channel is contained in ~~2.1.9 of Attachment C and~~ CAR-ANS Part 13, Chapter 4.

6.3.1.3 VHF localizer and associated monitor

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6.3.1.3.3.3 Above 7 degrees, the signals ~~should~~ **shall** be reduced to as low a value as practicable.

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6.3.1.3.4 *Course structure*

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Note 2.— Guidance material relevant to the localizer course structure is given in ~~2.1.4, 2.1.6 and 2.1.7~~ 2.1.3, 2.1.5, 2.1.6 and 2.1.9 of Attachment 6C.

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6.3.1.3.6 *Course alignment accuracy*

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*Note 3.— Guidance material on measurement of localizer course alignment is given in 2.1.3 of Attachment 6C. **Guidance material on protecting localizer course alignment is given in 2.1.9 of Attachment 6C.***

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6.3.1.3.10 Siting

Note.— Guidance material relevant to siting localizer antennas in the runway and taxiway environment is given in 2.1.9 of Attachment 6C.

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6.3.1.5 UHF glide path equipment and associated monitor

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6.3.1.5.1.2.1 The glide path angle shall be adjusted and maintained within:

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Note 1.— Guidance material on adjustment and maintenance of glide path angles is given in 2.4 of Attachment 6C.

Note 2.— Guidance material on ILS glide path curvature, alignment and siting, relevant to the selection of the height of the ILS reference datum is given in 2.4 of Attachment 6C and Figure C-5.

Note 3.— Guidance material relevant to protecting the ILS glide path course structure is given in 2.1.9 of Attachment 6C.

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6.3.1.5.4 ILS glide path structure

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*Note 3.— Guidance material relevant to the ILS glide path course structure is given in 2.1.4 of Attachment 6C. **Guidance material relevant to protecting the ILS glide path course structure is given in 2.1.9 of Attachment 6C.***

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6.3.1.5.7 Monitoring

6.3.1.5.7.1 The automatic monitor system shall provide a warning to the designated control points and cause radiation to cease within the periods specified in 6.3.1.5.7.3.1 if any of the following conditions persist:

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Note 1.— The value of 0.7475 θ from horizontal is intended to ensure adequate obstacle clearance. This value was derived from other parameters of the glide path and monitor specification. Since the measuring accuracy to four significant figures is not intended, the value of 0.75 θ may be used as a monitor limit for this purpose. Guidance on obstacle clearance criteria is given in the Procedures for Air Navigation Services — Aircraft Operations (PANS-OPS) (Doc 8168).

Note 2.— Subparagraphs f) and g) are not intended to establish a requirement for a separate monitor to protect against deviation of the lower limits of the half-sector below 0.7475 θ from horizontal

Note 3.— At glide path facilities where the selected nominal angular displacement sensitivity corresponds to an angle below the ILS glide path which is close to or at the maximum limits specified in 3.1.5.6, it may be necessary to adjust the monitor operating limits to protect against sector deviations below 0.7475 θ from horizontal.

Note ~~4~~.— Guidance material relating to the condition described in g) appears in Attachment 6C, ~~2.4.12~~ 2.4.11.

6.3.7 Requirements for the Global Navigation Satellite System (GNSS)

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6.3.7.2 General

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6.3.7.2.4 *Signal-in-space performance*

6.3.7.2.4.1 The combination of GNSS elements and a fault-free GNSS user receiver shall meet the signal-in-space requirements defined in Table 6.3.7.2.4-1 (located at the end of section 6.3.7).

Note 1.— The concept of a fault-free user receiver is applied only as a means of defining the performance of combinations of different GNSS elements. The fault-free receiver is assumed to be a receiver with nominal accuracy and time-to-alert performance. Such a receiver is assumed to have no failures that affect the integrity, availability and continuity performance.

Note 2.— For GBAS approach service (as defined in Attachment 6D, 7.1.2.1) intended to support approach and landing operations using Category III minima, performance requirements are defined that apply in addition to the signal-in-space requirements defined in Table 6.3.7.2.4.-1.

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6.3.7.3.4 *Satellite-based augmentation system (SBAS)*

6.3.7.3.4.1 *Performance.* SBAS combined with one or more of the other GNSS elements and a fault-free receiver shall meet the requirements for system accuracy, integrity, continuity and availability for the intended operation as stated in 6.3.7.2.4, throughout the corresponding service area (see 6.3.7.3.4.3).

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6.3.7.3.4.1.1 SBAS combined with one or more of the other GNSS elements and a fault-free receiver shall meet the requirements for signal-in-space integrity as stated in 6.3.7.2.4, throughout the SBAS coverage area.

Note.— Message types 27 or 28 can be used to comply with the integrity requirements in the coverage area. Additional guidance on the rationale and interpretation of this requirement is provided in Attachment 6D, 3.3.

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6.3.7.3.4.3 *Service area.* ~~The~~An SBAS service area **for any approved type of operation** shall be a ~~defined~~**declared** area within ~~an~~**the** SBAS coverage area where SBAS meets the **corresponding** requirements of 6.3.7.2.4 ~~**and supports the corresponding approved operations.**~~

Note 1.— An SBAS system can have different service areas corresponding to different types of operation (e.g. APV-I, Category I, etc.).

Note ~~1~~2.— The coverage area is that area within which the SBAS broadcast can be received (~~e.g.~~ i.e. the geostationary satellite footprints).

Note ~~2~~3.— SBAS coverage and service areas are discussed in Attachment 6D, 6.2.

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6.3.7.3.5 *Ground-based augmentation system (GBAS) and ground-based regional augmentation system (GRAS)*

Note ~~1.~~— Except where specifically annotated, GBAS Standards and Recommended Practices apply to GBAS and GRAS.

~~*Note 2.— Except where specifically annotated, reference to approach with vertical guidance (APV) means APV-I and APV-II.*~~

6.3.7.3.5.1 *Performance.* GBAS combined with one or more of the other GNSS elements and a fault-free GNSS receiver shall meet the requirements for system accuracy, continuity, availability and integrity for the intended operation as stated in 6.3.7.2.4 **within the service volume for the service used to support the operation as defined in 6.3.7.3.5.3.**

Note.— GBAS is intended to support all types of approach, landing, ***guided take-off,*** *departure and surface operations and may support en-route and terminal operations. GRAS is intended to support en-route, terminal, non-precision approach, departure, and approach with vertical guidance. The following SARPs are developed to support ~~Category I~~* ***all categories of*** *precision approach, approach with vertical guidance, and a GBAS positioning service. ~~In order to achieve interoperability and enable efficient spectrum utilization, it is intended that the data broadcast is the same for all operations.~~*

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6.3.7.3.5.3 *~~Coverage~~**Service volume***

6.3.7.3.5.3.1 *~~Category I precision approach and approach with vertical guidance~~ **General requirement for approach services.*** The **minimum** GBAS ~~**coverage to support each Category I precision approach or approach with vertical guidance**~~ **approach service volume** shall be as follows, except where topographical features dictate and operational requirements permit:

a) laterally, beginning at 140 m (450 ft) each side of the landing threshold point/fictitious threshold point (LTP/FTP) and projecting out ±35 degrees either side of the final approach path to 28 km (15 NM) and ±10 degrees either side of the final approach path to 37 km (20 NM); and

b) vertically, within the lateral region, up to the greater of 7 degrees or 1.75 promulgated glide path angle (GPA) above the horizontal with an origin at the glide path interception point (GPIP) **to an upper bound of 3 000 m (10 000 ft) height above threshold** (HAT) and 0.45 GPA above the horizontal or to such lower angle, down to 0.30 GPA, as required, to safeguard the promulgated glide path intercept procedure. ~~This coverage applies between~~ **The lower bound is half the lowest decision height supported or 3 ~~,~~.7 m (12 ft), whichever is larger** ~~30 m (100 ft) and 3 000 m (10 000 ft) height above threshold (HAT).~~

Note 1.— LTP/FTP and GPIP are defined in Appendix 6B, 3.6.4.5.1.

~~6.3.7.3.5.3.1.1 **Recommendation.— For Category I precision approach, the data broadcast as specified in 6.3.7.3.5.4 should extend down to 3.7 m (12 ft) above the runway surface.**~~

~~6.3.7.3.5.3.1.2 **Recommendation.— The data broadcast should be omnidirectional when required to support the intended applications.**~~

Note 2.— Guidance material concerning ~~coverage for Category I precision~~ the approach ~~and APV~~ service volume is provided in Attachment 6D, 7.3.

6.3.7.3.5.3.2 *Approach services supporting autoland and guided take-off.* The minimum additional GBAS service volume to support approach operations that include automatic landing and rollout, including during guided take-off, shall be as follows, except where operational requirements permit:

a) Horizontally within a sector spanning the width of the runway beginning at the stop end of the runway and extending parallel with the runway centre line towards the LTP to join the minimum service volume as described in 6.3.7.3.5.3.1.

b) Vertically, between two horizontal surfaces one at 3.7 m (12 ft) and the other at 30 m (100 ft) above the runway centreline to join the minimum service volume as described in 6.3.7.3.5.3.1.

Note.— Guidance material concerning the approach service volume is provided in Attachment 6D, 7.3.

6.3.7.3.5.3.~~2~~3 *GBAS positioning service.* The service volume for the GBAS positioning service ~~*area*~~ shall be ~~*that area*~~ where the data broadcast can be received and the positioning service meets the requirements of 6.3.7.2.4 and supports the corresponding approved operations.

Note.— Guidance material concerning the positioning service ***volume*** *~~coverage~~ is provided in Attachment 6D, 7.3.*

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6.3.7.3.5.4.4 *Data broadcast RF field strength and polarization*

Note 1.— GBAS can provide a VHF data broadcast with either horizontal (GBAS/H) or elliptical (GBAS/E) polarization that employs both horizontal polarization (HPOL) and vertical polarization (VPOL) components. Aircraft using a VPOL component will not be able to conduct operations with GBAS/H equipment Relevant guidance material is provided in Attachment 6D, 7.1.

Note 2.— The minimum and maximum field strengths are consistent with a minimum distance of 80 m (263 ft) from the transmitter antenna for a range of 43 km (23 NM).

Note 3.— When supporting approach services at airports with challenging VDB transmitter siting constraints, it is acceptable to adjust the service volume when operational requirements permit (as stated in the service volume definition sections 6.3.7.3.5.3.1 and 6.3.7.3.5.3.2). Such adjustments of the service volume may be operationally acceptable when they have no impact on the GBAS service outside a radius of 80 m from the VDB antenna, assuming a nominal effective isotropically radiated power of 47dBm (Attachment 6D, Table D-3).

6.3.7.3.5.4.4.1 *GBAS/H*

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6.3.7.3.5.4.4.1.2 The effective **isotropically** radiated power (EIRP) shall provide for a horizontally polarized signal with a minimum field strength of 215 microvolts per metre (-99 dBW/m^2) and a maximum field strength of ~~0.350~~ 0.879 volts per metre ~~(–35~~**27** dBW/m^2) within the GBAS **service**~~coverage~~ volume **as specified in 6.3.7.3.5.3.1**. The field strength shall be measured as an average over the period of the synchronization and ambiguity resolution field of the burst. ~~The RF phase offset between the HPOL and any VPOL components shall be such that the minimum signal power defined in Appendix B, 6.3.6.8.2.2.3 is achieved for HPOL users throughout the coverage volume.~~ **Within the additional GBAS service volume as specified in 6.3.7.3.5.3.2, the effective isotropic radiated power (EIRP) shall provide for a horizontally polarized signal with a minimum field strength of 215 microvolts per metre (–99 dBW/m^2) below 36 ft and down to 12 ft above the runway surface and 650 microvolts per metre (–89.5 dBW/m^2) at 36 ft or more above the runway surface.**

Note.— Guidance material concerning the approach service volume is provided in Attachment 6D, 7.3.

6.3.7.3.5.4.4.2 *GBAS/E*

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6.3.7.3.5.4.4.2.2 When an elliptically polarized signal is broadcast, the horizontally polarized component shall meet the requirements in 6.3.7.3.5.4.4.1.2, and the effective **isotropically** radiated power (EIRP) shall provide for a vertically polarized signal with a minimum field strength of 136 microvolts per metre (–103 dBW/m²) and a maximum field strength of ~~0.221~~0.555 volts per metre (~~–39~~31 dBW/m²) within the GBAS service~~coverage~~ volume. The field strength shall be measured as an average over the period of the synchronization and ambiguity resolution field of the burst. ~~The RF phase offset between the HPOL and VPOL components, shall be such that the minimum signal power defined in Appendix B, 6.3.6.8.2.2.3 is achieved for HPOL and VPOL users throughout the coverage volume.~~

~~*Note.— The minimum and maximum field strengths in 6.3.7.3.5.4.4.1.2 and 6.3.7.3.5.4.4.2.2 are consistent with a minimum receiver sensitivity of –87 dBm and minimum distance of 200 m (660 ft) from the transmitter antenna for a coverage range of 43 km (23 NM).*~~

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Table 6.3.7.2.4-1
Signal-in-space performance requirements

Typical operation	Accuracy horizontal 95% (Notes 1 and 3)	Accuracy vertical 95% (Notes 1 and 3)	Integrity (Note 2)	Time-to-alert (Note 3)	Continuity (Note 4)	Availability (Note 5)
En-route	3.7 km (2.0 NM)	N/A	$1 - 1 \times 10^{-7}$/h	5 min	$1 - 1 \times 10^{-4}$/h to $1 - 1 \times 10^{-8}$/h	0.99 to 0.99999
En-route, Terminal	0.74 km (0.4 NM)	N/A	$1 - 1 \times 10^{-7}$/h	15 s	$1 - 1 \times 10^{-4}$/h to $1 - 1 \times 10^{-8}$/h	0.99 to 0.99999
Initial approach, Intermediate approach, Non-precision approach (NPA), Departure	220 m (720 ft)	N/A	$1 - 1 \times 10^{-7}$/h	10 s	$1 - 1 \times 10^{-4}$/h to $1 - 1 \times 10^{-8}$/h	0.99 to 0.99999
Approach operations with vertical guidance (APV-I) (Note 8)	16.0 m (52 ft)	20 m (66 ft)	$1 - 2 \times 10^{-7}$ in any approach	10 s	$1 - 8 \times 10^{-6}$ per 15 s	0.99 to 0.99999
Approach operations with vertical guidance (APV-II) (Note 8)	16.0 m (52 ft)	8.0 m (26 ft)	$1 - 2 \times 10^{-7}$ in any approach	6 s	$1 - 8 \times 10^{-6}$ per 15 s	0.99 to 0.99999
Category I precision approach (Note 7)	16.0 m (52 ft)	6.0 m to 4.0 m (20 ft to 13 ft) (Note 6)	$1 - 2 \times 10^{-7}$ in any approach	6 s	$1 - 8 \times 10^{-6}$ per 15 s	0.99 to 0.99999

NOTES.—

1.The 95th percentile values for GNSS position errors are those required for the intended operation at the lowest height above threshold (HAT), if applicable. Detailed requirements are specified in Appendix B and guidance material is given in Attachment 6D, 3.2.

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7. GNSS performance requirements ***intended to support*** ~~*for*~~ *Category II and III precision approach operations* ***necessitate*** ~~*are under review and will be included at a later date*~~ ***lower level requirements in the technical appendix (Appendix 6B section 3.6) to be applied in addition to these signal- in- space (see Attachment 6D. 7.5.1)***

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APPENDIX 6B. TECHNICAL SPECIFICATIONS FOR THE GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS)

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3.5 Satellite-based augmentation system (SBAS)

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Table B-23. SBAS PRN codes

PRN code number	G2 delay (chips)	First 10 SBAS chips (Leftmost bit represents first transmitted chip, binary)
120	145	0110111001
121	175	0101011110
122	52	1101001000
123	21	1101100101
124	237	0001110000
125	235	0111000001
126	886	0000001011
127	657	1000110000
128	634	0010100101
129	762	0101010111
130	355	1100011110
131	1012	1010010110
132	176	1010101111
133	603	0000100110
134	130	1000111001
135	359	0101110001
136	595	1000011111
137	68	0111111000
138	386	1011010111
139	797	1100111010
140	456	0001010100

PRN code number	G2 delay (chips)	First 10 SBAS chips (Leftmost bit represents first transmitted chip, binary)
141	499	0011110110
142	883	0001011011
143	307	0100110101
144	127	0111001111
145	211	0010001111
146	121	1111100010
147	118	1100010010

148	163	1100100010
149	628	0101010011
150	853	0111011110
151	484	1110011101
152	289	0001011110
153	811	0010111011
154	202	1000010110
155	1021	0000000011
156	462	1110111000
157	568	0110010100
158	904	0010011101

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3.5.4.1 *PRN mask parameters.*

PRN mask parameters shall be as follows:

PRN code number: a number that uniquely identifies the satellite PRN code and related assignments as shown in Table B-25.

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Table B-25. PRN code number assignments

PRN code number	Assignment
1-37	GPS
38-61	GLONASS slot number plus 37
62-119	Spare
120- ~~138~~158	SBAS
~~139~~159-210	Spare

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3.6 Ground-based augmentation system (GBAS) and ground-based regional augmentation system (GRAS)

~~*Note.— In this section, except where specifically annotated, reference to approach with vertical guidance (APV) means APV-I and APV-II.*~~

3.6.1 GENERAL

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3.6.1.1 *GBAS service types.* **A GBAS ground subsystem shall support either the positioning service, approach service or both types of service.**

Note 1.— Service types refers to a matched set of ground and airborne functional and performance requirements that ensure that quantifiable navigation performance is achieved by the airborne equipment. Guidance material concerning service types is given in Attachment 6D, 7.1.

Note 2.— GBAS ground facilities are characterized by a GBAS facility classification (GFC). Many GBAS performance and functional requirements depend on the GFC. These SARPs are organized according to which requirements apply for a given facility classification element (i.e. the facility approach service type (FAST) letter, the facility polarization etc.). Guidance material concerning facility classifications is given in Attachment 6D, 7.1.4.1).

3.6.1.2 All GBAS ground subsystems shall comply with the requirements of 3.6.1, 3.6.2, 3.6.3, 3.6.4, 3.6.6. and 3.6.7 unless otherwise stated. A FAST D ground subsystem shall also comply with all FAST C requirements in addition to the specific FAST D requirements.

3.6.2 RF CHARACTERISTICS

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3.6.2.6 *Emissions in unassigned time slots.* Under all operating conditions, the maximum power over a 25 kHz channel bandwidth, centred on the assigned frequency, when measured over any unassigned time slot, shall not exceed −105 dBc referenced to the authorized transmitter power.

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Note.— ~~If the authorized transmitter power is higher than 150 W, t~~The −105 dBc may not protect reception of emissions in a slot assigned to another desired transmitter for receivers within ~~200~~ 80 metres from the undesired transmitting antenna.

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3.6.4 DATA CONTENT

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3.6.4.2.1 The Type 1 message shall provide the differential correction data for individual GNSS ranging sources (Table B-70). The message shall contain three sections:

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Note 1. — Transmission of the low-frequency data for SBAS ranging sources is optional.

Note 2. — All parameters in this message type apply to 100-second carrier-smoothed pseudo-ranges.

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Table B-63 GBAS VHF data broadcast messages

Message Type Identifier	Message name
0	Spare
1	Pseudo-range corrections
2	GBAS-related data
3	Null message
4	Final approach segment (FAS) data
5	Predicted ranging source availability
6	Reserved
7	Reserved for national applications
8	Reserved for test applications
9 to ~~100~~10	Spare
11	Pseudo-range corrections-30-second smoothed pseudo-ranges
12 to 100	Spare
101	GRAS pseudo-range corrections
102 to 255	Spare

Note: see 3.6.6 for message formats

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3.6.4.2.4 The measurement block parameters shall be as follows:

Ranging source ID: the identity of the ranging source to which subsequent measurement block data are applicable.

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Coding:
1 to 36 = GPS satellite IDs (PRN)
37 = reserved
38 to 61 = GLONASS satellite IDs (slot number plus 37)
62 to 119 = spare
120 to ~~138~~158 = SBAS satellite IDs (PRN)
~~139~~159 to 255 = spare

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B_1 through B_4: are the integrity parameters associated with the pseudo-range corrections provided in the same measurement block. For the i^{th} ranging source these parameters correspond to $B_{i,1}$ through $B_{i,4}$ (3.6.5.5.1.2, 3.6.5.5.2.2 and 3.6.7.2.2.4). During continuous operation the indices "1-4" correspond to the same physical reference receiver for every ~~frame~~epoch transmitted from a given ground subsystem ~~during continuous operation~~ with the following exception: the physical reference receiver tied to any of the indices 1 to 4 can be replaced by any other physical reference receiver (including a previously removed one) that has not been used for transmissions during the last 5 minutes.

Coding: 1000 0000 = Reference receiver was not used to compute the pseudo-range correction.

Note 1.— A physical reference receiver is a receiver with an antenna at a fixed location.

Note 2.— Some airborne inertial integrations ~~receivers~~ may expect a largely static correspondence of the reference receivers to the indices ~~for short service interruptions. However, the B-value indices may be reassigned after the ground subsystem has been out of service for an extended period of time, such as for maintenance.~~ Refer to RTCA/DO-253D, Appendix L.

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GBAS continuity/integrity designator (GCID): numeric designator indicating the operational status of the GBAS.

Coding: 0 = spare
1 = GCID 1
2 = GCID 2
3 = GCID 3
4 = GCID 4
5 = spare
6 = spare
7 = unhealthy

Note 1.— The values of GCID ~~2~~, 3 and 4 are specified in order to ensure compatibility of equipment with future GBAS.

Note 2.— The value of GCID 7 indicates that ~~a precisional~~all approach ~~or APV cannot be initiated~~ services supported by the ground facility are unavailable.

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3.6.4.3.1 *Additional data block 1 parameters.* Additional data block 1 parameters shall be as follows:

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MAXIMUM USE DISTANCE (D_{max}): the maximum distance (slant range) from the GBAS reference point ~~for which the integrity is assured~~within which pseudo-range corrections are applied by the aircraft element.

Note.— This parameter does not indicate a distance within which VHF data broadcast field strength requirements are met.

Coding: 0 = No distance limitation

GPS EPHEMERIS MISSED DETECTION PARAMETER, GBAS Positioning Service ($K_{md\_e\_POS,GPS}$): the multiplier for computation of the ephemeris error position bound for the

GBAS positioning service derived from the probability of missed detection given that there is an ephemeris error in a GPS satellite.

For GBAS ground subsystems that do not broadcast corrections for GPS ranging sources or that do not provide the GBAS positioning service, this parameter shall be coded as all zeros.

GPS EPHEMERIS MISSED DETECTION PARAMETER, ~~Category I Precision Approach and APV~~ GBAS approach service types A, B or C ($K_{md\_e,GPS}$): the multiplier for computation of the ephemeris error position bound for ~~Category I precision~~ GBAS approach service types A, B and C ~~APV~~ derived from the probability of missed detection given that there is an ephemeris error in a GPS satellite.

For GBAS ground subsystems that do not broadcast corrections for GPS ranging sources, this parameter shall be coded as all zeros

GLONASS EPHEMERIS MISSED DETECTION PARAMETER, GBAS Positioning Service ($K_{md\_e,\_POS,GLONASS}$): the multiplier for computation of the ephemeris error position bound for the GBAS positioning service derived from the probability of missed detection given that there is an ephemeris error in a GLONASS satellite.

For GBAS ground subsystems that do not broadcast corrections for GLONASS ranging sources or that do not provide positioning service, this parameter shall be coded as all zeros.

GLONASS EPHEMERIS MISSED DETECTION PARAMETER, GBAS approach service types A, B or C ~~Category I Precision~~ GBAS approach service types A, B and C ~~and APV~~ derived from the probability of missed detection given that there is an ephemeris error in a GLONASS satellite.

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3.6.4.3.2 *Additional data blocks.* For additional data blocks other than additional data block 1, the parameters for each data block shall be as follows:

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ADDITIONAL DATA BLOCK NUMBER: the numerical identifier of the type of additional data block.

Coding:	0 to 1	= reserved
	2	= additional data block 2, GRAS broadcast stations
	3	= ~~reserved for future services supporting Category II/III Operations~~ additional data block 3, GAST D parameters
	4	= additional data block 4, VDB authentication parameters
	5 to 255	= spare

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3.6.4.3.2.2 *GAST D parameters*

Parameters for additional data block 3 shall include parameters (Table B-65B) to be used when the active service type is GAST D as follows:

Kmd_e_D,GLONASS($K_{md\_e\_D,GLONASS}$): is the multiplier for computation of the ephemeris error position bound for GAST D derived from the probability of missed detection given that there is an ephemeris error in a GLONASS satellite. For GBAS ground sub-systems that do not broadcast corrections for GLONASS ranging sources, this parameter is coded as all zeros.

Note.— This parameter, Kmd_e_D,GLONASS, may be different than the ephemeris decorrelation parameter Kmd_e_GLONASS provided in additional data block 1 of the Type 2 message. Additional information regarding the difference in these parameters is given in Attachment 6D, 7.5.6.1.2 and 7.5.6.1.3.

Kmd_e_D,GPS ($K_{md\_e\_D,GPS}$): is the multiplier for computation of the ephemeris error position bound for GAST D derived from the probability of missed detection given that there is an ephemeris error in a GPS satellite. For GBAS ground sub-systems that do not broadcast corrections for GPS ranging sources, this parameter is coded as all zeros.

Note.— This parameter, Kmd_e_D,GPS, may be different than the ephemeris decorrelation parameter Kmd_e_GPS provided in additional data block 1 of the Type 2 message. Additional information regarding the difference in these parameters is given in Attachment 6D, 7.5.6.1.2 and 7.5.6.1.3

Sigma vert_iono_gradient_D ($\sigma_{vert\_iono\_gradient\_D}$): is the standard deviation of a normal distribution associated with the residual ionospheric uncertainty due to spatial decorrelation. This parameter is used by airborne equipment when its active approach service type is D.

*Note.— This parameter, Sigma_* vert *_iono_gradient_D, may be different than the ionospheric decorrelation parameter Sigma_vert_iono_gradient provided in the Type 2 message. Additional information regarding the difference in these parameters is given in Attachment 6D, 7.5.6.1.2 and 7.5.6.1.3.*

Y_{EIG}: is the maximum value of E_{IG} at zero distance from the GBAS reference point. This parameter is used by airborne equipment when its active approach service type is D.

M_{EIG}: is the slope of maximum E_{IG} versus distance from the GBAS reference point. This parameter is used by airborne equipment when its active approach service type is D.

3.6.4.3.2.~~2~~3 *VDB authentication parameters*

Additional data block 4 includes information needed to support VDB authentication protocols (Table B-65~~B~~C).

Slot group definition: This 8-bit field indicates which of the 8 slots (A-H) are assigned for use by the ground station. The field is transmitted LSB first. The LSB corresponds to slot A, the next bit to slot B, and so on. A "1" in the bit position indicates the slot is assigned to the ground station. A "0" indicates the slot is not assigned to the ground station.

Table B-65B. Additional Data Block 3 GAST D Parameters

Data content	Bits used	Range of values	Resolution
Kmd_e_D,GPS	8	0 to 12.75	0.05
Kmd_e_D,GLONASS	8	0 to 12.75	0.05
σvert_iono_gradient_D	8	$0 - 25.5 \times 10^{-6}$ m/m	0.1×10^{-6} m/m
Y_{EIG}	5	0 to 3.0 m	0.1
M_{EIG}	3	0 to 0.7 m/km	0.1

. . .

3.6.4.4 *TYPE 3 MESSAGE — NULL MESSAGE*

. . .

3.6.4.5 *Type 4 message — Final approach segment (FAS).* Type 4 message shall contain one or more sets of FAS data, each defining a single precision approach (Table B-72). Each Type 4 message data set shall include the following:

. . .

FAS data block: the set of parameters to identify an ~~single precision~~ approach ~~or APV~~ and define its associated approach path.

. . .

FASLAL/approach status: the value of the parameter FASLAL as used in 3.6.5.6.

Coding: 1111 1111 = Do not use approach.

Note.— The Procedures for Air Navigation Services — Aircraft Operations *(PANS-OPS) (Doc 8168), Volume II, specifies conventions to be used by procedure designers when applying the FAS data block definitions and codings below to encode procedures.*

Table B-65~~B~~C. VDB authentication parameters

Data content	Bits used	Range values	Resolution
Slot group definition	8	–	–

3.6.4.5.1 *FAS data block.* The FAS data block shall contain the parameters that define a single GAST A, B, C or D ~~precision~~ approach ~~or APV~~. The FAS path is a line in space defined by the landing threshold point/fictitious threshold point (LTP/FTP), flight path alignment point (FPAP), threshold crossing height (TCH) and glide path angle (GPA). The local level plane for the approach is a plane perpendicular to the local vertical passing through the LTP/FTP (i.e. tangent to the ellipsoid at the LTP/FTP). Local vertical for the approach is normal to the WGS-84 ellipsoid at the LTP/FTP. The glide path intercept point (GPIP) is where the final approach path intercepts the local level plane. FAS data block parameters shall be as follows:

. . .

Note.— Offset procedures are straight-in procedures and coded as "0".

. . .

Approach performance designator: the general information about the approach design.

Coding:
0 = ~~APV~~GAST A or B
1 = ~~Category I~~GAST C
2 = ~~reserved for Category II~~GAST C and GAST D
3 = ~~reserved for Category III~~GAST C, GAST D and an additional approach service type to be defined in the future
4 = GAST C, GAST D and two additional approach service types to be defined in the future
45 to 7 = spare

. . .

3.6.4.10 *TYPE 101 MESSAGE — GRAS PSEUDO-RANGE CORRECTIONS*

3.6.4.10.1 The Type 101 message shall provide the differential correction data for individual GNSS ranging sources (Table B-70A). The message shall contain three sections:

. . .

c) satellite data measurement blocks.

Note .— All parameters in this message type apply to 100-second carrier-smoothed pseudo-ranges.

. . .

3.6.4.11 *TYPE 11 MESSAGE — PSEUDO-RANGE CORRECTIONS – 30-SECOND SMOOTHED PSEUDO-RANGES*

3.6.4.11.1 The Type 11 message shall provide the differential correction data for individual GNSS ranging sources (Table B-70B) with 30-second code-carrier smoothing applied. The message shall contain three sections:

a) message information (time of validity, additional message flag, number of measurements and the measurement type);

b) low-frequency information (ephemeris decorrelation parameter); and

c) satellite data measurement blocks.

Note.— Transmission of the low-frequency data for SBAS ranging sources is optional.

3.6.4.11.2 Each Type 11 message shall include the ephemeris decorrelation parameter for one satellite ranging source. The ephemeris decorrelation parameter shall apply to the first ranging source in the message.

Note.— The ephemeris CRC and source availability duration parameters are not included in the Type 11 message because they are provided in the Type 1 message.

3.6.4.11.3 Pseudo-range correction parameters for the Type 11 message shall be as follows:

Modified Z-count: as defined in 3.6.4.2.3.

Additional message flag: an identification of whether the set of measurement blocks in a single frame for a particular measurement type is contained in a single Type 11 message or a linked pair of messages.

Coding: 0 = All measurement blocks for a particular measurement type are contained in one Type 11 message.
1 = This is the first transmitted message of a linked pair of Type 11 messages that together contain the set of all measurement blocks for a particular measurement type.
2 = Spare
3 = This is the second transmitted message of a linked pair of Type 11 messages that together contain the set of all measurement blocks for a particular measurement type.

Number of measurements: the number of measurement blocks in the message.

Measurement type: as defined in 3.6.4.2.3.

Ephemeris decorrelation parameter D (P_D): a parameter that characterizes the impact of residual ephemeris errors due to decorrelation for the first measurement block in the message.

Note.— This parameter, P_D, may be different than the ephemeris decorrelation parameter P provided in the Type 1 message. Additional information regarding the difference in these parameters is given in Attachment 6D, 7.5.6.1.3 and 7.5.6.1.4.

For an SBAS geostationary satellite, the ephemeris decorrelation parameter, if transmitted, shall be coded as all zeros.

3.6.4.11.4 The measurement block parameters shall be as follows:

Ranging source ID: as defined in 3.6.4.2.3.

Pseudo-range correction (PRC_{30}): the correction to the ranging source pseudo-range based on 30-second carrier smoothing.

Range rate correction (RRC_{30}): the rate of change of the pseudo-range correction based on 30-second carrier smoothing.

Sigma_PR_gnd_D ($\sigma_{pr\_gnd\_D}$): the standard deviation of a normal distribution associated with the signal-in-space contribution of the pseudo-range error in the 100-second smoothed correction in the Type 1 message at the GBAS reference point (3.6.5.5.1 and 3.6.7.2.2.4).

Note.— The parameter $\sigma_{pr\_gnd\_D}$ differs from σpr_gnd for the corresponding measurement in the Type 1 message in that $\sigma_{pr\_gnd\_D}$ shall include no inflation to address overbounding of decorrelated ionospheric errors.

Coding: 1111 1111 = Ranging source correction invalid.

Sigma_PR_gnd_30 ($\sigma_{pr\_gnd\_30}$): the standard deviation of a normal distribution that describes the nominal accuracy of corrected pseudo-range smoothed with a time constant of 30 seconds at the GBAS reference point.

Note.— The normal distribution $N(0, \sigma_{pr\_gnd\_30})$ is intended to be an appropriate description of the errors to be used in optimizing the weighting used in a weighted least squares position solution. The distribution need not bound the errors as described in 3.6.5.5.1 and 3.6.7.2.2.4.

Coding: 1111 1111 = Ranging source correction invalid.

3.6.5 DEFINITIONS OF PROTOCOLS FOR DATA APPLICATION

. . .

3.6.5.1 *Measured and carrier smoothed pseudo-range.* The broadcast correction is applicable to carrier smoothed code pseudo-range measurements that have not had the satellite broadcast troposphere and ionosphere corrections applied to them. The carrier smoothing is defined by the following filter:

where

P_{CSCn} = the smoothed pseudo-range;

P_{CSCn-1} = the previous smoothed pseudo-range;

P = the raw pseudo-range measurement where the raw pseudo-range measurements are obtained from a carrier driven code loop, first order or higher and with a one-sided noise bandwidth greater than or equal to 0.125 Hz;

λ = the L1 wavelength

ϕ_n = the carrier phase;

ϕ_{n-1} = the previous carrier phase; and

α = the filter weighting function equal to the sample interval divided by the smoothing time constant. For GBAS pseudo-range corrections in Message Type 1 and Message Type 101, the smoothing time constant is ~~of~~ 100 seconds, except as specified in 3.6.8.3.5.1 for airborne equipment. For GBAS pseudo-range corrections in Message Type 11, the smoothing time constant is 30 seconds.

3.6.5.2 *Corrected pseudo-range.* The corrected pseudo-range for a given satellite at time *t* is:

$$PR_{corrected} = P_{CSC} + PRC + RRC \times (t - \text{tz-count}) + TC + c \times (\Delta t_{sv})_{L1}$$

where

P_{CSC} = the smoothed pseudo-range (defined in 3.6.5.1);
PRC = the pseudo-range correction from the appropriate message

a) for 100-second smoothed pseudo-ranges, PRC is taken from message type 1 or type 101 ~~(~~defined in 3.6.4.2; and

b) for 30-second smoothed pseudo-ranges, PRC is PRC_{30} taken from message type 11 defined in 3.6.4.11~~);~~

RRC = the pseudo-range correction rate from the appropriate message:

a) ~~(~~for 100-second smoothed pseudo-ranges, RRC is taken from message type 1 or type 101 defined in 3.6.4.2, and

b) for 30-second smoothed pseudo-ranges, RRC is RRC_{30} taken from message type 11 defined in 3.6.4.11~~);~~

t = the current time;

tz-count = the time of applicability derived from the modified Z-count of the message containing PRC and RRC ~~(defined in 3.6.4.2)~~

TC = the tropospheric correction (defined in 3.6.5.3); and
c and $(\Delta t_{sv})_{L1}$ are as defined in 3.1.2.2 for GPS satellites.

3.6.5.3 *TROPOSPHERIC DELAY*

. . .

3.6.5.4 *Residual ionospheric uncertainty.* The residual ionospheric uncertainty for a given satellite is:

$$\sigma_{iono} = F_{pp} \times \cancel{\sigma_{vert\_iono\_gradient}}\ \sigma_{vig} \times (x_{air} + 2 \times \tau \times v_{air})$$

where

F_{pp} = the vertical-to-slant obliquity factor for a given satellite (3.5.5.5.2);

$\cancel{\sigma_{vert\_iono\_gradient}}$ σvig = **is dependent on the active GAST. For GAST A, B or C, σ_{vig} = $\sigma_{vert\_iono\_gradient}$** (as defined in 3.6.4.3); **For GAST D, σvig = $\sigma_{vert\_iono\_gradient\_D}$ (as defined in 3.6.4.3.2.2);**

x_{air} = the distance (slant range) in metres between current aircraft location and the GBAS reference point indicated in the Type 2 message;

τ = is dependent on the active GAST.
For GAST A, B or C, τ =100 seconds (time constant used in 3.6.5.1); and **For GAST D, the value of τ depends on whether σ_{iono} is applied in measurement weighting or in integrity bounding. τ = 100 seconds when σ_{iono} is used for integrity bounding (per section 3.6.5.5.1.1.1) and τ = 30 seconds when σ_{iono} is used for measurement weighting (per section.3.6.5.5.1.1.2).**

v_{air} = the aircraft horizontal approach velocity (metres per second).

3.6.5.5 *PROTECTION LEVELS*

3.6.5.5.1 ***Protection levels for all GBAS approach service types*** ~~*Category I precision approach and APV*~~. The signal-in-space vertical and lateral protection levels (VPL and LPL) are upper confidence bounds on the error in the position relative to the GBAS reference point defined as:

$$VPL = MAX\{VPL_{H0}, VPL_{H1}\}$$

$$LPL = MAX\{LPL_{H0}, LPL_{H1}\}$$

3.6.5.5.1.1 *Normal measurement conditions*

3.6.5.5.1.1.1 The vertical protection level (VPL_{H0}) and lateral protection level (LPL_{H0}), assuming that normal measurement conditions (i.e. no faults) exist in all reference receivers and on all ranging sources, is calculated as:

$$VPL_{H0} = K_{ffmd}\sigma_{vert} + D_V$$

$$LPL_{H0} = K_{ffmd}\sigma_{lat} + D_L$$

$$\cancel{VPL_{H0} = K_{ffmd}\sqrt{\sum_{i=1}^{N} s\_vert_i^2 \times \sigma_i^2}}$$

$$\cancel{LPL_{H0} = K_{ffmd}\sqrt{\sum_{i=1}^{N} s\_lat_i^2 \times \sigma_i^2}}$$

where

$$\sigma_{vert} = \sqrt{\sum_{i=1}^{N} s\_vert_i^2 \times \sigma_i^2}$$

$$\sigma_{lat} = \sqrt{\sum_{i=1}^{N} s\_lat_i^2 \times \sigma_i^2}$$

$$\sigma_i^2 = \sigma^2_{pr\_gnd,i} + \sigma^2_{tropo,i} + \sigma^2_{pr\_air,i} + \sigma^2_{iono,i};$$

and

$\sigma_{pr\_gnd,i}$ is dependent on the active GAST.
For GAST A, B or C: $\sigma_{pr\_gnd,i} = \sigma_{pr\_gnd}$ for the i^{th} ranging source as defined in (3.6.4.2);
For GAST D: $\sigma_{pr\_gnd,i} = \sigma_{pr\_gnd\_D}$ for the i^{th} ranging source (3.6.4.11);
$\sigma^2_{tropo,i}$, $\sigma^2_{pr\_air,i}$ and $\sigma^2_{iono,i}$ are as defined in section 3.6.5.5.1.1.2;

K_{ffmd}	= the multiplier derived from the probability of fault-free missed detection;
s_vert_i	$= s_{v,i} + s_{x,i} \times \tan(GPA)$;
s_lat_i	$= s_{y,i}$;
$s_{x,i}$	= the partial derivative of position error in the x-direction with respect to pseudo- range error on the i^{th} satellite;

$s_{y,i}$ = the partial derivative of position error in the y-direction with respect to pseudo-range error on the i^{th} satellite;

$s_{v,I}$ = the partial derivative of position error in the vertical direction with respect to pseudo-range error on the i^{th} satellite;

GPA = the glidepath angle for the final approach path (3.6.4.5.1);

N = the number of ranging sources used in the position solution; and

i = the ranging source index for ranging sources used in the position solution.

D_V = an airborne determined parameter depending on the active GAST
For GAST A, B or C: $D_V = 0$
For GAST D: D_V is calculated as the magnitude of the vertical projection of the difference between the 30-second and 100-second position solutions.

D_L = an airborne determined parameter depending on the active GAST
For GAST A, B or C: $D_L = 0$
For GAST D: D_L is calculated as the magnitude of the lateral projection of the difference between the 30-second and 100-second position solutions.

Note 1.— The airborne 30-second and 100-second position solutions, DV and DL are defined in RTCA MOPS DO-253D.

Note 2.— The coordinate reference frame is defined such that x is along track positive forward, y is crosstrack positive left in the local level tangent plane and v is the positive up and orthogonal to x and y.

3.6.5.5.1.1.2 For a general-least-squares position solution, the projection matrix S is defined as:

$$S \equiv \begin{bmatrix} S_{x,1} & S_{x,2} & \cdots & S_{x,N} \\ S_{y,1} & S_{y,2} & \cdots & S_{y,N} \\ S_{v,1} & S_{v,2} & \cdots & S_{v,N} \\ S_{t,1} & S_{t,2} & \cdots & S_{t,N} \end{bmatrix} = (G^T \times W \times G)^{-1} \times G^T \times W$$

where

$$G_i = [-\cos El_i \cos Az_i \; -\cos El_i \sin Az_i \; -\sin El_i \; 1] = i^{th} \text{ row of } G; \text{ and}$$

$$\cancel{W =} \begin{bmatrix} \sigma_1^2 & 0 & \cdots & 0 \\ 0 & \sigma_2^2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \sigma_N^2 \end{bmatrix}^{-1}$$

$$W = \begin{bmatrix} \sigma_{w,1}^2 & 0 & \cdots & 0 \\ 0 & \sigma_{w,2}^2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \sigma_{w,N}^2 \end{bmatrix}^{-1}$$

$$\text{where } \sigma^2_{w,i} = \sigma^2_{pr\_gnd,i} + \sigma^2_{tropo,i} + \sigma^2_{pr\_air,i} + \sigma^2_{iono,i};$$

where

$\sigma_{pr\_gnd,i}$ = is dependent on the active GAST.
For GAST A, B or C or the GBAS positioning service: $\sigma_{pr\_gnd,i} = \sigma_{pr\_gnd}$ for the i[th] ranging source as defined in (3.6.4.2);

For GAST D: $\sigma_{pr\_gnd,i} = \sigma_{pr\_gnd\_30}$ for the ith ranging source (3.6.4.11);

$\sigma_{tropo,i}$ = the residual tropospheric uncertainty for the i[th] ranging source (3.6.5.3);

$\sigma_{iono,i}$ = the residual ionospheric delay (due to spatial decorrelation) uncertainty for the i[th] ranging source (3.6.5.4); and

$\sigma_{pr\_air,i} = \sqrt{\sigma^2_{receiver}(El_i) + \sigma^2_{multipath}(El_i)}$, the standard deviation of the aircraft contribution to the corrected pseudo-range error for the i[th] ranging source. The total aircraft contribution includes the receiver contribution (3.6.8.2.1) and a standard allowance for airframe multipath:

. . .

3.6.5.5.1.2 *Faulted measurement conditions.* When the Type 101 message is broadcast without B parameter blocks, the values for VPL_{H1} and LPL_{H1} are defined as zero. Otherwise, the vertical protection level (VPL_{H1}) and lateral protection level (LPL_{H1}), assuming that a latent fault exists in one, and only one reference receiver, are:

$$VPL_{H1} = \max [VPL_j] + D_V$$
$$LPL_{H1} = \max [LPL_j] + D_L$$

where VPL_j and LPL_j for $_j$ = 1 to 4 are

$VPL_j = |B_{\_vertj}| + K_{md}\ \sigma_{vert,H1}$ and
$LPLj = |B_{\_latj}| + K_{md}\ \sigma_{lat,H1}$
D_V = an airborne determined parameter depending on the active GAST (3.6.5.5.1.1.1)
D_L = an airborne determined parameter depending on the active GAST (3.6.5.5.1.1.1)
and

$B\_vert_j \;=\; \sum_{i=1}^{N}(s\_vert_i \times B_{i,j});$

$B\_lat_j \;=\; \sum_{i=1}^{N}(s\_lat_i \times B_{i,j});$

$B_{i,j}$ = the broadcast differences between the broadcast pseudo-range corrections and the corrections obtained excluding the j^{th} reference receiver measurement for the i^{th} ranging source;

K_{md} = the multiplier derived from the probability of missed detection given that the ground subsystem is faulted;

$\sigma^2_{vert,H1} \;=\; \sum_{i=1}^{N}(s\_vert_i^2 \times \sigma\_H1_i^2);$

$\sigma^2_{lat,H1} \;=\; \sum_{i=1}^{N}(s\_lat_i^2 \times \sigma\_H1_i^2);$

$\sigma\_H1^2_i \;=\; \left(\frac{M_i}{U_i}\right)\sigma^2_{pr\_gnd,i} + \sigma^2_{pr\_air,i} + \sigma^2_{tropo,i} + \sigma^2_{iono,i};$

$\sigma_{pr\_gnd,i}$ is dependent on the active GAST.
For GAST A, B or C: $\sigma_{pr\_gnd,i} = \sigma_{pr\_gnd}$ for the i^{th} ranging source as defined in (3.6.4.2);
For GAST D: $\sigma_{pr\_gnd,i} = \sigma_{pr\_gnd\_D}$ for the i^{th} ranging source (3.6.4.11);

$\sigma^2_{tropo,i}$, $\sigma^2_{pr\_air,i}$ and $\sigma^2_{iono,i}$ are as defined in section 3.6.5.5.1.1.2;

M_i = the number of reference receivers used to compute the pseudo-range corrections for the i^{th} ranging source (indicated by the B values); and

U_i = the number of reference receivers used to compute the pseudo-range corrections for the i^{th} ranging source, excluding the j^{th} reference receiver.

Note.— A latent fault includes any erroneous measurement(s) that is not immediately detected by the ground subsystem, such that the broadcast data are affected and there is an induced position error in the aircraft subsystem.

3.6.5.5.1.3 *Definition of K multipliers for GBAS approach services ~~Category I precision approach and APV~~.* The multipliers are given in Table B-67.

Table B-67. K-multipliers for GBAS approach services ~~Category I precision approach and APV~~

	M_i			
Multiplier	1 (Note)	2	3	4
K_{ffmd}	6.86	5.762	5.81	5.847
K_{md}	Not used	2.935	2.898	2.878

Note.- For GAST A ~~APV-I approaches~~ supported by Type 101 messages broadcast without the B parameter block.

. . .

3.6.5.5.2 *GBAS positioning service.* The signal-in-space horizontal protection level is an upper confidence bound on the horizontal error in the position relative to the GBAS reference point defined as:

$$HPL = MAX\{HPL_{H0}, HPL_{H1}, HEB\}$$

. . .

3.6.5.5.2.2 *Faulted measurement conditions.*

$$HPL_j = |B\_horz_j| + K_{md\_POS}\, d_{major,H1}$$

3.6.5.6 *ALERT LIMITS*

Note 1.— Guidance concerning the calculation of alert limits, including approaches associated with channel numbers 40 000 to 99 999, is provided in Attachment 6D, 7.13.

Note 2. — Computation of alert limits depends on the active service type.

3.6.5.6.1 ***GAST C and D alert limits*** ~~*Category I precision approach alert limits.*~~ The alert limits are defined in Tables B-68 and B-69. For aircraft positions at which the lateral deviation exceeds twice the deviation at which full-scale lateral deflection of a course deviation indicator is achieved, or vertical deviation exceeds twice the deviation at which full-scale fly-down deflection of a course deviation indicator is achieved, both the lateral and vertical alert limits are set to the maximum values given in the tables.

3.6.5.6.2 ***GAST A and B*** ~~*APV*~~ *alert limits.* The alert limits are equal to the FASLAL and FASVAL **taken from the Type 4 message** for approaches with channel numbers in the range of 20 001 to 39 999. For approaches with channel numbers in the range 40 000 to 99 999, the alert limits are stored in the on-board database.

3.6.5.7 *Channel number.* Each GBAS approach transmitted from the ground subsystem is associated with a channel number in the range of 20 001 to 39 999. If provided, the GBAS positioning service is associated with a separate channel number in the range of 20 001 to 39 999. The channel number is given by:

Channel number = 20 000 + 40(F – 108.0) + 411(S)

where

F = the data broadcast frequency (MHz)
S = RPDS or RSDS

and

RPDS = the reference path data selector for the FAS data block (as defined in 3.6.4.5.1)
RSDS = the reference station data selector for the GBAS ground subsystem (as defined in 3.6.4.3.1)

Table B-68 GAST C AND D ~~Category I~~ lateral alert limit

Horizontal distance of aircraft position From the LTP/FTP as translated Along the final approach path (metres)	Lateral alert limit (metres)
~~291~~≤ D ≤ 873	FASLAL
873 < D ≤ 7 500	0.0044D (m) +FASLAL -3.85
D >7 500	FASLAL + 29.15

Table B-69. GAST C and D ~~Category I~~ vertical alert limit

Height above LTP/FTP of aircraft position translated onto the final approach path (feet)	Vertical alert limit (metres)
~~100~~ H≤ 200	FASVAL
200 < H ≤ 1 340	0.02925H (ft) +FASVAL-5.85
H > 1 340	FASVAL + 33.35

For channel numbers transmitted in the additional data block 2 of Type 2 message (as defined in 3.6.4.3.2.1), only RSDS are used.

Note 1.— When the FAS is not broadcast for an approach supported by GAST A or B ~~APV~~, the GBAS approach is associated with a channel number in the range 40 000 to 99 999.

Note 2.— Guidance material concerning channel number selection is provided in Attachment 6D, 7.7.

3.6.5.8 *EPHEMERIS ERROR POSITION BOUND*

. . .

3.6.5.8.1 *~~Category I precision a~~ GBAS approach ~~and APV~~.* The vertical and lateral ephemeris error position bounds are defined as:

$$VEB = \underset{j}{MAX}\{VEB_j\} + D_V$$

$$LEB = \underset{j}{MAX}\{LEB_j\} + D_L$$

The vertical and lateral ephemeris error position bounds for the j[th] core satellite constellation ranging source used in the position solution are given by:

$$\cancel{VEB_j = |s\_vert_j| x_{air} P_j + K_{md\_e,j} \sqrt{\sum_{i=1}^{N} s\_vert_i^2 \times \sigma_i^2}}$$

$$VEB_j = |s\_vert_j| x_{air} P_{ej} + K_{md\_ej} \sqrt{\sum_{i=1}^{N} s\_vert_i^2 \times \sigma_i^2}$$

$$\cancel{LEB_j = |s\_lat_j| x_{air} P_j + K_{md\_e,j} \sqrt{\sum_{i=1}^{N} s\_lat_i^2 \times \sigma_i^2}}$$

$$LEB_j = |s\_lat_j| x_{air} P_{ej} + K_{md\_ej} \sqrt{\sum_{i=1}^{N} s\_lat_i^2 \times \sigma_i^2}$$

where:

D_V	= an airborne determined parameter depending on the active GAST (3.6.5.5.1.1.1)
D_L	= an airborne determined parameter depending on the active GAST (3.6.5.5.1.1.1)
$s\_vert_{i \text{ or } j}$	is defined in 3.6.5.5.1.1
$s\_lat_{i \text{ or } j}$	is defined in 3.6.5.5.1.1
x_{air}	is defined in 3.6.5.4
N	is the number of ranging sources used in the position solution
σ_i	is defined in 3.6.5.5.1.1
P_{ej}	is the broadcast ephemeris decorrelation parameter for the j[th] ranging source. The source of this parameter depends on the active GBAS approach service type: GAST A,B or C: Pej=P from the Type 1 or Type 101 Message corresponding to the j[th] ranging source (section 3.6.4.2.3) GAST D: $P_{ej}=P_D$ from type 11 Message corresponding to the jth ranging source (section 3.6.4.11.3).
$K_{md\_e,j}$	Is the broadcast ephemeris missed detection multiplier for ~~Category I precision approach and APV~~ GAST A-C associated with the satellite constellation for the j[th] ranging source ~~($K_{md\_e,GPS}$ or $K_{md\_e,GLONASS}$)~~ The source of this parameter depends on the active GBAS approach service type GAST A, B or C; $K_{md\_e,j} = K_{md\_e,GPS}$ or $K_{md\_e,GLONASS}$ as obtained from the Type 2 Message Additional Data Block 1 (section 3.6.4.3.1) GAST D: $K_{md\_e,j} = K_{md\_e\_D,GPS}$ or $K_{md\_e\_D,GLONASS}$ are from the Type 2 Message Additional Data block 3 (section 3.6.4.3.2.2).

3.6.5.8.2 *GBAS positioning service*. The horizontal ephemeris error position bound is defined as:

$$HEB = \underset{j}{MAX}\{HEB_j\}$$

The horizontal ephemeris error position bound for the j[th] core satellite constellation ranging source used in the position solution is given by:

$$\cancel{HEB_j = |s_{horzj}| x_{air} P_j + K_{md\_e\_POS} d_{major}}$$

$$HEB_j = |s_{horzj}| x_{air} P_j + K_{md\_e\_POS} d_{major}$$

where:

$s_{hor,zj}^2 = s_{xj}^2 + s_{yj}^2$

$s_{x,j}$ is as defined in 3.6.5.5.2.1

$s_{y,j}$ is as defined in 3.6.5.5.2.1

x_{air} is defined in 3.6.5.4

P_j is the broadcast ephemeris decorrelation parameter for the j[th] ranging source. The source of this parameter does not depend on the active GBAS approach service type. In all cases P_j=P from the Type 1 or Type 101 Message (section 3.6.4.2.3) corresponding to the j[th] ranging source.

$K_{md\_e\_POS}$ is the broadcast ephemeris missed detection multiplier for the GBAS positioning service associated with the satellite constellation for the jth ranging source ($K_{md\_e\_POS,GPS}$ or $K_{md\_e\_POS,GLONASS}$)

d_{major} is as defined in 3.6.5.5.2.1

3.6.5.9 *Ionospheric gradient error*

The maximum undetected 30-second smoothed corrected pseudo-range error due to an ionospheric gradient (E_{IG}) is calculated, based on the broadcast parameters Y_{EIG} and M_{EIG}, as:

$E_{IG} = Y_{EIG} + M_{EIG} \times D_{EIG}$

where

Y_{EIG} = maximum value of E_{IG} (metres) in the Type 2 message;

M_{EIG} = slope of maximum E_{IG} (m/km) in the Type 2 message;

D_{EIG} = the distance in kilometres between the LTP location for the selected approach broadcast in the Type 4 Message and the GBAS reference point in the Type 2 message.

3.6.6 MESSAGE TABLES

Each GBAS message shall be coded in accordance with the corresponding message format defined in Tables B-70 through B-73.

Note.— Message type structure is defined in 3.6.4.1.

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Table B-70B. Type 11 pseudo-range corrections (30-second smoothed pseudo-ranges) message

Data content	Bits used	Range of values	Resolution
Modified Z-count	14	0-1199.9 sec	0.1 sec
Additional message flag	2	0-3	1
Number of measurements	5	0-18	1
Measurement type	3	0-7	1
Ephemeris decorrelation parameter D (P_D) (Notes 1.3)	8	0-1.275x10^{-3} mm	5x10^{-6} m/m
For N measurement blocks:			
Ranging source ID	8	1-255	1
Pseudo-range correction (PRC_{30})	16	± 327.67 m	0.01m
Range rate correction (RRC_{30})	16	± 32.767 m/s	0.001 m/s
Sigma _PR_gnd_D ($\sigma_{pr\_gnd\_D}$) (Note 2)	8	0 - 5.08 m	0.02 m
Sigma_PR_gnd30s($\sigma_{pr\_gnd\_30}$) (Note2)	8	0 - 5.08 m	0.02 m

Notes:

1.For SBAS satellites, the parameter is set to zeros.

2. 1111 1111 indicates the source is invalid.

3. Parameter is associated with the first transmitted measurement block.

. . .

Table B -71A. Type 2 GBAS-related data message

Data content	Bits used	Range of values	Resolution
GBAS reference receivers	2	2 to 4	——
Ground accuracy designator letter	2	——	——
Spare	1	——	——
GBAS continuity/integrity designator	3	0 to 7	1
Local magnetic variation	11	± 180°	0.25 °
Reserved and set to zero(00000)	5	——	——

~~Spare~~			
$\sigma_{vert\_iono\_gradient}$	8	0 to 25.5 x 10^{-6} m/m	0.1 x 10^{-6} m/m
Refractivity index	8	16 to 781	3
Scale Height	8	0 to 25 500 m	100 m
Refractivity uncertainty	8	0 to 255	1
Latitude	32	± 90.0°	0.0005 arcsec
Longtitude	32	± 180.0°	0.0005 arcsec
GBAS reference point height	24	± 83 886.07 m	0.01 m
Additional data block 1 (if provided)			
Reference station data selector	8	0 to 48	1
Maximum use distance (D_{max})	8	2 to 510 km	2 km
$K_{md\_e\_POS,GPS}$	8	0 to 12.75	0.05
$K_{md\_e\_GPS}$	8	0 to 12.75	0.05
$K_{md\_e\_POS,GLONASS}$	8	0 to 12.75	0.05
Kmd_e,GLONASS	8	0 to 12.75	0.05
Additional data blocks (repeated for all provided) ~~2 (if provided)~~			
Additional data block length	8	2 to 255	1
Additional data block number	8	2 to 255	1
Additional data parameters	Variable	——	——

Note.- Multiple additional data blocks may be appended to a Type 2 message.

. . .

Table B-72. Type 4 FAS data message

Data content	Bits used	Range of values	Resolution
For N data sets			
Data set length	8	2 to 212	1 byte
FAS data block	304	——	——
FAS vertical alert limit/approach status	8		
1. When associated approach performance designator ~~indicates APV - I~~ (APD) is coded as 0~~)~~		0 to 50.8 m	0.2 m
2. When associated approach performance designator ~~does not indicate APV - I~~(APD) is not coded as 0~~)~~		0 to 25.4 m	0.1 m
FAS lateral alert limit/approach status	8	0 to 58 m	0.2m

. . .

3.6.7 NON-AIRCRAFT ELEMENTS

3.6.7.1 *PERFORMANCE*

3.6.7.1.1 Accuracy

3.6.7.1.1.1 The root-mean-square (RMS) (1 sigma) of the ground subsystem contribution to the corrected 100-second smoothed pseudo-range accuracy for GPS and GLONASS satellites shall be:

. . .

Note 1.— The GBAS ground subsystem accuracy requirement is determined by the GAD letter and the number of ~~installed~~ reference receivers.

Note 2.— The ground subsystem contribution to the corrected 100-second smoothed pseudo-range error specified by the curves defined in Tables B-74 and B-75 and the contribution to the SBAS satellites do not include aircraft noise and aircraft multipath.

3.6.7.1.1.2 The RMS of the ground subsystem contribution to the corrected 100-second smoothed pseudo-range accuracy for SBAS satellites shall be:

. . .

3.6.7.1.2 *Integrity*

3.6.7.1.2.1 *GBAS ground subsystem integrity risk*

3.6.7.1.2.1.1 *Ground subsystem integrity risk for GBAS approach services*

3.6.7.1.2.1.1.1 *Ground subsystem signal-in-space integrity risk for GBAS approach service types A, B or C~~Category I precision approach and APV~~.* For a GBAS ground subsystem ~~that~~ classified as FAST A, B or C ~~provides the Category I precision approach or APV~~, the integrity risk shall be less than 1.5×10^{-7} per approach.

Note 1.— The integrity risk assigned to the GBAS ground subsystem is a subset of the GBAS signal-in-space integrity risk, where the protection level integrity risk (3.6.7.1.2.2.1) has been excluded and the effects of all other GBAS, SBAS and core satellite constellations failures are included. The GBAS ground subsystem integrity risk includes the integrity risk of satellite signal monitoring required in ~~3.6.7.2.6~~ 3.6.7.3.3~~and the integrity risk associated with the monitoring in 3.6.7.3.~~

Note 2.— GBAS signal-in-space integrity risk is defined as the probability that the ground subsystem provides information which when processed by a fault-free receiver, using any GBAS data that could be used by the aircraft in the service volume, results in an out-of-tolerance lateral or vertical relative position error without annunciation for a period longer than the maximum signal-in-space time-to-alert. An out-of-tolerance lateral or vertical relative position error is defined as an error that exceeds the GBAS approach services ~~Category I precision approach or APV~~ protection level and, if additional data block 1 is broadcast, the ephemeris error position bound.

3.6.7.1.2.1.1.2 *Ground subsystem signal-in-space integrity risk for GBAS approach service type D.* For a GBAS ground subsystem classified as FAST D the integrity risk for all effects other than errors induced by anomalous ionospheric conditions shall be less than 1.5×10^{-7} per approach.

Note 1.— The integrity risk assigned to the GBAS ground subsystem classified as FAST D is a subset of the GBAS signal-in-space integrity risk, where the protection level integrity risk (3.6.7.1.2.2.1) has been excluded and the effects of all other GBAS, SBAS and core satellite constellations failures are included.

Note 2.— For GAST D the GBAS signal-in-space integrity risk is defined as the probability that the ground subsystem provides information which when processed by a fault-free receiver, using any GBAS data that could be used by the aircraft in the service volume, in the absence of an ionospheric anomaly results in an out-of-tolerance lateral or vertical relative position error without annunciation for a period longer than the maximum signal-in-space time-to-alert. An out-of-tolerance lateral or vertical relative position error is defined as an error that exceeds the GBAS approach services protection level and the ephemeris error position bound. For GAST D, out of tolerance conditions caused by anomalous ionospheric errors are excluded from this integrity risk as the risk due to ionospheric anomalies has been allocated to and is mitigated by the airborne segment.

3.6.7.1.2.1.1.3 *Ground subsystem integrity risk for GAST D.* For a GBAS ground subsystem classified as FAST D, the probability that the ground subsystem internally generates and transmits non-compliant information for longer than 1.5 seconds shall be less than 1×10^{-9} in any one landing.

Note 1.— This additional integrity risk requirement assigned to FAST D GBAS ground subsystems is defined in terms of the probability that internal ground subsystem faults generate non-compliant information. Non-compliant information in this context is defined in terms of the intended function of the ground subsystem to support landing operations in Category III minima. For example, non-compliant information includes any broadcast signal or broadcast information that is not monitored in accordance with the standard.

Note 2.— Environmental conditions (anomalous ionosphere, troposphere, radio frequency interference, GNSS signal multipath, etc.) are not considered faults; however, faults in ground subsystem equipment used to monitor for or mitigate the effects of these environmental conditions are included in this requirement. Similarly, the core satellite constellation ranging source faults are excluded from this requirement; however, the ground subsystem's capability to provide integrity monitoring for these ranging sources is included. Monitoring requirements for ranging source faults and ionosphere environmental conditions are separately specified in 3.6.7.3.3.2, 3.6.7.3.3.3 and 3.6.7.3.4.

Note 3.— Faults that occur in ground receivers used to generate the broadcast corrections are excluded from this requirement if they occur in any one, and only one, ground receiver at any time. Such faults are constrained by the requirement in.3.6.7.1.2.2.1.2 and the associated integrity risk requirement in 3.6.7.1.2.2.1 and 3.6.7.1.2.2.1.1.

3.6.7.1.2.1.2. *Ground subsystem time to alert for GBAS approach services*

3.6.7.1.2.1.2.1 *Maximum time to alert for approach services*

3.6.7.1.2.1.~~1~~2.1.1 **For a ground segment classified as FAST A, B, C or D,** ~~T~~the GBAS ground subsystem maximum time-to-alert shall be less than or equal to 3 seconds **for all signal-in-space integrity requirements (see Appendix 6B, 3.6.7.1.2.1.1.1, 3.6.7.1.2.1.1.2, 3.6.7.1.2.2.1)** when Type 1 messages are broadcast.

Note 1.— The ***ground subsystem*** *time-to-alert above is the time between the onset of the out-of-tolerance lateral or vertical relative position error and the transmission of the last bit of the message that contains the integrity data that reflects the condition* ***(see Attachment 6D, 7.5.14).***

Note 2.— For FAST D ***ground subsystems, additional range domain monitoring requirements apply as defined in section 3.6.7.3.3.2, 3.6.7.3.3.3 and 3.6.7.3.4. In these sections, time limits are defined for the ground system to detect and alert the airborne receiver of out-of-tolerance differential pseudo-range errors.***

3.6.7.1.2.1.~~1~~.2.1.2 **For a ground segment classified as FAST A,** ~~T~~the GBAS ground subsystem maximum **signal-in-space** time-to-alert shall be less than or equal to 5.5 seconds when Type 101 messages are broadcast.

3.6.7.1.2.1.3 *Ground subsystem FASLAL and FASVAL*

3.6.7.1.2.1.~~1~~.3.1 For **Message Type 4 FAS data blocks with APD coded as 1, 2, 3 or 4** ~~Category I precision approach,~~ the value FASLAL for each FAS block, as defined in the FAS lateral alert limit field of the Type 4 message shall be no greater than 40 metres, and the value FASVAL for each FAS block, as defined in the FAS vertical alert limit field of the Type 4 message, shall be no greater than 10 metres.

3.6.7.1.2.1.~~1~~.3.2~~4~~ For **Message Type 4 FAS data blocks with APD coded as zero** ~~APV~~, the value FASLAL and FASVAL shall be no greater than the lateral and vertical alert limits given in CAR-ANS 6.3.7.2.4 **for the intended operational use.**

3.6.7.1.2.1.~~2~~4 ***Ground subsystem signal-in-space integrity risk for*** *GBAS positioning service.* For GBAS ground subsystem that provides the GBAS positioning service, integrity risk shall be less than 9.9×10^{-8} per hour.

Note 1.— The integrity risk assigned to the GBAS ground subsystem is a subset of the GBAS signal-in-space integrity risk, where the protection level integrity risk (3.6.7.1.2.2.2) has been excluded and the effects of all other GBAS, SBAS and core satellite constellations failures are included. The GBAS ground subsystem integrity risk includes the integrity risk of satellite signal monitoring required in ~~6.3.6.7.2.6~~ 3.6.7.3.3 ~~and the integrity risk associated with the monitoring in 6.3.6.7.3.~~

...

3.6.7.1.2.1.~~2~~4.1 *Time to alert for GBAS positioning service.* The GBAS ground subsystem maximum time-to-alert shall be less than or equal to 3 seconds when Type 1 messages are broadcast and less than or equal to 5.5 seconds when Type 101 messages are broadcast.

...

3.6.7.1.2.2 *Protection level integrity risk*

3.6.7.1.2.2.1 For a GBAS ground subsystem that provides ~~the~~ GBAS approach services ~~Category I precision approach or APV,~~ the protection level integrity risk shall be less than 5×10^{-8} per approach.

Note.— For approach services, the ~~The Category I precision approach and APV~~ protection level integrity risk is the integrity risk due to undetected errors in the 100-second smoothed position solution relative to the GBAS reference point greater than the associated protection levels under the two following conditions:

a) normal measurement conditions defined in 3.6.5.5.1.1 with D_V and D_L set to zero; and

b) faulted measurement conditions defined in 3.6.5.5.1.2 with D_V and D_L set to zero.

Note.— The ground subsystem bounding of the 100-second smoothed GAST D position solution will ensure that the 30s smoothed GAST D position solution is bounded.

3.6.7.1.2.2.1.1 *Additional bounding requirements for FAST D ground subsystems.* The σ_{vert} (used in computing the protection level VPL_{H0}) and σ_{lat} (used in computing the protection level LPL_{H0}) for GAST D formed based on the broadcast parameters (defined in 3.6.5.5.1.1.1) and excluding the airborne contribution shall satisfy the condition that a normal distribution with zero mean and a standard deviation equal to σ_{vert} and σ_{lat} bounds the vertical and lateral error distributions of the combined differential correction errors as follows:

$$\int_{y}^{\infty} f_n(x)dx \leq Q\left(\frac{y}{\sigma}\right) \text{ for all } \frac{y}{\sigma} \geq 0 \text{ and}$$

$$\int_{-\infty}^{-y} f_n(x)dx \le Q\left(\frac{y}{\sigma}\right) \text{ for all } \frac{y}{\sigma} \ge 0$$

where

$f_n(x)$ = probability density function of the differential vertical or lateral position error excluding the airborne contribution, and

$$Q(x) = \frac{1}{\sqrt{2\pi}}\int_{x}^{\infty} e^{-\frac{t^2}{2}}dt$$

The $\sigma_{vert.H1}$ (used in computing the protection level VPL_{H1}) and $\sigma_{lat.H1}$ (used in computing the protection level LPL_{H1}) for GAST D formed based on the broadcast parameters (defined in 3.6.5.5.1.2) and excluding the airborne contribution, shall bound the combined differential correction errors (as defined above) formed by all possible subsets with one reference receiver excluded.

Note 1.— The airborne contribution is addressed in 3.6.8.3.2.1 in combination with the use of the standard airborne multipath model defined in 3.6.5.5.1.1.2.

Note 2.— The combined differential correction errors refer to code carrier smoothed corrections based on 100-second smoothing time constant.

3.6.7.1.2.2.1.2 For a GBAS ground subsystem classified as FAST D, the rate of faulted measurements from any one, and only one, reference receiver shall be less than 1×10^{-5} per 150 seconds.

Note.— Faulted measurements can occur from faults within the receiver or from environmental conditions unique to a single reference receiver location.

...

3.6.7.1.3 *Continuity of service*

3.6.7.1.3.1 *Continuity of service for* approach services ~~*Category I precision approach and APV.*~~ The GBAS ground subsystem continuity of service shall be greater than or equal to 1 – 8.0 × 10^{-6} per 15 seconds.

...

3.6.7.1.3.2 *Additional continuity of service requirements for FAST D.* The probability of a GBAS ground subsystem failure or false alert, excluding ranging source monitoring, causing an unscheduled interruption of service for a period equal to or greater than 1.5 seconds shall not exceed 2.0 x 10^{-6} during any 15 second interval. The probability that the ground subsystem excludes any individual fault-free ranging source from the Type 1 or Type 11 corrections due to a false detection by the ground integrity monitors shall not exceed 2.0 x 10^{-7} during any 15 second interval.

Note 1.— Loss of service includes failures resulting in loss of the VHF data broadcast, failure to meet the VHF data broadcast field strength, failures resulting in transmission of out-of-tolerance VHF broadcast data, and alert due to an integrity failure. Guidance material on the potential causes of loss of service and monitor false detections are contained in Attachment 6D, 7.6.2.1.

Note 2. – Continuity for FAST D is defined as the probability that the ground subsystem continues to provide the services associated with the intended ground subsystem functions. Total aircraft continuity of navigation system performance in the position domain must be evaluated in the context of a specific satellite geometry and aeroplane integration. Evaluation of position domain navigation service continuity is the responsibility of the airborne user for GAST D. Additional information regarding continuity is given in Attachment 6D, 7.6.2.1.

3.6.7.1.3.3~~2~~ *Continuity of service for positioning service*

Note.— For GBAS ground subsystems that provide the GBAS positioning service, there may be additional continuity requirements depending on the intended operations.

3.6.7.2 *FUNCTIONAL REQUIREMENTS*

3.6.7.2.1 *General*

3.6.7.2.1.1 *Data broadcast* requirements ~~*rates.*~~

3.6.7.2.1.1.1 A GBAS ground subsystem ~~that supports Category I precision approach or APV-II~~ shall broadcast Message Types as defined in Table B-75A according to the service types supported by the ~~1 messages. A GBAS~~ ground subsystem ~~that does not support Category I precision approach or APV-II shall broadcast either Type 1 or Type 101 messages. A GBAS ground subsystem shall not broadcast both Type 1 and Type 101 messages.~~

~~*Note. Guidance material concerning usage of the Type 101 message is provided in Attachment 6D, 7.18.*~~

3.6.7.2.1.1.2 Each GBAS ground subsystem shall broadcast Type 2 messages **with additional data blocks as required to support the intended operations.**

Note.— Guidance material concerning usage of the Type 2 message additional data blocks is provided in Attachment 6D 7.17.

3.6.7.2.1.1.3 Each GBAS ground subsystem ~~shall broadcast FAS blocks in Type 4 messages for all Category I precision approaches~~ **which supports GBAS approach service type (GAST) B, C or D shall broadcast FAS blocks in Type 4 messages for these** ~~all~~ approaches ~~supported by that GBAS ground subsystem.~~ If a GBAS ground subsystem supports ~~APV~~ **any approach using GAST A or B** and does not broadcast FAS blocks for the corresponding approaches, it shall broadcast additional data block 1 in the Type 2 message.

Note.— FAS blocks for APV procedures may be held within a database on board the aircraft. Broadcasting additional data block 1 allows the airborne receiver to select the GBAS ground subsystem that supports the approach procedures in the airborne database. FAS blocks may also be broadcast to support operations by aircraft without an airborne database. These procedures use different channel numbers as described in Attachment 6D, 7.7.

3.6.7.2.1.1.4 When the Type 5 message is used, the ground subsystem shall broadcast the Type 5 message at a rate in accordance with Table B-76.

3.6.7.2.1.1.5 *Data broadcast rates.* For all message types required to be broadcast, messages meeting the field strength requirements of CAR-ANS 6.3, 6.3.7.3.5.4.4.1.2 and 6.3.7.3.5.4.4.2.2 and the minimum rates shown in Table B-76 shall be provided at every point within the **service volume** ~~coverage~~. The total message broadcast rates from all antenna systems of the ground subsystem combined shall not exceed the maximum rates shown in Table B-76.

Note.— Guidance material concerning the use of multiple antenna systems is provided in Attachment 6D, 7.12.4.

3.6.7.2.1.2 *Message block identifier.* The MBI shall be set to either normal or test according to the coding given in 3.6.3.4.1.

Table B-75A. GBAS message types for supported service types

Message Type	GAST A-Note 1	GAST B-Note1	GAST C–Note 1	GAST D-Note 1
MT 1	Optional- Note 2	Required	Required	Required
MT 2	Required	Required	Required	Required
MT2-ADB 1	Optional–Note 3	Optional-Note 3	Optional-Note 3	Required
MT2-ADB 2	Optional-Note 4	Optional-Note 4	Optional-Note 4	Optional
MT2-ADB 3	Not used	Not used	Not used	Required
MT2-ADB 4	Recommended	Recommended	Recommended	Required
MT3- ADB 5	Recommended	Recommended	Recommended	Required
MT 4	Optional	Required	Required	Required
MT 5	Optional	Optional	Optional	Optional
MT11- Note 6	Not used	Not used	Not used	Required
MT 101	Optional-Note 2	Not allowed	Not allowed	Not allowed

Note 1.— Definition of terms:

- *Required: Message needs to be transmitted when supporting the service type;*
- *Optional: Message transmission is optional when supporting the service type (not used by some or all airborne subsystems);*
- *Recommended: Use of the message is optional, but recommended, when supporting the service type;*
- *Not used: Message is not used by airborne subsystems for this service type;*
- *Not allowed: Message transmission is not allowed when supporting the service type.*

Note 2.— Ground subsystems supporting GAST A service types may broadcast Type 1 or 101 Messages but not both. Guidance material concerning usage of the Type 101 message is provided in Attachment 6D, 7.18.

Note 3.— MT2-ADB1 is required if positioning service is offered.

Note 4.— MT2-ADB2 is required if GRAS Service is offered.

Note 5.— MT3 is recommended (GAST A, B, C) or required (GAST-D) to be used only in order to meet slot occupancy requirements in 3.6.7.4.1.3.

Note 6.— Guidance material concerning usage of the Type 11 message is provided in Attachment 6D, 7.20.

Table B-76. GBAS VHF data broadcast rates

Message Type	Minimum broadcast rate	Maximum broadcast rate
1 or 101	For each measurement type: All measurement blocks once per frame (Note)	For each measurement type: All measurement blocks once per slot
2	Once per 20 consecutive frames	Once per frame (except as stated in 3.6.7.4.1.2)
3	Rate depends on message length and scheduling of other message (see section 3.6.7.4.1.3)	Once per slot and eight times per frame
4	All FAS blocks once per 20 consecutive frames	All FAS blocks once per frame
5	All impacted sources once per 20 consecutive frames	All impacted sources once per 5 consecutive frames
11	For each measurement type: All measurement blocks once per frame (Note)	For each measurement type: All measurement blocks once per slot

Note.— One Type 1, Type 11 or Type 101 message or two Type 1, Type 11 or Type 101 messages that are linked using the additional message flag described in 3.6.4.2, 3.6.4.10.3 or 3.6.4.11.3.

3.6.7.2.1.3 *VDB authentication*

~~*Note.— This section is reserved for forward compatibility with future authentication functions.*~~

3.6.7.2.1.3.1 All GBAS ground subsystems shall support VDB authentication (section 3.6.7.4).

3.6.7.2.1.3.2 All ground subsystems classified as FAST D shall support VDB authentication (section 3.6.7.4).

3.6.7.2.2 *Pseudo-range corrections*

3.6.7.2.2.1 *Message latency.* The time between the time indicated by the modified Z-count and the last bit of the broadcast Type 1, Type 11 or Type 101 message shall not exceed 0.5 seconds.

3.6.7.2.2.2 *Low-frequency data.* Except during an ephemeris change, the first ranging source in the Type 1, Type 11 or Type 101 message shall sequence so that the ephemeris decorrelation parameter, ephemeris CRC and source availability duration for each core satellite constellation's ranging source are transmitted at least once every 10 seconds. During an ephemeris change, the first ranging source shall sequence so that the ephemeris decorrelation parameter, ephemeris CRC and source availability duration for each core satellite constellation's ranging source are transmitted at least once every 27 seconds. When new ephemeris data are received from a core satellite constellation's ranging source, the ground subsystem shall use the previous ephemeris data from each satellite until the new ephemeris data have been continuously received for at least 2 minutes but shall make a transition to the new ephemeris data before 3 minutes have passed. When this transition is made to using the new ephemeris data for a given ranging source, the ground subsystem shall broadcast the new ephemeris CRC and associated low frequency information, notably P and P_D for all occurrences of that ranging source in the low-frequency information of Type 1, Type 11 or Type 101 message in the next 3 consecutive frames. For a given ranging source, the ground subsystem shall continue to transmit data corresponding to the previous ephemeris data until the new CRC ephemeris is transmitted in the low-frequency data of Type 1, Type 11 or Type 101 message (see *Note*). If the ephemeris CRC changes and the IOD does not, the ground subsystem shall consider the ranging source invalid.

Note.— The delay before the ephemeris transition allow sufficient time for the aircraft subsystem to collect new ephemeris data.

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3.6.7.2.2.3 *Broadcast pseudo-range correction.* Each broadcast pseudo-range correction shall be determined by combining the pseudo-range correction estimates for the relevant ranging source calculated from each of the reference receivers. For each satellite, the measurements used in this combination shall be obtained from the same ephemeris data. The corrections shall be based on smoothed code pseudo-range measurements for each satellite using the carrier measurement from a smoothing filter and the approach service type specific smoothing parameters in accordance with Appendix 6B, section 3.6.5.1.

3.6.7.2.2.4 *Broadcast signal-in-space integrity parameters.* The ground subsystem shall provide σ_{pr_gnd} and B parameters for each pseudo-range correction in Type 1 message such that the protection level integrity risk requirements defined in 3.6.7.1.2.2 for GAST A, B, and C are satisfied. At least two B values that are not using the special coding (as defined in section 3.6.4.2.4) shall be provided with each pseudo-range correction. The ground subsystem shall provide σ_{pr_gnd} and, if necessary, B parameters for each pseudo-range correction in Type 101 message such that the protection level integrity risk requirements defined in 3.6.7.1.2.2 are satisfied.

Note.— Broadcast of the B parameters are optional for Type 101 messages. Guidance material regarding the B parameters in Type 101 messages is contained in Attachment 6D, 7.5.11.

3.6.7.2.2.4.1 *Broadcast signal-in-space integrity parameters for FAST D Ground subsystems.* Ground subsystems that support GAST D shall provide Sigma_PR_gnd_D in the Type 11 message and B parameters for each pseudo-range correction in the Type 1 message such that the protection level integrity risk requirement defined in 3.6.7.1.2.2.1 is satisfied.

3.6.7.2.2.4.2 For FAST D systems broadcasting the Type 11 message, if σ_{pr_gnd} is coded as invalid in the Type 1 message, then the Sigma_PR_gnd_D for the associated satellite in the Type 11 message shall also be coded as invalid.

...

3.6.7.2.2.6 *Repeated transmission of Type 1, Type 2, Type 11 or Type 101 messages.* For a given measurement type and within a given frame, all broadcasts of Type 1, Type 2, Type 11 or Type 101 messages or linked pairs from all GBAS broadcast stations that share a common GBAS identification, shall have identical data content.

...

3.6.7.2.2.9 *Linked pair of Type 1, Type 11 or Type 101 messages.* If a linked pair of Type 1, Type 11 or Type 101 messages is transmitted then,

...

d) the two messages shall be broadcast in different time slots;~~and~~

e) the order of the B values in the two messages shall be the same;

f) for a particular measurement type, the number of measurements and low-frequency data shall be computed separately for each of the two individual messages;

g) in the case of FAST D, when a pair of linked Type 1 messages are transmitted, there shall also be a linked pair of Type 11 messages; and

h) if linked message types of Type 1 or Type 11 are used, the satellites shall be divided into the same sets and order in both Type 1 and Type 11 messages.

Note.— Type 1 messages may include additional satellites not available in Type 11 messages, but the relative order of those satellites available in both messages is the same in Type 1 and Type 11 messages. Airborne processing is not possible for satellites included in the Type 11 message but not included in the associated Type 1 message.

3.6.7.2.2.9.1 Linked messages shall only be used when there are more pseudo-range corrections to transmit than will fit in one Type 1 message.

3.6.7.2.2.10 *Modified Z-count requirements*

3.6.7.2.2.10.1 *Modified Z-count update.* The modified Z-count for Type 1, Type 11 or Type 101 messages of a given measurement type shall advance every frame.

3.6.7.2.2.10.2 If Message Type 11 is broadcast, the associated Type 1 and Type 11 messages shall have the same modified Z-count.

3.6.7.2.2.11 *Ephemeris decorrelation parameters*

3.6.7.2.2.11.1 *Ephemeris decorrelation parameter for approach services~~Category I precision approach and APV~~.* For ground subsystems that broadcast the additional data block 1 in the Type 2 message, the ground subsystem shall broadcast the ephemeris decorrelation parameter in the Type 1 message for each core satellite constellation ranging source such that the ground subsystem integrity risk of 3.6.7.1.2.1.1.1 is met.

3.6.7.2.2.11.2 *Ephemeris decorrelation parameter for GAST D.* **Ground subsystems classified as FAST D shall broadcast the ephemeris decorrelation parameter in the Type 11 message for each core satellite constellation ranging source such that the ground subsystem signal-in-space integrity risk of 3.6.7.1.2.1.1.2 is met.**

3.6.7.2.2.11.~~2~~3 *GBAS positioning service.* For ground subsystems that provide the GBAS positioning service, the ground subsystem shall broadcast the ephemeris decorrelation parameter **in the Type 1 message** for each core satellite constellation's ranging source such that the ground subsystem **signal-in-space** integrity risk of 3.6.7.1.2.1.~~2~~4 is met.

...

3.6.7.2.3 *GBAS-related data*

...

3.6.7.2.3.2 *GCID indication.*

3.6.7.2.3.2.1 *GCID indication **for FAST A, B or C**.* If the ground subsystem meets the requirements of 3.6.7.1.2.1.1.1, 3.6.7.1.2.2.1, ~~and~~ 3.6.7.1.3.1, **3.6.7.3.2 and 3.6.7.3.3.1 but not all of 3.6.7.1.2.1.1.2, 3.6.7.1.2.1.1.3, 3.6.7.1.2.2.1.1, and 3.6.7.1.3.2** the GCID shall be set to 1, otherwise it shall be set to 7.

Note.— Some of the requirements applicable to FAST D are redundant with the FAST A, B and C requirements. The phrase "not all of" refers to the condition where a ground subsystem may meet some of the requirements applicable to FAST D but not all of them. Therefore, in that condition the GCID would be set to 1, indicating that the ground subsystem meets only FAST A, B or C.

3.6.7.2.3.2.2 *GCID indication for FAST D.* **If the ground subsystem meets the requirements of 3.6.7.1.2.1.1.1, 3.6.7.1.2.1.1.2, 3.6.7.1.2.1.1.3, 3.6.7.1.2.2.1.1, 3.6.7.1.2.2.1, 3.6.7.1.3.1, 3.6.7.1.3.2, 3.6.7.3.2 and 3.6.7.3.3, the GCID shall be set to 2, otherwise it shall be set in accordance with 3.6.7.2.3.2.1.**

3.6.7.2.3.2.3 **GCID values of 3 and 4 are reserved for future service types and shall not be used.**

...

3.6.7.2.3.5 *Ionospheric uncertainty estimate parameter.*

3.6.7.2.3.5.1 ***Ionospheric uncertainty estimate parameter for all ground subsystems.*** The ground subsystem shall broadcast an ionospheric delay gradient parameter in the Type 2 message such that the protection level integrity risk requirements defined in 3.6.7.1.2.2 are satisfied.

3.6.7.2.3.5.2 ***Ionospheric uncertainty estimate parameter for FAST D ground subsystems.*** **The ground subsystem shall broadcast an ionospheric delay gradient parameter in the Type 2 message, additional data block 3, such that the protection level integrity risk requirements defined in 3.6.7.1.2.2 are satisfied.**

Note.— Guidance material concerning FAST D position domain error bounding for ionospheric errors may be found in Attachment 6D, .7.5.6.1.3 and 7.5.6.1.4.

...

3.6.7.2.3.8.1 *Maximum use distance.* The ground subsystem shall provide the maximum use distance (D_{max}). ~~from the GBAS reference point that defines a volume within which~~ When the positioning service is provided the ground subsystem integrity risk in 3.6.7.1.2.1.4 and the protection level integrity risk in 3.6.7.1.2.2.2 ~~are~~shall be met within D_{max}. When approach service is provided, the maximum use distance shall at least encompass all approach service volumes supported.

...

3.6.7.2.4.4 *LTP/FTP for FAST D.* For an approach that supports GAST D, the LTP/FTP point in the corresponding FAS definition shall be located at the intersection of the runway centerline and the landing threshold.

Note.— Airborne systems may compute the distance to the landing threshold using the LTP/FTP. For GAST D approaches, the LTP/FTP is to be at the threshold so that these distance to go computations reliably reflect the distance to the threshold.

3.6.7.2.4.5 *FPAP location for FAST D.* For an approach that supports GAST D, the FPAP point in the corresponding FAS definition shall be located on the extended runway centerline and the ΔLength offset parameter shall be coded to correctly indicate the stop end of the runway.

3.6.7.2.5 *Predicted ranging source availability data*

Note.— Ranging source availability data are optional for ~~Category I and APV~~ FAST A, B, C or D ground subsystems and may be required for possible future operations.

~~3.6.7.2.6 *Integrity monitoring for GNSS ranging sources.* The ground subsystem shall monitor the satellite signals to detect conditions that will result in improper operation of differential processing for airborne receivers complying with the tracking constraints in Attachment 6D, 8.11. The ground subsystem shall use the strongest correlation peak in all receivers used to generate the pseudo-range corrections. The monitor time-to-alert shall comply with 3.6.7.1.2. The monitor action shall be to set σpr_gnd to the bit pattern "1111 1111" for the satellite or to exclude the satellite from the Type 1 or Type 101 message. The ground subsystem shall also detect conditions that cause more than one zero crossing for airborne receivers that use the Early-Late discriminator function as described in Attachment 6D, 8.11.~~

3.6.7.2.6 *General functional requirements on augmentation*

3.6.7.2.6.1 GBAS ground subsystems classified as FAST C or FAST D shall provide augmentation based on GPS at a minimum.

3.6.7.2.6.2 Ground subsystems classified as FAST C shall be able to process and broadcast corrections for at least 12 satellites of each core constellation for which differential corrections are provided.

3.6.7.2.6.3 Ground subsystems classified as FAST D shall be able to process and broadcast differential corrections for at least 12 satellites of one core constellation.

Note.— Technical validation has only been completed for GAST D when applied to GPS.

3.6.7.2.6.4 Whenever possible, differential corrections for all visible satellites with an elevation greater than 5 degrees above the local horizontal plane tangent to the ellipsoid at the ground subsystem reference location shall be provided for each core constellation for which augmentation is provided.

Note.— The phrase "whenever possible" in this context means whenever meeting another requirement in these SARPs (for example 3.6.7.3.3.1) does not preclude providing a differential correction for a particular satellite.

3.6.7.3 *MONITORING*

3.6.7.3.1 *RF monitoring*

3.6.7.3.1.1 *VHF data broadcast monitoring.* The data broadcast transmissions shall be monitored. The transmission of the data shall cease within 0.5 seconds in case of continuous disagreement during any 3-second period between the transmitted application data and the application data derived or stored by the monitoring system prior to transmission. For FAST D ground subsystems, the transmission of the data shall cease within 0.5 seconds in case of continuous disagreement during any 1-second period between the transmitted application data and the application data derived or stored by the monitoring system prior to transmission.

Note.— For ground subsystems that support authentication, ceasing the transmission of data means ceasing the transmission of Type 1 messages and Type 11 messages if applicable or ceasing the transmission of Type 101 messages. In accordance with 6.3.6.7.4.1.3, the ground subsystem must still transmit messages such that the defined percentage or more of every assigned slot is occupied. This can be accomplished by transmitting Type 2, Type 3, Type 4 and/or Type 5 messages.

...

3.6.7.3.2 *Data monitoring*

3.6.7.3.2.1 *Broadcast quality monitor.* The ground subsystem monitoring shall comply with the time-to-alert requirements given in 3.6.7.1.2.1. The monitoring action shall be one of the following:

a) to broadcast Type 1 (and Type 11 if broadcast) or Type 101 messages with no measurement blocks; or

b) to broadcast Type 1 (and Type 11 if broadcast) or Type 101 messages with the $\sigma_{pr\_gnd,i}$ (and $\sigma_{pr\_gnd\_D,I}$ if broadcast) field set to indicate the ranging source is invalid for every ranging source included in the previously transmitted frame; or

c) to terminate the data broadcast.

Note.— Monitoring actions a) and b) are preferred to c) if the particular failure mode permits such a response, because actions a) and b) typically have a reduced signal-in-space time-to-alert.

3.6.7.3.3 *Integrity monitoring for GNSS ranging sources*

3.6.7.3.3.1 The ground subsystem shall monitor the satellite signals to detect conditions that will result in improper operation of differential processing for airborne receivers complying with the tracking constraints in Attachment 6D, 8.11. The monitor time-to-alert shall comply with 3.6.7.1.2. The monitor action shall be to set σ_{pr_gnd} to the bit pattern "1111 1111" for the satellite or to exclude the satellite from the Type 1, Type 11 or Type 101 message.

3.6.7.3.3.1.1 The ground subsystem shall use the strongest correlation peak in all receivers used to generate the pseudo-range corrections. The ground subsystem shall also detect conditions that cause more than one zero crossing for airborne receivers that use the Early-Late discriminator function as described in Attachment 6D, 8.11.

3.6.7.3.3.2 For FAST D ground subsystems, the probability that the error at the landing threshold point (LTP) of any runway for which the ground subsystem supports GAST D, $|Er|$, on the 30-second smoothed corrected pseudo-range (section 3.6.5.2) caused by a ranging source fault, is not detected and reflected in the broadcast Type 11 message within 1.5 s shall fall within the region specified in Table B-76A.

Ranging source faults for which this requirement applies are:

a) signal deformation (Note 1.);

b) code/carrier divergence;

c) excessive pseudo-range acceleration, such as a step or other rapid change; and

d) erroneous broadcast of ephemeris data from the satellite.

Note 1.— Refer to Attachment 6D, section 8.11 for further information on GAEC-D avionics relating to signal deformation fault.

Note 2.— Upon detection, a ranging source fault may be reflected in the Type 11 message by either:

a) removing the correction for the associated satellite from the Type 11 message; or *b) marking the satellite as invalid using the coding of $\sigma_{pr\_gnd\_D}$ (section 3.6.4.11.4).*

Note 3.— The acceptable probability of missed detection region is defined with respect to differentially corrected pseudo-range error. The differentially corrected pseudo-range error, |Er|, includes the error resulting from a single ranging source fault, given the correct application of GBAS ground subsystem Message Type 11 broadcast corrections (i.e. pseudorange correction and range rate corrections defined in Section 3.6.4.11) by the aircraft avionics as specified within section 3.6.8.3. Evaluation of P_{md} performance includes GBAS ground subsystem fault-free noise. The growth of |Er| with time shall consider the data latency of the ground subsystem, but not the airborne latency, as described in Attachment 6D, 7.5.14.

Note 4.— Additional information regarding the ranging source fault conditions and monitoring requirements for FAST D ground subsystems may be found in Attachment 6D, 7.5.14. Missed messages do not need to be considered as part of compliance with this requirement.

Table B-76 A. P_{md_limit} Parameters

Probability of Missed Detection	Pseudo-range Error (metres)
P_{md} limit ≤ 1	$0 \leq \lvert E_r \rvert < 0.75$
P_{md}_limit $\leq 10^{(-2.56x\lvert Er \rvert+1.92)}$	$0.75 \leq \lvert Er \rvert < 2.7$
Pmd_limit $\leq 10^{-5}$	$2.7 \leq \lvert Er \rvert < \infty$

3.6.7.3.3.3 For FAST D ground subsystems, the probability that an error at the landing threshold point (LTP) of any runway for which the ground subsystem supports GAST D, |Er|, greater than 1.6 metres on the 30-second smoothed corrected pseudo-range (section 3.6.5.2), caused by a ranging source fault, is not detected and reflected in the broadcast Type 11 message within 1.5 seconds shall be less than $1x10^{-9}$ in any one landing when multiplied by the prior probability ($P_{apriori}$).

Ranging source faults for which this requirement applies are:

a) signal deformation (Note 1.);

b) code/carrier divergence;

c) excessive pseudo-range acceleration, such as a step or other rapid change; and

d) erroneous broadcast of ephemeris data from the satellite.

Note 1.— Refer to Attachment 6D, 8.11 for further information on GAEC-D avionics relating to signal deformation fault.

Note 2.— It is intended that the prior probability of each ranging source fault ($P_{apriori}$) be the same value that is used in the analysis to show compliance with error bounding requirements for FAST C and D (see Appendix 6B, 3.6.5.5.1.1.1).

Note 3.— Upon detection, a ranging source fault may be reflected in the Type 11 message by either:

a) removing the faulty satellite correction from the Type 11 message; or

b) marking the satellite as invalid using the coding of $\sigma_{pr\_gnd\_D}$ (section 3.6.4.11.4).

Note 4.— Additional information regarding the ranging source fault conditions and monitoring requirements for FAST D ground subsystems may be found in Attachment 6D, 7.5.14. Missed messages do not need to be considered as part of compliance with this requirement.

3.6.7.3.4 *Ionospheric gradient mitigation*

For FAST D ground subsystems, the probability of an error (|Er|) in the 30-second smoothed corrected pseudo-range at the landing threshold point (LTP) for every GAST D supported runway that: (a) is caused by a spatial ionospheric delay gradient, (b) is greater than the E_{IG} value computed from broadcast Type 2 message, and (c) is not detected and reflected in the broadcast Type 11 message within 1.5 seconds shall be less than 1×10^{-9} in any one landing. The FAST D ground subsystem shall limit the Type 2 broadcast parameters to ensure that the maximum E_{IG} at every LTP supporting GAST D operations shall not exceed 2.75 metres.

Note 1.— The total probability of an undetected delay gradient includes the prior probability of the gradient and the monitor(s) probability of missed detection.

Note 2.— Validation guidance for this requirement can be found in 7.5.6.1.8.

3.6.7.4 *FUNCTIONAL REQUIREMENTS FOR AUTHENTICATION PROTOCOLS*

...

3.6.7.4.1.2 The ground subsystem shall broadcast every Type 2 message only in ~~the~~ one of a set of slots defined as the MT 2 sanctioned slots. ~~that~~ The first slot in the group of MT 2 sanctioned slots corresponds to the SSID coding for the ground subsystem. Slot A is represented by SSID = 0, B by 1, C by 2, and H by 7. The group of MT 2 sanctioned slots then also includes the next slot after the slot corresponding to the station SSID if it exists in the frame. If there is not an additional slot before the end of the frame, only the SSID is included in the set.

Note.— For example, the MT 2 sanctioned slot group for SSID = 0 would include slots {A, B} while the MT 2 sanctioned slot group for SSID = 6 would include slots {G, H}. The MT 2 sanctioned slot group for SSID = 7 includes slot {H} only.

3.6.7.4.1.2.1 The set of slots assigned to a ground station shall include at a minimum all the slots in the MT 2 sanctioned slots as described in section 3.6.7.4.1.2.

3.6.7.4.1.3 *Assigned slot occupancy.* The ground subsystem shall transmit messages such that ~~87~~ **89** per cent or more of every assigned slot is occupied. If necessary, Type 3 messages ~~will~~ **may** be used to fill unused space in any assigned time slot.

Note 1.– More information on the calculation of the slot occupancy is provided in Attachment 6D, 7.21.

Note 2.— The requirement applies to the aggregate transmissions from all transmitters of a GBAS ground subsystem. Due to signal blockage, not all of those transmissions may be received in the service volume.

3.6.7.4.1.4 *Reference path identifier coding.* Every reference path identifier included in every final approach segment data block broadcast by the ground ~~station~~ **subsystem** via the Type 4 messages shall have the first letter selected to indicate the SSID of the ground ~~station~~ **subsystem** in accordance with the following coding.

Coding: A = SSID of 0
X = SSID of 1
Z = SSID of 2
J = SSID of 3
C = SSID of 4
V = SSID of 5
P = SSID of 6
T = SSID of 7

3.6.7.4.2 *Functional requirements for ground subsystems that do not support authentication*

3.6.7.4.2.1 *Reference path ~~indicator~~ **identifier** coding.* Characters in this set: {A X Z J C V P T} shall not be used as the first character of the reference path identifier included in any FAS block broadcast by the ground ~~station~~ **subsystem** via the Type 4 messages.

3.6.8 AIRCRAFT ELEMENTS

3.6.8.1 *GNSS receiver.* The GBAS-capable GNSS receiver shall process signals of GBAS in accordance with the requirements specified in this section as well as with requirements in 3.1.3.1 and/or 3.2.3.1 and/or 3.5.8.1.

Note.— In order to ensure the required performance and functional objectives for GAST D are achieved, it is necessary for the airborne equipment to meet defined performance and functional standards. The relevant minimum operational performance standards are detailed in RTCA DO-253D.

...

3.6.8.2.2.3 *VHF data broadcast ~~sensitivity, range and message~~ failure rate.* The VHF data broadcast receiver shall achieve a message failure rate less than or equal to one failed message per 1 000 full-length (222 bytes) application data messages, ~~while~~ **within the range of the RF field strength defined in 3.7.3.5.4.4 as received by the airborne antenna** ~~operating~~

~~over a range from −87 dBm to −1 dBm~~, provided that the variation in the average received signal power between successive bursts in a given time slot does not exceed 40 dB. Failed messages include those lost by the VHF data broadcast receiver system or which do not pass the CRC after application of the FEC.

Note 1.— An ~~A~~aircraft VHF data broadcast receiving antenna can be horizontally or vertically polarized. Due to the difference in the signal strength of horizontally and vertically polarized components of the broadcast signal, the maximum total aircraft implementation loss ~~is limited to 15 dB~~ for horizontally polarized receiving antennas is 4 dB higher than the maximum loss ~~and 11 dB~~ for vertically polarized receiving antennas. For guidance in determining aircraft implementation loss see Attachment 6D, 7.2.

Note 2.— It is acceptable to exceed the signal power variation requirement in limited parts of the service volume when operational requirements permit. Refer to Attachment 6D, 7.12.4.1 for guidance.

3.6.8.2.2.4 *VHF data broadcast time slot decoding.* The VHF data broadcast receiver shall meet the requirements of 3.6.8.2.2.3 for all message types required (section 3.6.8.3.1.2.1) ~~Type 1, 2 and 4 messages~~ from the selected GBAS ground subsystem. These requirements shall be met in the presence of other GBAS transmissions in any and all time slots respecting the levels as indicated in 3.6.8.2.2.5.1 b).

Note.— Other GBAS transmissions may include: a) ~~messages~~ other message types ~~than Type 1, 2 and 4~~ with the same SSID, and b) messages with different SSIDs.

~~3.6.8.2.2.4.1 *Decoding of Type 101 messages.* A VHF data broadcast receiver capable of receiving Type 101 messages, shall meet the requirements of 3.6.8.2.2.3 for all Type 101 messages from the selected GBAS ground subsystem. These requirements shall be met in the presence of other GBAS transmissions in any and all time slots respecting the levels as indicated in 3.6.8.2.2.5.1 b).~~

3.6.8.2.2.5 *Co-channel rejection*

3.6.8.2.2.5.1 *VHF data broadcast as the undesired signal source.* The VHF data broadcast receiver shall meet the requirements specified in 3.6.8.2.2.3 in the presence of an undesired co-channel VHF data broadcast signal that is either:

a) assigned to the same time slot(s) and 26 dB below the desired VHF data broadcast signal power at the receiver input or lower; or

b) assigned different time slot(s) and ~~whose power is~~ no more than 72 dB above the minimum desired VHF data broadcast signal field strength defined in 3.7.3.5.4.4 ~~up to 15 dBm at the receiver input.~~

3.6.8.2.2.5.2 *VOR as the undesired signal.* The VHF data broadcast receiver shall meet the requirements specified in 3.6.8.2.2.3 in the presence of an undesired co-channel VOR signal that is 26 dB below the desired VHF data broadcast signal power at the receiver input.

3.6.8.2.2.6 *Adjacent channel rejection*

3.6.8.2.2.6.1 *First adjacent 25 kHz channels (±25 kHz).* The VHF data broadcast receiver shall meet the requirements specified in 3.6.8.2.2.3 in the presence of a transmitted undesired signal offset by 25 kHz on either side of the desired channel that is either:

a) 18 dB above the desired signal power at the receiver input when the undesired signal is another VHF data broadcast signal assigned to the same time slot(s); or

b) equal in power at the receiver input when the undesired signal is VOR.

3.6.8.2.2.6.2 *Second adjacent 25 kHz channels (±50 kHz).* The VHF data broadcast receiver shall meet the requirements specified in 3.6.8.2.2.3 in the presence of a transmitted undesired signal offset by 50 kHz on either side of the desired channel that is either:

a) 43 dB above the desired signal power at the receiver input when the undesired signal is another VHF data broadcast source assigned to the same time slot(s); or

b) 34 dB above the desired signal power at the receiver input when the undesired signal is VOR.

3.6.8.2.2.6.3 *Third and beyond adjacent 25 kHz channels (±75 kHz or more).* The VHF data broadcast receiver shall meet the requirements specified in 3.6.8.2.2.3 in the presence of a transmitted undesired signal offset by 75 kHz or more on either side of the desired channel that is either:

a) 46 dB above the desired signal power at the receiver input when the undesired signal is another VHF data broadcast signal assigned to the same time slot(s); or

b) 46 dB above the desired signal power at the receiver input when the undesired signal is VOR.

...

3.6.8.2.2.8.2 *Desensitization.* The VHF data broadcast receiver shall meet the requirements specified in 3.6.8.2.2.3 in the presence of VHF FM broadcast signals with signal levels shown in Tables B-80 and B-81.

Table B-79. Maximum levels of undesired signals

Frequency	Maximum level of undesired signals at the receiver input (dB~~m~~ above S_{max})
50 kHz up to 88 MHz	-12~~13~~
88 MHz – 107.900 MHz	(see 3.6.8.2.2.8.2 and 3.6.8.2.2.8.3)
108.000 MHz – 117.975 MHz	Excluded

118.000 MHz	-43~~44~~
118.025 MHz	-40~~41~~
118.050 MHz up to 1 660.5 MHz	-12~~13~~

Frequency	Maximum level of undesired signals at the receiver input (dB~~m~~ above S_{max})
50 kHz up to 88 to 1 660.5 MHz	-12~~13~~
88 MHz – 107.900 MHz	(see 3.6.8.2.2.8.2)
108.000 MHz – 117.975 MHz	Excluded
118.000 MHz	-43~~44~~
118.025 MHz	-40~~41~~
118.050 MHz up to 1 660.5 MHz	-12~~13~~

Notes.—

1. *The relationship is linear between single adjacent points designated by the above frequencies.*

2. *These interference immunity requirements may not be adequate to ensure compatibility between VHF data broadcast receivers and VHF communication systems, particularly for aircraft that use the vertically polarized component of the VHF data broadcast. Without coordination between COM and NAV frequencies assignments or respect of a guard band at the top end of the 112 – 117.975 MHz band, the maximum levels quoted at the lowest COM VHF channels (118.000, 118.00833, 118.01666, 118.025, 118.03333, 118.04166, 118.05) may be exceeded at the input of the VDB receivers. In that case, some means to attenuate the COM signals at the input of the VDB receivers (e.g. antenna separation) will have to be implemented. The final compatibility will have to be assured when equipment is installed on the aircraft.*

3. *S_{max} is the maximum desired VHF data broadcast signal power at the receiver input.*

Table B-80. Desensitization frequency and power requirements that apply for VDB frequencies from 108.025 to 111.975 MHz

Frequency	Maximum level of undesired signals at the receiver input (dB~~m~~ above S_{max})
88 MHz ≤ f ≤ 102 MHz	16~~15~~
104 MHz	11~~10~~
106 MHz	6~~5~~
107.9 MHz	-9~~10~~

Notes.—

1. *The relationship is linear between single adjacent points designated by the above frequencies.*

2. *This desensitization requirement is not applied for FM carriers above 107.7 MHz and VDB channels at 108.025 or 108.050 MHz. See Attachment 6D, 7.2.1.2.2.*

3. S_{max} *is the maximum desired VHF data broadcast signal power at the receiver input.*

Table B-81. Desensitization frequency and power requirements that apply for VDB frequencies from 112.000 to 117.975 MHz

Frequency	Maximum level of undesired signals at the receiver input (dB~~m~~ above S_{max})
88 MHz ≤ f ≤ 104 MHz	16~~15~~
106 MHz	11~~10~~
107 MHz	6~~5~~
107.9 MHz	1~~0~~

Notes.—
1. *The relationship is linear between single adjacent points designated by the above frequencies.*
2. S_{max} *is the maximum desired VHF data broadcast signal power at the receiver input.*

3.6.8.2.2.8.3 *VHF data broadcast FM intermodulation immunity.* The VHF data broadcast receiver shall meet the requirements specified in 3.6.8.2.2.3 in the presence of interference from two-signal, third-order intermodulation products of two VHF FM broadcast signals having levels in accordance with the following:

$$2N_1 + N_2 + 3\,[23 - S_{max}] \le 0$$

$$\cancel{2N_1 + N_2 + 72 \le 0}$$

for VHF FM sound broadcasting signals in the range 107.7 – 108.0 MHz and

$$2N_1 + N_2 + 3\,[\,23 - S_{max} - 20\,\mathrm{Log}\,(\Delta f / 0.4)\,] \le 0$$

$$\cancel{2N_1 + N_2 + 3\left(24\ 20\log \frac{\Delta f}{0.4}\right) \le 0}$$

for VHF FM sound broadcasting signals below 107.7 MHz

where the frequencies of the two VHF FM sound broadcasting signals produce, within the receiver, a two signal, third-order intermodulation product on the desired VDB frequency.

N_1 and N_2 are the levels (dBm) of the two VHF FM sound broadcasting signals at the VHF data broadcast receiver input. Neither level shall exceed the desensitization criteria set forth in 3.6.8.2.2.8.2.

$\Delta f = 108.1 - f_1$, where f_1 is the frequency of N_1, the VHF FM sound broadcasting signal closer to 108.1 MHz.

S_{max} is the maximum desired VHF data broadcast signal power at the receiver input.

Note.— The FM intermodulation immunity requirements are not applied to a VHF data broadcast channel operating below 108.1 MHz, hence frequencies below 108.1 MHz are not intended for general assignments. Additional information is provided in Attachment 6D, 7.2.1.2.

3.6.8.3 *AIRCRAFT FUNCTIONAL REQUIREMENTS*

Note.— Unless otherwise specified, the following requirements apply to all GBAS airborne equipment classifications as described in Attachment 6D, 7.1.4.3.

...

3.6.8.3.1.2.1 *GBAS message processing capability.* The GBAS receiver shall at a minimum process GBAS message types in accordance with Table B-82.

Table B – 82. Airborne equipment message type processing

~~Airborne equipment designed performance~~ GBAS airborne equipment classification (GAEC)	Minimum message types processed
~~APV-I~~GAEC A	MT 1 OR 101, MT 2 (including ADB 1 AND 2 IF provided)
~~APV-II~~GAEC B	MT 1,MT 2 (including ADB 1 and 2 if provided), MT 4
~~Category I~~GAEC C	MT I, MT 2 (including ADB I if provided), MT 4
GAEC D	**MT 1, MT 2 (including ADB 1 and 2 ,3 and 4), MT4, MT 11**

...

3.6.8.3.1.5 The receiver shall only apply pseudo-range corrections from the most recently received set of corrections for a given measurement type. If the number of measurement fields in the most recently received **message types (as required in Appendix 6B, section 3.6.7.2.1.1.1 for the active service type)**~~Type 1 or Type 101 message~~ indicates that there are no measurement blocks, then the receiver shall not apply GBAS corrections for that measurement type.

3.6.8.3.1.6 *Validity of pseudo-range corrections*

3.6.8.3.1.6.1 When the active service type is A, B or C, t~~T~~he receiver shall exclude from the differential navigation solution any ranging sources for which σ_{pr_gnd} in the Type 1 or Type 101 messages is set to the bit pattern "1111 1111".

3.6.8.3.1.6.2 If the active service type is D, the receiver shall exclude from the differential navigation solution any ranging source for which $\sigma_{pr\_gnd\_D}$ in the Type 11 message or σ_{pr_gnd} in the Type 1 message is set to the bit pattern "1111 1111".

3.6.8.3.1.7 The receiver shall only use a ranging source in the differential navigation solution if the time of applicability indicated by the modified Z-count in the Type 1, Type 11 or Type 101 message containing the ephemeris decorrelation parameter for that ranging source is less than 120 seconds old.

3.6.8.3.1.8 *Conditions for use of data to support ~~Category I precision~~ approach ~~and APV~~services*

3.6.8.3.1.8.1 During the final stages of ~~a Category I or APV~~ an approach, the receiver shall use only measurement blocks from Type 1, Type 11 or Type 101 messages that were received within the last 3.5 seconds.

Note.— Guidance concerning time to alert is given in Attachment 6D, 7.5.14

3.6.8.3.1.8.2 *GCID Indications.*

3.6.8.3.1.8.2.1 When the active service type is A, B or C, t~~T~~he receiver shall use message data from a GBAS ground subsystem for ~~Category I precision approach or APV~~ guidance only if the GCID indicates 1, 2, 3 or 4 prior to initiating the final stages of an approach.

3.6.8.3.1.8.2.2 When the active service type is D, the receiver shall use message data from a GBAS ground subsystem for guidance only if the GCID indicates 2, 3 or 4 prior to initiating the final stages of an approach.

...

3.6.8.3.1.8.9.2 The receiver shall use the Type 4 messages to determine the FAS for approaches which are supported by GBAS approach service type (GAST) A or B~~-APV~~ associated with a channel number between 20 001 and 39 999.

3.6.8.3.1.8.9.3 The receiver shall use the FAS held within the on-board database for approaches which are supported by GBAS approach service type (GAST) A ~~APV~~ associated with a channel number between 40 000 and 99 999.

...

3.6.8.3.2.2 *Use of GBAS integrity parameters.* The aircraft element shall compute and apply the vertical, lateral and horizontal protection levels described in 3.6.5.5 ~~using the GBAS broadcast σ_{pr_gnd}, σ_N, h_0, $\sigma_{vert\_iono\_gradient}$, and B parameters as well as the σ_{pr_air} parameter.~~ If a $B_{i,j}$ parameter is set to the bit pattern "1000 0000" indicating that the measurement is not available, the aircraft element shall assume that $B_{i,j}$ has a value of zero. For~~Category I precision approach and APV~~**any active service type**, the aircraft element shall verify that the computed vertical and lateral protection levels are ~~smaller~~ **no larger** than the corresponding vertical and lateral alert limits defined in 3.6.5.6.

...

3.6.8.3.3.2 *CRC check.* The receiver shall compute the ephemeris CRC for each core satellite constellation's ranging source used in the position solution. The computed CRC shall be validated against the ephemeris CRC broadcast in the Type 1 or Type 101 messages **prior to use in the position solution and** within one second of receiving a new broadcast CRC. The receiver shall immediately cease using any satellite for which the computed and broadcast CRC values fail to match.

~~*Note.— During initial acquisition of the VHF data broadcast, the receiver may incorporate a satellite into the position solution before receiving the broadcast ephemeris CRC for that satellite.*~~

3.6.8.3.3.3 *Ephemeris error position bounds*

3.6.8.3.3.3.1 *Ephemeris error position bounds for ~~Category I precision~~ **GBAS** approach **services** ~~and APV~~.* If the ground subsystem provides additional data block 1 in the Type 2 messages, the aircraft element shall compute the ephemeris error position bounds defined in 3.6.5.8.1 for each core satellite constellation's ranging source used in the **approach** position solution within 1s of receiving the necessary broadcast parameters. The aircraft element shall ~~exclude from the approach position solution satellites for which~~**verify that** the computed vertical ~~or~~ **and** lateral ephemeris error position bounds (VEB_j ~~or~~ **and** LEB_j) are **no** larger than the corresponding vertical and lateral alert limits defined in 3.6.5.6.

~~*Note.— During initial acquisition of the VHF data broadcast, the receiver may incorporate a satellite into the position solution before receiving the necessary broadcast parameters for that satellite to compute the ephemeris error position bounds.*~~

3.6.8.3.3.3.2 *Ephemeris error position bound for the GBAS positioning service.* The aircraft element shall compute and apply the horizontal ephemeris error position bound (HEB_j) defined in 3.6.5.8.2 for each core satellite constellation's ranging source used in the **positioning service** position solution.

3.6.8.3.4 *Message loss*

3.6.8.3.4.1 For ~~Category I precision approach~~ **airborne equipment operating with GAST C as the active service type**, the receiver shall provide an appropriate alert if no Type 1 ~~or Type 101~~ message was received during the last 3.5 seconds.

3.6.8.3.4.2 For ~~APV~~ airborne equipment operating with GAST A or B as the active service type, the receiver shall provide an appropriate alert if no Type 1 and no Type 101 message was received during the last 3.5 seconds.

3.6.8.3.4.3 For the airborne equipment operating with GAST D as the active service type, the receiver shall provide an appropriate alert or modify the active service type if any of the following conditions are met:

a) The computed position solution is less than 200 ft above the LTP/FTP for the selected approach and no Type 1 message was received during the last 1.5 seconds.

b) The computed position solution is less than 200 ft above the LTP/FTP for the selected approach and no Type 11 message was received during the last 1.5 seconds.

c) The computed position solution is 200 ft or more above the LTP/FTP of the selected approach and no Type 1 message was received during the last 3.5 seconds.

d) The computed position solution is 200 ft or more above the LTP/FTP of the selected approach and no Type 11 message was received during the last 3.5 seconds.

3.6.8.3.4.~~3~~4 For the GBAS positioning service using Type 1 messages, the receiver shall provide an appropriate alert if no Type 1 message was received during the last 7.5 seconds.

3.6.8.3.4.~~4~~5 For the GBAS positioning service using Type 101 messages, the receiver shall provide an appropriate alert if no Type 101 message was received during the last 5 seconds.

...

3.6.8.3.5 *Airborne pseudo-range measurements*

3.6.8.3.5.1 *Carrier smoothing for airborne equipment.* Airborne equipment shall utilize the standard 100-second carrier smoothing of code phase measurements defined in 3.6.5.1. During the first 100 seconds after filter start-up, the value of α shall be either:

a) a constant equal to the sample interval divided by 100 seconds; or

b) a variable quantity defined by the sample interval divided by the time in seconds since filter start-up.

3.6.8.3.5.2 *Carrier smoothing of airborne equipment operating with GAST D as the active service type.* Airborne equipment operating with GAST D as the active service type, shall utilize 30-second carrier smoothing of code phase measurements as defined in 3.6.5.1.

Note.— For equipment that supports GAST D, two set of smoothed pseudo-ranges are used. The form of the smoothing filter given in section 3.6.5.1 is the same for both sets, and only the time constant differs (i.e. 100 seconds and 30 seconds). Guidance concerning carrier smoothing for GAST D is given in Attachment 6D, 7.19.3.

3.6.8.3.6 *Service type specific differential position solution requirements.* The airborne equipment shall compute all position solutions in a manner that is consistent with the protocols for application of the data (section 3.6.5.5.1.1.2).

Note.— The general form for the weighting used in the differential position solution is given in 3.6.5.5.1.1.2. Exactly which information from the ground subsystem is used in the differential position solution depends on the type of service (i.e. positioning service vs. approach service) and the active approach service type. The specific requirements for each service type are defined in RTCA DO-253D. Additional information concerning the normal processing of position information is given in Attachment 6D, 7.19.

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ATTACHMENT 6B. STRATEGY FOR INTRODUCTION AND APPLICATION OF NON-VISUAL AIDS TO APPROACH AND LANDING

(see CAR-ANS 6.2, 6.2.1)

...

2. Objectives of strategy

The strategy must:

a) maintain at least the current safety level of all weather operations;

b) retain at least the existing level or planned improved level of service;

c) support lateral and vertical path guidance as outlined in Resolution A37-11;

~~e~~d) maintain global interoperability;

~~d~~e) provide regional flexibility based on coordinated regional planning;

~~e~~f) ~~be applicable until at least the year 2020~~support infrastructure investment planning cycles; ~~and~~

g) be maintained by periodic review; and

~~f~~h) take account of economic, operational and technical issues.

...

3. Considerations

...

3.2 ILS-related considerations

a) There is a limited risk that ILS Category II or III operations cannot be safely sustained at specific locations;

b) ILS receivers have implemented interference immunity performance Standards contained in CAR-ANS 6.3, 6.3.1.4 ~~contains interference immunity performance standards for ILS receivers;~~

c) in some regions, expansion of ILS is limited by channel availability (40 paired ILS/DME channels);

~~d) many aging ILS ground installations will need to be replaced; and~~

~~e~~d) in most areas of the world, ILS can be maintained in the foreseeable future~~.~~;

e) due to cost and efficiency considerations, some States are rationalizing some of their ILS infrastructure at Category I airports with limited operational usage; and

f) based on user-equipage considerations, GNSS-based approaches providing lateral and vertical path guidance may offer a cost-effective option when considering introduction of Category I approach service or when replacing or removing an existing ILS.

3.3 MLS-related considerations

a) MLS Category ~~I~~III is operational;

~~b) Category II capable ground equipment is certified. Ground and airborne Category IIIB equipment certification is in progress and is scheduled to be completed in the 2004-2005 time frame; and~~

~~c~~b) MLS ~~implementation is planned~~ has been implemented at specific locations to improve runway utilization in low visibility conditions~~.~~; and

c) further MLS deployment is unlikely.

3.4 GNSS-related considerations

a) Standards and Recommended Practices (SARPs) are in place for GNSS with augmentation to support APV and Category I precision approach;

~~b) SARPs for ground-based regional augmentation system (GRAS) for APV operations are under development;~~

~~c~~b) GNSS with satellite-based augmentation system (SBAS) for APV and Category I precision approach operations is operational ~~in some regions of the world~~;

~~d~~c) GNSS with ground-based augmentation system (GBAS) for Category I precision approach operations is ~~expected to be~~ operational ~~by 2006~~;

ed) it is ~~not~~ expected that an internationally accepted ~~GNSS with augmentation as required may~~ GBAS will be available for Category II and III operations ~~before the 2010-2015 time frame~~ in the 2018-2020 timeframe;

e) ongoing dual-frequency, multi-constellation (DFMC) GNSS developments will enhance performance of GNSS augmentations as well as enable new operational capabilities in the 2025 timeframe;

f) technical and operational issues associated with GNSS approach, landing and departure operations, such as vulnerabilities due to ionospheric propagation and radio frequency interference, must be ~~solved~~ addressed in a timely manner; and

g) ~~institutional~~ issues associated with DFMC GNSS ~~approach, landing and departure operations~~ must be ~~solved~~ addressed in a timely manner.

...

3.6 Other considerations

a) There is an increasing demand for Category II and/or III operations in some areas;

b) GNSS can potentially offer unique operational benefits for low-visibility operations, including new procedures, flexible siting requirements and provision of airport surface guidance;

c) only the three standard systems (ILS, MLS and GNSS with augmentation as required) are considered to play a ~~major~~ role in supporting all weather operations. The use of head-up displays in conjunction with enhanced and~~/or~~ synthetic vision systems may provide operational benefits;

d) a consequence of the global strategy is that there will not be a rapid or complete transition from ILS to ~~new systems such as~~ GNSS or MLS. It is therefore essential for the implementation of the strategy that the radio frequency spectrum used by all of these systems be adequately protected;

~~e) to the extent practical, a transition directly from ILS to GNSS is preferable. In some States, however, it may not be possible to make this transition without losing the current level of Category II or III operations;~~

fe) ~~as long as some users of a given runway continue to rely on ILS,~~ the potential operational benefits resulting from the introduction of new landing systems may be limited by the constraints of mixed-system ~~operations~~ aircraft equipage;

gf) APV operations may be conducted using GNSS with augmentation as required or barometric vertical guidance, and GNSS with ABAS ~~or DME/DME RNAV~~ lateral guidance; ~~and~~

~~h~~g) APV operations provide enhanced safety and generally lower operational minima as compared to non-precision approaches~~.~~;

h) adequate redundancy shall be provided when terrestrial navigation aids are withdrawn; and

i) rationalization shall be part of a national or regional strategy on terrestrial navigation aids; guidance is provided in Attachment 6H.

4. Strategy

Based on the considerations above, the need to consult aircraft operators, airport operators and international organizations, and to ensure safety, efficiency and cost-effectiveness of the proposed solutions, the global strategy is to:

a) continue ILS operations to the highest level of service as long as operationally acceptable and economically beneficial ~~so as to ensure that airport access is not denied to aircraft solely equipped with ILS;~~

b) ~~implement~~ continue MLS operations where operationally required and economically beneficial;

c) implement GNSS with augmentation (i.e. ABAS, SBAS, GBAS) as required for APV and ~~Category I~~ precision approach operations where operationally required and economically beneficial~~, while ensuring that the issues associated with ionospheric propagation in the equatorial regions are duly addressed and resolved~~;

d) promote the continuing development and use of a multi-modal airborne approach and landing capability;

e) promote the use of APV operations, particularly those using GNSS vertical guidance, to enhance safety and accessibility; and

~~f) identify and resolve operational and technical feasibility issues for GNSS with ground-based augmentation system (GBAS) to support Category II and III operations. Implement GNSS for Category II and III operations where operationally required and economically beneficial; and~~

g~~f~~) enable each region to develop an implementation strategy for these systems in line with ~~the~~ this global strategy.

ATTACHMENT 6C. INFORMATION AND MATERIAL FOR GUIDANCE IN THE APPLICATION OF THE STANDARDS AND RECOMMENDED PRACTICES FOR ILS, VOR, PAR, 75 MHz MARKER BEACONS (EN-ROUTE), NDB AND DME

...

2. Material concerning ILS installations

...

2.1.9 *ILS multipath interference*

~~*Note.— This guidance material does not consider how new large aircraft impact the sizes of critical and sensitive areas. It is being updated to consider the effect on the critical and sensitive areas of such aircraft, and of the considerable changes in airport and operational environment since the first development of the material. States are urged to use caution in applying the examples described below, as they do not consider several factors that impact quality of signal-in-space.*~~

Note 1.— This guidance material reflects how new larger aeroplanes (NLA) may impact the size of the ILS critical and sensitive areas. It also documents established engineering practices for determining critical and sensitive area dimensions, outlines the associated operational trade-offs, and presents indicative examples of the resulting sizes of the areas. In practice, however, the size of critical and sensitive areas at an aerodrome may need to be determined by specific assessments at that aerodrome.

Note 2.— This guidance material is not intended to create a need to review established critical and sensitive area dimensions which have been demonstrated to be satisfactory at a particular aerodrome, unless the operational environment has evolved significantly (such as through the introduction of NLA operations at the aerodrome or the construction of new buildings) or the ILS installation has been changed in a way that may affect the dimensions of the areas.

2.1.9.1 ~~The occurrence of interference to ILS signals is dependent on the total environment around the ILS antennas, and the antenna characteristics. Any large reflecting objects, including vehicles or fixed objects such as structures within the radiated signal coverage, will potentially cause multipath interference to the ILS course and path structure. The location and size of the reflecting fixed objects and structures in conjunction with the directional qualities of the antennas will determine the static course or path structure quality whether Category I, II or III. Movable objects can degrade this structure to the extent that it becomes unacceptable. The areas within which this degradable interference is possible need to be defined and recognized. For the purposes of developing protective zoning criteria, these areas can be divided into two types, i.e. critical areas and sensitive areas:~~ *ILS environmental effects.* Large reflecting objects within the ILS coverage volume, whether fixed objects or vehicles, including aircraft, can potentially cause degradation of the signal-in-space, through signal blockage and/or multipath interference, with the consequence that the signal-in-space tolerances defined in CAR-ANS 6.3, 3.1 may be exceeded. The amount of degradation is a function of the location, size and orientation of the reflecting surfaces, and of the ILS antenna characteristics. The objective of identifying critical and sensitive areas (see 2.1.9.2) and associated management procedures is to prevent such degradation and ensure that aircraft using the ILS can rely on the signal-in-space meeting the requirements of CAR-ANS 6.3, 6.3.1.

2.1.9.2 *ILS critical and sensitive areas.* **States differ in the way they choose to identify ILS protection areas. Practices also differ in how vehicle movement restrictions are managed. One method is to identify critical areas and sensitive areas as follows:**

a) the ILS critical area is an area of defined dimensions about the localizer and glide path antennas where vehicles, including aircraft, are excluded during all ILS operations. The critical area is protected because the presence of vehicles and/or aircraft inside its boundaries will cause unacceptable disturbance to the ILS signal-in-space;

b) the ILS sensitive area is an area ~~**extending beyond the critical area**~~ where the parking and/or movement of vehicles, including aircraft, is controlled to prevent the possibility of unacceptable interference to the ILS signal during ILS operations. The sensitive area is protected against interference caused by large moving objects outside the critical area but still normally within the airfield boundary.

*Note 1.— ~~The objective of defining critical and sensitive areas is to afford adequate protection to the ILS. The manner in which the terminology is applied may vary between States~~. In some States, the term "critical area" is ~~also~~ used to describe ~~the~~ **an** area that* ***combines*** *~~is referred to herein as~~ the* ***critical and*** *sensitive areas* ***identified in this guidance material. In cases where the critical area overlaps operational areas, specific operational management procedures are required to ensure protection of aircraft using the ILS for intercept and final approach guidance.***

Note 2.— It is expected that at sites, where ILS and MLS are to be collocated, the MLS might be located within ILS critical areas in accordance with guidance material in Attachment 6G, 4.1.

~~**2.1.9.2 Typical examples of critical and sensitive areas that need to be protected are shown in Figures C-3A, C-3B, C-4A and C-4B. To protect the critical area, it is necessary to normally prohibit all entry of vehicles and the taxiing or parking of aircraft within this area during all ILS operations. The critical area determined for each localizer and glide path should be clearly designated. Suitable signal devices may need to be provided at taxiways and roadways which penetrate the critical area to restrict the entry of vehicles and aircraft. With respect to sensitive areas, it may be necessary to exclude some or all moving traffic depending on interference potential and category of operation. It would be advisable to have the aerodrome boundaries include all the sensitive areas so that adequate control can be exercised over all moving traffic to prevent unacceptable interference to the ILS signals. If these areas fall outside the aerodrome boundaries, it is essential that the cooperation of appropriate authorities be obtained to ensure adequate control. Operational procedures need to be developed for the protection of sensitive areas.**~~

~~**2.1.9.3 The size of the sensitive area depends on a number of factors including the type of ILS antenna, the topography, and the size and orientation of man-made objects, including large aircraft and vehicles. Modern designs of localizer and glide path antennas can be very effective in reducing the disturbance possibilities and hence the extent of the sensitive areas. Because of the greater potential of the larger types of aircraft for disturbing ILS signals, the**~~

~~sensitive areas for these aircraft extend a considerable distance beyond the critical areas. The problem is aggravated by increased traffic density on the ground.~~

~~2.1.9.3.1 In the case of the localizer, any large objects illuminated by the main directional radiation of the antenna must be considered as possible sources of unacceptable signal interference. This will include aircraft on the runway and on some taxiways. The dimensions of the sensitive areas required to protect Category I, II and III operations will vary, the largest being required for Category III. Only the least disturbance can be tolerated for Category III, but an out-of-tolerance course along the runway surface would have no effect on Category I or II operations. If the course structure is already marginal due to static multipath effects, less additional interference will cause an unacceptable signal. In such cases a larger-size sensitive area may have to be recognized.~~

~~2.1.9.3.2 In the case of the glide path, experience has shown that any object penetrating a surface above the reflection plane of the glide path antenna and within azimuth coverage of the antenna must be considered as a source of signal interference. The angle of the surface above the horizontal plane of the antenna is dependent on the type of glide path antenna array in use at the time. Very large aircraft, when parked or taxiing within several thousand feet of the glide path antenna and directly between it and the approach path, will usually cause serious disturbance to the glide path signal. On the other hand, the effect of small aircraft beyond a few hundred feet of the glide path antenna has been shown to be negligible.~~

~~2.1.9.3.3 Experience has shown that the major features affecting the reflection and diffraction of the ILS signal to produce multipath interference are the height and orientation of the vertical surfaces of aircraft and vehicles. The maximum height of vertical surface likely to be encountered must be established, together with the "worst case" orientation. This is because certain orientations can cause out-of-tolerance localizer or glide path deviations at greater distances than parallel or perpendicular orientations.~~

~~2.1.9.4 Computer or model techniques can be employed to calculate the probable location, magnitude and duration of ILS disturbances caused by objects, whether by structures or by aircraft of various sizes and orientation at different locations. Issues involved with these techniques include the following:~~

~~a) computerized mathematical models are in general use and are applied by personnel with a wide variety of experience levels. However, engineering knowledge of and judgement about the appropriate assumptions and limitations are required when applying such models to specific multipath environments. ILS performance information relative to this subject should normally be made available by the ILS equipment manufacturer;~~

~~Figure C-3A. Typical localizer critical and sensitive areas dimension variations for a 3 000 m (10 000 ft) runway~~

~~Figure C-3B. Typical glide path critical and sensitive areas dimension variations~~

~~Figure C-4A. Example of critical and sensitive area application at specific sites with B-747 aircraft interference~~

~~Figure C-4B. Example of critical and sensitive area application at specific sites with B-747 aircraft interference~~

~~b) where an ILS has been installed and found satisfactory, computers and simulation techniques can be employed to predict the probable extent of ILS disturbance which may arise as a result of proposed new construction. Wherever possible, the results of such computer-aided simulation should be validated by direct comparison with actual flight measurements of the results of new construction; and~~

~~c) taking into account the maximum allowable multipath degradation of the signal due to aircraft on the ground, the corresponding minimum sensitive area limits can be determined. Models have been used to determine the critical and sensitive areas in Figures C-3A, C-3B, C-4A and C-4B, by taking into account the maximum allowable multipath degradation of ILS signals due to aircraft on the ground. The factors that affect the size and shape of the critical and sensitive areas include: aircraft types likely to cause interference, antenna aperture and type (log periodic dipole/dipole, etc.), type of clearance signals (single/dual frequency), category of operations proposed, runway length, and static bends caused by existing structures. Such use of models should involve their validation, which includes spot check comparison of computed results with actual field demonstration data on parked aircraft interference to the ILS signal.~~

~~2.1.9.5 Control of critical areas and the designation of sensitive areas on the airport proper may still not be sufficient to protect an ILS from multipath effects caused by large, fixed ground structures. This is particularly significant when considering the size of new buildings being erected for larger new aircraft and other purposes. Structures outside the boundaries of the airport may also cause difficulty to the ILS course quality, even though they meet restrictions with regard to obstruction~~
~~heights.~~

~~2.1.9.5.1 Should the environment of an airport in terms of large fixed objects such as tall buildings cause the structure of the localizer and/or glide path to be near the tolerance limits for the category of operation, much larger sensitive areas may need to be established. This is because the effect of moving objects, which the sensitive areas are designed to protect the ILS against, has to be added to the static beam bends caused by fixed objects. However, direct addition of the maximum bend amplitudes is not considered appropriate and a root sum square combination is felt to be more realistic. Examples are as follows:~~

~~a) localizer course bends due to static objects equals plus or minus 1½μA. Limit plus or minus 5μA. Therefore allowance for moving objects to define localizer sensitive area is~~

~~$\sqrt{52 - 1.52} = 4.77\mu 4$~~

~~b) localizer course bends due to static objects equals plus or minus 4μ4. Limit plus or minus 5μ4. Therefore allowance for moving objects to define localizer sensitive area is~~

~~$\sqrt{52 - 42} = 3\mu A$~~

~~In case b) the sensitive area would be larger, thus keeping interfering objects further away from the runway so that they produce $3\mu A$ or less distortion of the localizer beam. The same principle is applied to the glide path sensitive area.~~

2.1.9.3 *Technical and operational logic associated with critical and sensitive areas.* Ideally, the critical area is enforced during all ILS operations with protection afforded down to at least the Category I decision height. A critical area disturbance would normally impact all aircraft using the ILS signal at a given time (entire approach). The critical area is typically safeguarded through marked boundaries, limiting access to the area or through procedural means if there are overlaps into operational areas. From an operational perspective, the sensitive area would ideally protect aircraft operations at least from the Category I decision height down to the runway, and be activated during low visibility conditions only (e.g. Category II and III). A sensitive area disturbance would normally be of a transient nature, and produce a local disturbance affecting a single aircraft only. However, at many locations, it may not be possible to achieve this ideal situation, and corresponding technical and operational mitigations will be required.

Note.— Guidance on operational procedures for the protection of critical and sensitive areas is provided in ICAO EUR DOC 013, "European Guidance Material on All Weather Operations at Aerodromes".

2.1.9.4 *Technical determination of critical and sensitive area dimensions.* Critical and sensitive areas are normally calculated in the planning stage, prior to ILS installation, using computer simulation. A similar process is used when there are changes to the installation or to the environment. When using computer simulations, it is necessary to allocate the protection of individual parts of the approach to either the critical or sensitive area. It is desirable to ensure that the combined critical and sensitive areas protect the entire approach. However, this may not be possible in all cases. Furthermore, if the logic described in 2.1.9.3 is used, this may lead to restrictively large critical areas. Some States have found that a reasonable compromise can be achieved using a different logic, whereby the critical area protects the segment from the edge of coverage down to 2 NM from the runway threshold, while the sensitive area protects the approach from 2 NM down to the runway. In this case, a Category I sensitive area will exist and may require operational mitigation. Depending on the operational environment (such as timing between leading aircraft on runway roll-out and trailing aircraft on final approach), no particular measures may be needed. There may not necessarily be a direct link between the approach allocation used in simulations to determine critical and sensitive areas, and their operational management. It is a State's responsibility to define the relevant areas. If different disturbance acceptance criteria or different flight segment protections are to be applied, they must be validated through a safety analysis. The safety analysis must take all relevant factors into account, including the aerodrome configuration, traffic density and any operational issues or capacity restrictions.

2.1.9.5 *Factors impacting the sizes of critical and sensitive areas.* Localizer and glide path antennas with optimized radiation patterns, especially when combined with two-frequency transmitters, can be very effective in reducing the potential for signal disturbance and hence the sizes of the critical and sensitive areas. Other factors affecting the sizes of the areas include the category of approach and landing operation to be supported, the amount of static disturbance, locations, sizes and orientations of aircraft and other vehicles (particularly of their vertical surfaces), runway and taxiway layout, and antenna locations. In particular, the maximum heights of vertical aircraft tail surfaces likely to be encountered must be established, together with all possible orientations at a given location, which may include non-parallel or non-perpendicular orientations with respect to the runway. While critical and sensitive areas are evaluated in a two-dimensional (horizontal) context, protection shall actually be extended to volumes, as departing aircraft and/or manoeuvring helicopters/aircraft can also cause disturbances to the ILS signals. The vertical profiles of the protection volumes depend on the vertical patterns of the transmitting arrays.

2.1.9.6 *Allocation of multipath error budget.* It is convenient to consider disturbances caused by mobile objects such as aircraft and other vehicles separately from the static disturbances caused by fixed objects such as buildings and terrain. Once the static multipath is known, the remainder can be allocated to dynamic disturbances. If measurements indicate that the real static multipath is significantly different from that assumed in the simulations, the allocation may need to be revised. In most cases, the root sum square combination of the disturbances due to fixed and mobile objects gives a more statistically valid representation of the total disturbance than an algebraic sum. For example, a limit of plus or minus 5μA for localizer course structure would be respected with plus or minus 3μA of disturbance due to static objects and an allowance of plus or minus 4μA for dynamic objects:

$$\sqrt{(3\mu A)^2 + (4\mu A)^2} = 5\mu\text{A}$$

2.1.9.7 *Site study and computer simulations.* Normally, a site specific study is conducted for a particular airport installation. The study will take into account different assumptions for the static multipath environment, airport topography, types and effective heights of ILS arrays, and orientations of maneuvering aircraft, such as runway crossings, 180° turns at threshold or holding orientations other than parallel or perpendicular. Simulation models can be employed to calculate the probable location, magnitude and duration of ILS disturbances caused by objects, whether by structures or by aircraft of various sizes and orientation at different locations. Air navigation service providers (ANSPs) will need to ensure that simulation models used have been validated by direct comparison with ground and flight measurements for a variety of specific situations and environments, and that the subsequent application of such models is conducted by personnel with appropriate engineering knowledge and judgement to take into account the assumptions and limitations of applying such models to specific multipath environments.

2.1.9.8 *Changes in airport environment.* Shall major changes in the airport environment cause an increase in the static disturbances of the localizer and/or glide path, the sizes of the critical and sensitive areas may need to be redefined, with potential impact on airport efficiency or capacity. This is particularly significant when considering the location, size and orientation of proposed new buildings within or outside the airport boundary. It is recommended that suitable safeguarding criteria be employed to protect the ILS operations.

Note.— Example guidance can be found in ICAO EUR DOC 015 "European Guidance Material on Managing Building Restricted Areas".

2.1.9.9 *Typical examples of critical and sensitive areas.* Figures C-3 and C-4 (including associated Tables C-1, C2-A and C2-B)) show examples of critical and sensitive areas for different classes of vehicle/aircraft heights and several localizer and glide path antenna types. The calculation of these examples has been done with a simulation model using an exact method of resolution of ILS propagation equations applied to a 3D model of corresponding aircraft. The dimensions are based on assumptions of flat terrain, 3.0° glide path, allocations of 60 per cent of applicable tolerances for static multipath and 80 per cent for dynamic multipath, an approaching aircraft at 105 knots, i.e. with a 2.1 rad/s low-pass filter and an omnidirectional receiving antenna pattern. The examples consider typical orientations of reflecting surfaces of taxiing, holding and maneuvering aircraft/large ground vehicles. The tail heights for the ground vehicles/small aircraft, medium, large and very large aircraft categories correspond to CAAP MOS Aerodromes aerodrome reference code letters A, B/C, D/E and F, respectively, as detailed within FAA Advisory Circular 150/5300-13. In case of uncertainty about which category an aircraft belongs to for the purposes of critical and sensitive areas assessment, the tail height is the determining feature.

2.1.9.9.1 *Purpose and correct application of typical examples.* Since it will be rare that an actual installation fits exactly the assumptions used in these examples, adaptation to local conditions will be required. The examples serve to provide a rough order of magnitude indication of critical and sensitive area sizes, depending on how much local conditions differ from assumptions used in these examples. The example tables may also be used to assess the tools used in simulations, using the listed assumptions. In many installations, airports have established critical and sensitive areas which are different from those listed in these examples, through a combination of further technical optimizations, operational mitigations, experience, and safety assessments applicable to the particular operational environment. In the case of new airport construction projects, potential conflicts of the example areas provided here with planned operational uses shall lead to further evaluations, and may lead to implementing more advanced ILS antenna systems, for example wider aperture localizer antennas, including advanced designs such as very large aperture arrays. The typical examples provided here do not take such specific optimized systems into account. The tables differ slightly between the localizer and the glide path in terms of how different aircraft orientations are considered. These details are explained in the notes to Tables C-1 (note 9), C-2A and C-2B (note 8). In accordance with these notes, in some glide path cases the half-wingspan of aircraft needs to be added to ensure that no portion of the aircraft enters the critical or sensitive areas.

2.1.9.9.2 *Limits of multipath assumptions used in example simulations.* The allocation of 60 per cent for static and 80 per cent for dynamic multipath used in 2.1.9.6 represents a conservative approach which is suitable in locations where both types of multipath coincide.

A different allocation may be appropriate for the glide path, especially in the case of flat terrain, as in that case the static multipath will be very small. In locations where static and dynamic multi-path do not coincide, due to the specific layout of the airport, the full tolerance can be consumed by the dynamic multipath. A simulation tool able to model the complete environment (static and dynamic reflection sources) and to compute the combined effect may avoid having to apply the root sum square approximation. This may lead to an optimization of the critical and/or sensitive area dimensions.

2.1.9.9.3 *Flight segment protection allocations used in example simulations.* The examples given in Figure C-3 for the localizer use a 2 NM transition point as described in 2.1.9.4. The examples given in Figure C-4 for the glide path use a 0.6 NM transition point (corresponding to the Category I decision height). Depending on local operations, other transition points may be more suitable.

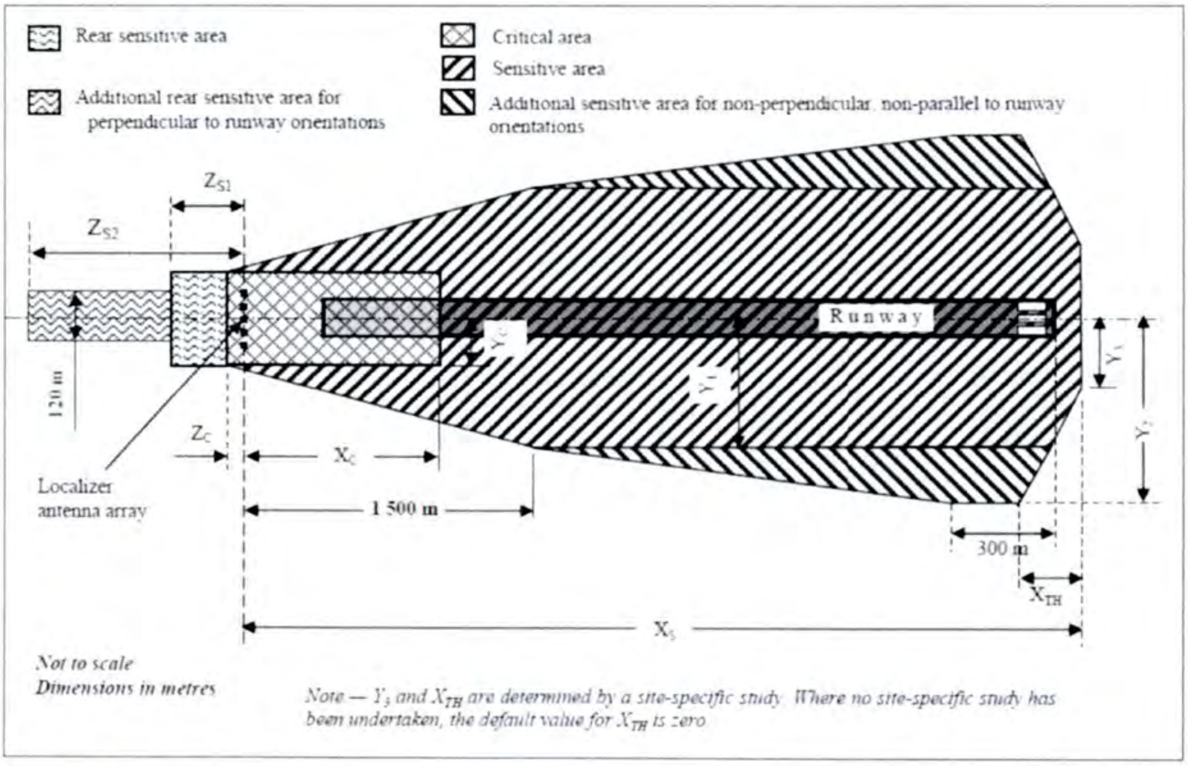

Figure C-3. Example of localizer critical and sensitive area dimensions

(values in associated Table C-1 below)

Table C-1. Typical localizer critical and sensitive area sizes

Aircraft/vehicle height	H ≤ 6 m (see Note 1) Ground vehicle			6 m < H ≤ 14 m Medium aircraft			14 m < H ≤ 20 m Large aircraft		20 m < H ≤ 25 m Very large aircraft	
Antenna aperture (see Note 3)	Small	Medium	Large	Small	Medium	Large	Medium	Large	Medium	Large
Critical area CAT I X_C	180 m	65 m	45 m	360 m	200 m	150 m	500 m	410 m	660 m	580 m
Z_C	10 m	10 m	10 m	35 m	35 m	35 m	50 m	50 m	60 m	60 m
(see Note 10) Y_C	50 m	15 m	20 m	110 m	25 m	25 m	50 m	30 m	55 m	40 m
Sensitive area CAT I X_S	200 m	No sensitive area		500 m	No sensitive area		No sensitive area		1 300 m	1 100 m
Y_1	40 m			90 m					90 m	50 m
Y_2	40 m			90 m					90 m	50 m
Z_{S1}	15 m			35 m					60 m	60 m
(see Note 7) Z_{S2}	15 m			35 m					60 m	60 m

Aircraft/vehicle height	H ≤ 6 m (see Note 1) Ground vehicle		6 m < H ≤ 14 m Medium aircraft		14 m < H ≤ 20 m Large aircraft		20 m < H ≤ 25 m Very large aircraft	
Antenna aperture (see Note 3)	Medium	Large	Medium	Large	Medium	Large	Medium	Large
Critical area CAT II X_C	75 m	55 m	200 m	200 m	500 m	475 m	750 m	675 m
Z_C	10 m	10 m	35 m	35 m	50 m	50 m	60 m	60 m
(see Note 10) Y_C	15 m	20 m	25 m	25 m	50 m	30 m	70 m	50 m
Sensitive area CAT II X_S	75 m	No sensitive area	500 m	No sensitive area	2 100 m	1 400 m	Localizer to threshold distance	Localizer to threshold distance
Y_1	15 m		50 m		125 m × K	60 m × K	180 m × K	100 m × K
Y_2	15 m		50 m		125 m × K	60 m × K	180 m × K	125 m × K
Z_{S1}	15 m	15 m	35 m	35 m	60 m	60 m	70 m	70 m
(see Note 7) Z_{S2}	15 m	15 m	45 m	45 m	160 m	160 m	250 m	250 m

Aircraft/vehicle height	H ≤ 6 m (see Note 1) Ground vehicle		6 m < H ≤ 14 m Medium aircraft		14 m < H ≤ 20 m Large aircraft		20 m < H ≤ 25 m Very large aircraft	
Antenna aperture (see Note 3)	Medium	Large	Medium	Large	Medium	Large	Medium	Large
Critical area CAT III X_C	75 m	55 m	200 m	200 m	500 m	475 m	750 m	675 m
Z_C	10 m	10 m	35 m	35 m	50 m	50 m	60 m	60 m
(see Note 10) Y_C	15 m	20 m	25 m	25 m	50 m	30 m	70 m	50 m
Sensitive area CAT III X_S	100 m	No sensitive area	900 m	No sensitive area	3 100 m	3 100 m	Localizer to threshold distance	Localizer to threshold distance
Y_1	15 m		50 m		140 m × K	120 m × K	180 m × K	150 m × K
Y_2	15 m		50 m		160 m × K	120 m × K	260 m × K	180 m × K
Z_{S1}	15 m	15 m	35 m	35 m	60 m	60 m	70 m	70 m
(see Note 7) Z_{S2}	15 m	15 m	45 m	45 m	160 m	160 m	250 m	250 m

Notes:

1. For vehicles smaller than 2.5 m in height, $Z_C = 3$ m, assuming a 23 dB front/back ratio for the transmitting antenna for both course and clearance signals.

2. For systems with near-field monitor antennas, vehicles must not enter between the monitor antennas and the transmitting antenna.

3. Small aperture: 11 elements or less. Medium aperture: 12 to 15 elements. Large aperture: 16 elements or more. Simulations have been conducted using a commonly installed 12 element system for the medium and a commonly installed 20 element system for the large aperture cases. It is assumed that Category II/III operations are not conducted on runways equipped with small aperture localizers, and that aircraft as large as a 747 are not operating on such runways.

4. For localizer arrays with very low height, additional critical area will be needed due to the greater attenuation of the direct signal at low vertical angles.

5. A specific study for a particular airport, considering realistic orientations, static multipath environment, and airport topography and type of ILS antennas, may define different critical areas.

6. $K = \sqrt{\dfrac{\text{localizer to threshold distance}}{3300\ m}}$

7. The rear dimensions for sensitive areas may be changed based on specific study results considering fielded antenna pattern characteristics. A directional array with a 23 dB front/back ratio is assumed for course and clearance signals.

8. Single aircraft taxiing or holding parallel to the runway does not generate out-of-tolerance signals.

9. Boundaries for critical areas or rear sensitive areas apply to the entire longitudinal axis (both tail and fuselage) of the interfering aircraft. Boundaries for sensitive areas apply only to the tail of the interfering aircraft.

10. The critical area semi-width, Yc, shall exceed the actual physical dimension of the localizer antenna array by at least 10 m laterally (on both sides) in its portion between the localizer antenna array and the stop end of the runway.

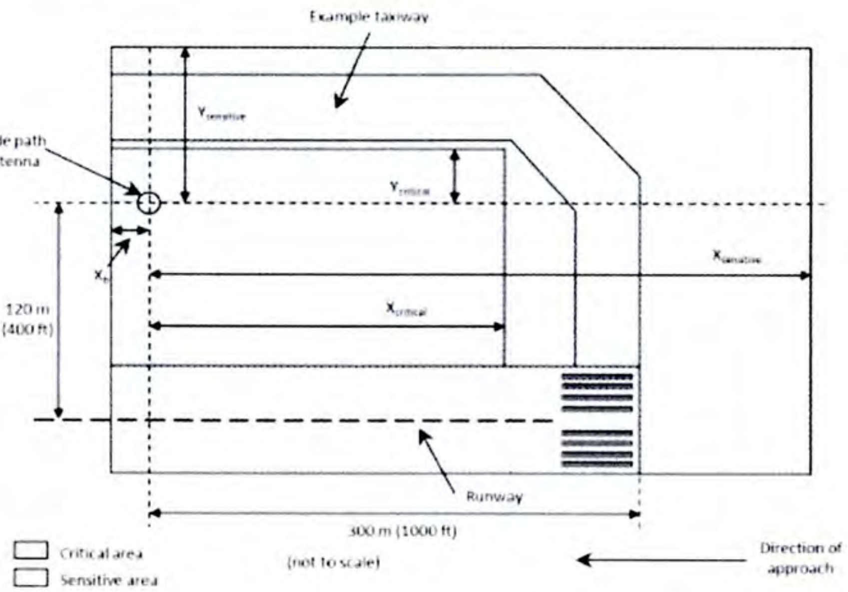

Figure C-4 Example of glide path critical and sensitive area dimensions
(Values in associated Table C-2A below)

Table C.2A example of Glide path critical and sensitive area dimensions for parallel and perpendicular orientations:

Aircraft/vehicle height	Ground vehicle $H \leq 6$ m		Medium aircraft $6 \text{ m} < H \leq 14$ m		Large aircraft $14 \text{ m} < H \leq 20$ m		Very large aircraft $20 \text{ m} < H \leq 25$ m	
Glide path type	M-array	Null-ref	M-array	Null-ref	M-array	Null-ref	M-array	Null-ref
CAT I critical area								
X	299 m	191 m	329 m	829 m	467 m	1 117 m	610 m	1 360 m
Y	29 m	29 m	20 m	20 m	22 m	22 m	15 m	15 m
CAT I sensitive area								
X	299 m	399 m	279 m	529 m	417 m	717 m	510 m	760 m
Y	29 m	15 m	20 m	20 m	22 m	16 m	15 m	15 m
CAT II/III critical area								
X	299 m	449 m	329 m	829 m	567 m	1 267 m	660 m	1 410 m
Y	29 m	29 m	20 m	20 m	22 m	22 m	15 m	15 m
CAT II/III sensitive area								
X	299 m	449 m	429 m	629 m	517 m	767 m	560 m	1 010 m
Y	29 m	29 m	20 m	20 m	22 m	22 m	15 m	15 m

Table C-2B. Example of glide path critical and sensitive area dimensions for other orientations

Aircraft/vehicle height	Ground vehicle $H \leq 6$ m		Medium aircraft $6 \text{ m} < H \leq 14$ m		Large aircraft $14 \text{ m} < H \leq 20$ m		Very large aircraft $20 \text{ m} < H \leq 25$ m	
Glide path type	M-array	Null-ref	M-array	Null-ref	M-array	Null-ref	M-array	Null-ref
CAT I critical area								
X	298 m	191 m	297 m	829 m	444 m	**1 167 m**	591 m	1 360 m
Y	24 m	15 m	**39 m**	**39 m**	**35 m**	**55 m**	**34 m**	**55 m**
CAT I sensitive area								
X	298 m	394 m	**297 m**	**537 m**	**444 m**	717 m	**541 m**	710 m
Y	24 m	**24 m**	**39 m**	**39 m**	**25 m**	**18 m**	**24 m**	**24 m**
CAT II/III critical area								
X	298 m	443 m	**347 m**	829 m	544 m	1 267 m	**672 m**	1 410 m
Y	24 m	25 m	**39 m**	**39 m**	**35 m**	**55 m**	**34 m**	**55 m**
CAT II/III sensitive area								
X	298 m	445 m	297 m	**829 m**	**528 m**	**817 m**	**610 m**	1 010 m
Y	24 m	24 m	**39 m**	**39 m**	**25 m**	**25 m**	**24 m**	**24 m**

Notes:

1. X_b = 50 m and applies to both critical and sensitive areas for the large and very large aircraft category only. Otherwise, X_b = 0 m.

2. The ground vehicle category also applies to small aircraft. Simulations have approximated these aircraft or large ground vehicles using a rectangular box (4 m high 12 m long 3 m wide). Depending on local conditions, it may be possible to reduce especially Category I critical area dimensions such that taxiing or driving on the taxiway directly in front of the glide path antenna may be allowed.

3. Separate tables (C-2A and C-2B) are given for parallel/perpendicular and for other orientations in order to not penalize parallel taxiway operations. To derive worst-case keep-out areas, the largest number among the two tables must be used. Values in Table C-2B ("other orientations") that are larger than the corresponding ones in Table C-2A ("parallel and perpendicular orientations") are highlighted in bold. Perpendicular orientations covered in Table C-2A include only the orientation where the nose of the aircraft is pointing towards the runway. Perpendicular orientations with the tail of the aircraft pointing towards the runway are covered in Table C-2B. Table C-2B also considers aircraft turning towards the runway for line-up at angles of 15, 30, 45, 60 and 75 degrees. Orientations causing the largest keep-out areas (i.e. worst aircraft orientation among all orientations causing out-of-tolerance signals) have been derived based on an A380 using an M-array antenna. Since the number of simulations required to cover all possible orientations for all categories of vehicles over a large area would be excessive, the impact of worst-case orientations on the critical and sensitive areas may need to be verified taking into account the particular taxiway layout.

4. Simulations are referenced to the glide path antenna mast using a typical perpendicular distance to the runway centre line of 120 m and a nominal parallel distance from the runway threshold of 300 m. For different antenna-to-runway offsets, the critical and sensitive areas have to be shifted accordingly.

5. The edge of the runway closer to the glide path antenna defines the inner limit of the critical area. The farther edge of the runway defines the inner limit of the sensitive area. This sensitive area limit needs to be extended by another 50 m on the opposite side of the runway (starting from the runway centre line) for the large and very large aircraft categories when using a Null-Ref antenna.

6. Depending on simulation choices (transition point), the critical area may be larger than the sensitive area and impact associated management procedures.

7. In line with the operational logic described in 2.1.9.4 (no protection of the Category I glide path is required below decision height) as well as the observation that in Tables C-1, C-2A and C-2B, the Category I critical area is typically equal or larger than the sensitive area, protecting the Category I sensitive area may not be necessary.

8. Boundaries for critical and sensitive areas apply to the entire aircraft (entire fuselage and wings).

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Table C- ~~1~~3 Required distance separation

	Frequency separation	Minimum separation between second facility and the protection point of the first facility km (NM)		
		List A	List B	List C
Localizer	Co-channel	148 (80)	148 (80)	148 (80)
	50 kHz	---	37 (20)	9 (5)
	100kHz	65 (35)	9 (5)	0
	150 kHz	---	0	0
	200 kHz	11 (6)	0	0
Glide path	Co-channel	93 (50)	93 (50)	93 (50)
	150 kHz	---	20 (11)	2 (1)
	300 kHz	46 (25)	2 (1)	0
	450 kHz	---	0	0
	600 kHz	9 (5)	0	0

List A refers to the use of localizer receivers designed for 200 kHz channel spacing coupled with glide path receivers designed for 600 kHz channel spacing and applicable only in regions where the density of facilities is low.

List B refers to the use of localizer receivers designed for 100 kHz channel spacing coupled with glide path receivers designed for 300 kHz channel spacing

List C refers to the use of localizer receivers designed for 50 kHz channel spacing coupled with glide path receivers designed for 150 kHz channel spacing.

Note 1.- The above figures are based on the assumption of protection points for the localizer at 46 km (25 Nm) distance and 1 900 m (6 250 ft) height and for the ILS glide path at 18.5 km (10 NM) distance and 760 m (2 500 ft) height.

Note 2. – States, in applying the separations shown in the table, have to recognize the necessity to site the ILS and VOR facilities in a manner which will preclude the possibility of airborne receiver error due to overloading by high unwanted signal levels when the aircraft is in the initial and final approach phases.

Note 3. – States, in applying the separations shown in the table, have to recognize the necessity to site the ILS glide path facilities in a manner which will preclude the possibility of erroneous glide indications due to reception of adjacent channel signals when the desired signal ceases to radiate for any reason while the aircraft is in the final approach phase.

Table C- ~~2~~ 4. Integrity and continuity of service objectives

Level	Localizer or glide path		
	Integrity	Continuity of service	MTBO (hours)
1.		Not demonstrated, or less than required for Level 2	
2.	$1 - 10^{-7}$ in any one landing	$1\text{-}4 \times 10^{-6}$ in any period of 15 seconds	1000
3.	$1\text{-}0.5 \times 10^{-9}$ in any one landing	$1\text{-}2 \times 10^{-6}$ in any period of 15 seconds	2000
4.	$1\text{-}0.5 \times 10^{-9}$ in any one landing	$1\text{-}2 \times 10^{-6}$ in any period of 30 seconds (localizer) 15 seconds (glide path)	4000 (localizer) 2000(glide path)

Note. – For currently installed systems, in the event that the level 2 integrity value is not available or cannot be readily calculated , it is necessary to at least perform a detailed analysis of the integrity to assure proper monitor fail-safe operation.

Table C-~~3~~5. Values of geographical separation distances for co-channel operation

		VOR facilities of equal effective radiated power		VOR facilities which differ in effective radiated power by 6 dB				VOR facilities which differ in effective radiated power by 12 dB			
		Minimum geographical separation between facilities is $2D_1 + \frac{20}{S}$ if D_1 D_2 or $2D_2 + \frac{20}{S}$ if D_2 D_1		Minimum geographical separation between facilities is $2D_1 + \frac{20-K}{S}$ if D_1 $D_2 + \frac{K}{S}$ or $2D_2 + \frac{20+K}{S}$ if D_1 $D_2 + \frac{K}{S}$				Minimum geographical separation between facilities is $2D_1 + \frac{20-K}{S}$ if D_1 $D_2 + \frac{K}{S}$ or $2D_2 + \frac{20+K}{S}$ if D_1 $D_2 + \frac{K}{S}$			
Altitude m (ft)	S dB/km (NM)	K dB	$\frac{20}{S}$ km (NM)	K dB	$\frac{K}{S}$ km (NM)	$\frac{20-K}{S}$ km (NM)	$\frac{20+K}{S}$ km (NM)	K dB	$\frac{K}{S}$ km (NM)	$\frac{20-K}{S}$ km (NM)	$\frac{20+K}{S}$ km (NM)
1	2	3	4	5	6	7	8	9	10	11	12
1 200 (4 000)	0 32 (0 60)	0	61 (33)	6	19 (10)	43 (23)	80 (43)	12	37 (20)	24 (13)	98 (53)
3 000 (10 000)	0 23 (0.43)	0	87 (47)	6	26 (14)	61 (33)	113 (61)	12	52 (28)	35 (19)	137 (74)
4 500 (15 000)	0 18 (0 34)	0	109 (59)	6	33 (18)	76 (41)	143 (77)	12	67 (36)	44 (24)	174 (94)
6 000 (20 000)	0 15 (0 29)	0	128 (69)	6	39 (21)	89 (48)	167 (90)	12	78 (42)	52 (28)	206 (110)
7 500 (25 000)	0 13 (0 25)	0	148 (80)	6	44 (24)	104 (56)	193 (104)	12	89 (48)	59 (32)	237 (128)
9 000 (30 000)	0 12 (0 23)	0	161 (87)	6	48 (26)	113 (61)	209 (113)	12	96 (52)	65 (35)	258 (139)
12 000 (40 000)	0 10 (0 19)	0	195 (105)	6	59 (32)	135 (73)	254 (137)	12	119 (64)	78 (42)	311 (168)
18 000 (60 000)	0 09 (0 17)	0	219 (118)	6	65 (35)	154 (83)	284 (153)	12	130 (70)	87 (47)	348 (188)

Note — S, K and the sign of K are defined in 3 4 5.

In the above formulae:

D1, D2 = service distances required of the two facilities (km).

K = the ratio (db) by which the effective radiated power of the facility providing *D1* coverage exceeds that of the facility providing *D2* coverage.

Note. - if the facility providing D_2 is of higher effective radiated power, then "K" will have a negative value.

S = *slope of the curve showing field strength against distance for constant altitude (dB/km).*

Table C- 46. Protection ratio D/U (dB)

Type of assignment	A	B
Co-frequency :		
Same pulse code	8	8
Different pulse code	8	-42
First adjacent frequency:		
Same pulse code	$-(P_u - 1)$	-42
Different pulse code	$-(P_u+7)$	-75
Second adjacent frequency		
Same pulse code	$-(P_u+19)$	-75
Different pulse code	$-(P_u+27)$	-75

Note 1.- The D/U ratios column A protect those DME/N interrogators Operating on x or y channels. Column a applies to decoder rejection of 6 microseconds

Note 2.- The D/u ratios in Column B protect those in DME/N or DME/N or DME/P interrogators utilizing discrimination in conformance with 6.3.5.5.3.4.2 and 6.3.5.5.3.4.3 of CAR-ANS 6.3

Note 3.- Pu is the peak effective radiated power of the undesired signal in dBw.

Note- 4. The frequency protection requirement is dependent upon the antenna patterns of the desired and undesired facility and the ERP of the undesired ERP of the underside facility

Note.- 5 In assessing adjacent channel protection, the magnitude of D/U ratio in Column A should not exceed the magnitude of the value on column B.

Table C-~~5~~ 7

Function	Typical distance from the threshold	PFE (95%)	CMN (95% probability)
Approach (7.3.2.1.3)			
-extended runway centre line	37 km (20 NM)	± 250m (±820 ft)	± 68m(± 223 ft)
-at 40° azimuth	37 km (20 NM)	±375 m (±1 230 ft)	±68m(± 223 ft)
Approach (7.3.2.1.4)			
-extended runway centre line	9 km (5 NM)	±85 m (± 279 ft)	±34 m (±111ft)
-at 40° azimuth	9 km (5 NM)	± 127 m (±417 ft)	± 34 m (±111ft)
Marker replacement			
-outer marker	9 km (5 NM)	±800 m (±2 625 ft)	not applicable
-middle marker	1 060 m (0.57 NM)	±400 m (±1 312 ft)	not applicable
30 m decision height determination (100 ft) (7.3.2.1.5)			
-3° glide path (CTOL)	556 m (0.3 NM)	±30 m (±100 ft)	not applicable
-6° glide path (STOL)	556 m (0.3 NM)	±15 m (±50 ft)	not applicable
Flare initiation over uneven terrain (7.3.2.1.6)			
-3° glide path (CTOL)	0	±30 m (± 100 ft)	±18 m (±60 ft)
-6° glide path (STOL)	0	±12 m (±40 ft)	±12 m (± 40 ft)
Sensitivity modifications (7.3.2.1.7) (autopilot gain scheduling)	37 km (20 NM) to 0	± 250m (±820 ft)	not applicable
Flare manoeuver with MLS flare elevation (7.3.2.1.8)			
-CTOL	0	±30 m (± 100 ft)	±12 m (±40 ft)
-STOL	0	±12 m (± 40 ft)	±12 m (± 40 ft)
Long Flare alert (7.3.2.1.9)	Runway region	±30 m (± 100 ft)	not applicable
CTOL high speed roll-out/turnoffs (7.3.2.1.10)	Runway region	±12 m (± 40 ft)	±30 m (±100 ft)
Departure climb and missed approach	0 to 9 km (5NM)	100 m (±328 ft)	± 68 m (±223 ft)
VTOL approaches (7.3.2.1.11)	925 m (0.5 NM) to 0	±12 m (± 40 ft)	±12 m (± 40 ft)
Coordinate translations (7.3.2.1.12)	-	±12 m (± 30 ft) (±40 ft to ± 100ft)	±12 m (± 40 ft)

Table C-~~6~~8. Example of DME/P error budget

		FA mode Standard 1		FA mode Standard 2		IA mode	
Error source	Error component	PFE m (ft)	CMN m (ft)	PFE m (ft)	CMN m (ft)	PFE m (ft)	CMN m (ft)
	Transponder	± 10 (±33)	±8 (±26)	±5(±16)	± 5(±16)	±15(±50)	±10(±33)
Instrumentation	Interrogator	± 15 (±50)	±10 (±33)	±7(±23)	± 7(±23)	±30(±100)	±15(±50)
Site related	Down-link specular multipath	±10 (±33)	±8(±26)	±3(±10)	±3(±10)	±37(±121)	±20(±66)
	Up-link specular multipath	±10 (±33)	±8(±26)	±3(±10)	±3(±10)	±37(±121)	±20(±66)
	Non-specular (Diffuse) multipath	±3 (±10)	±3(±10)	±3(±10)	±3(±10)	±3(±10)	±3(±10)
	Garble	±6 (±20)	±6(±20)	±6(±20)	±6(±20)	±6(±20)	±6(±20)

Note 1.- The figures for "non-specular multipath" and for garble are the totals of the up-link and down-link components.

Note 2.- PFE contains both bias and time varying components. In the above table the time varying components and most site related errors are assumed to be essentially statistically independent. The bias components may not conform to any particular statistical distribution. In considering these error budgets, caution is to be exercised when combining the individual components in any particular mathematical manner.

Note 3. The transmitter wave form is assumed to have a 1 200 nanosecond rise time.

Table C-~~7~~9. CTOL ground-to-air power budget

Power budget items	41km (22 NM)	13 km (7 NM)	Ref. datum	Roll-out
Peak effective radiated power, dBm	55	55	55	55
Ground multipath loss,dB	-5	-3	-4	-17
Antenna pattern loss, dB	-4	-2	-5	-5
Path loss dB	-125	-115	-107	-103
Monitor loss dB	-1	-1	-1	-1
Polarization and rain loss, dB	-1	-1	0	0
Received signal at aircraft, dBm	-81	-67	-62	-71
Power density at aircraft, dBW/m^2	-89	-75	-70	-79
Aircraft antenna gain, dB	0	0	0	0
Aircraft cable loss, dB	-4	-4	-4	-4
Received signal at interrogator, dBm	-85	-71	-66	-75
Receiver noise video, dBm				
(Noise factor (NF) = 9dB)				
IF BW: 3.5 MHz		-103	-103	-103
IF BW: 0.8 MHz	-109			
Signal-to-noise ratio (video), dB	24	32	37	28

Table C- ~~8~~10. CTOL air-to-ground power budget

Power budget items	41 km (22 NM)	13km (7 NM)	Ref. datum	Roll-out
Interrogator transmitter power,dBm	57	57	57	57
Aircraft antenna gain, dB	0	0	0	0
Aircraft cable loss,dB	-4	-4	-4	-4
Peak effective radiated,dB	53	53	53	53
Ground multipath loss, dB	-5	-3	-4	-17
Path loss, dB	-125	-115	-107	-103
Polarization and rain loss,dB	-1	-1	0	0
Received signal at transponder antenna, dBm	-78	-66	-58	-67
Ground antenna gain,dB	-8	8	8	8
Pattern loss,dB	-4	-2	-5	-5
Cable loss, dB	-3	-3	-3	-3
Received signal at transponder, dBm	-77	-63	-58	-67
Receiver noise video,dBm				
(noise factor (NF) =9 dB)				
IF BW : 3.5 MHz		-106	-106	-106
IF BW : 0.8 MHz	-112			
Signal-to-noise ratio (video), dB	35	43	48	39

Table C-~~9~~11.Power supply switch over times for ground-based radio aids used at aerodromes

©©	Aids requiring power	maximum switch over times (seconds)
Instrument approach	SRE	15
	VOR	15
	NDB	15
	D/F facility	15
Precision approach, Category I	ILS localizer	10
	ILS glide path	10
	ILS middle marker	10
	ILS outer marker	10
Precision approach, Category II	ILS localizer	0
	ILS glide path	0
	ILS inner marker	1
	ILS middle marker	1
	ILS outer marker	10
Precision approach, category III	(same as category II)	

7.2 Guidance material concerning DME/N only

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7.2.3 *DME-DME RNAV*

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7.2.3.3 Errors in published DME facility locations will result in RNAV position errors. It is therefore important that DME positions are correctly surveyed and that adequate procedures are in place to ensure that the location data are correctly published. For DME facilities collocated with VOR, the DME position ~~should~~ shall be separately surveyed and published if the separation distance exceeds 30 m (100 ft).

Note.— ~~Standards for~~ Specifications concerning data quality and publication of DME location information are ~~given~~ contained in ~~Annex 15 — Aeronautical Information Services~~ PANS-AIM (Doc 10066), Appendix 1.

ATTACHMENT 6D. INFORMATION AND MATERIAL FOR GUIDANCE IN THE APPLICATION OF THE GNSS STANDARDS AND RECOMMENDED PRACTICES

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3. NAVIGATION SYSTEM PERFORMANCE REQUIREMENTS

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3.2 Accuracy

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3.2.7.1 Requirements for position domain accuracy to support precision approach operations below Category I are not defined in the SARPs. GBAS service types intended to support operations with lower than Category I minima are required to meet the SIS accuracy requirements for Category I at a minimum. In addition, specific pseudo-range accuracy requirements apply to support the assessment of adequate performance during aircraft certification. The additional requirements on pseudo-range accuracy may be combined with geometry screening to ensure the resulting position domain accuracy is adequate for a given aeroplane design to achieve suitable landing performance. See 7.5.12.2.

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3.2.9 SBAS and GBAS receivers will be more accurate, and their accuracy will be characterized in real time by the receiver using standard error models, as described in CAR-ANS 6.3, 6.3.5, for SBAS and 6.3, 6.3.6, for GBAS.

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Note 2.— The term "GBAS receiver" designates the GNSS avionics that at least meet the requirements for a GBAS receiver as outlined in Annex 10, Volume I and the specifications of the RTCA ~~DO-253A~~ documents covering the applicable performance types, ~~as~~ amended by United States FAA TSO-~~C161 and TSO-C162~~ (or equivalent).

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3.3 Integrity and time-to-alert

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3.3.10 For GBAS, a technical provision has been made to broadcast the alert limit to aircraft. ~~GBAS standards require the alert limit of 10 m (33 ft).~~ For SBAS, technical provisions have been made to specify the alert limit through an updatable database (see Attachment 6C).

3.3.10.1 For GBAS approach service type D (see 7.1.2.1) additional lower level performance and functional requirements are introduced in order to achieve a total system capable of supporting aircraft landing operations. This service type also supports guided take-off operations.

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3.3.15 Another environmental effect that ~~should~~ shall be accounted for in the ground system design is the errors due to multipath at the ground reference receivers, which depend on the physical environment of monitoring station antennas as well as on satellite elevations and times in track.

3.3.16 SBAS needs to assure the integrity of its broadcast corrections as required in 3.7.2.4 throughout its coverage area. This requirement also applies outside the intended service area, where user receivers could navigate using either an SBAS navigation solution, if available, or a fault detection and exclusion (FDE) navigation solution. The SBAS contributions to a FDE navigation solution are limited to assuring the integrity of the transmitted corrections. SBAS systems have to comply with all the integrity requirements for all typical operations from En-route to Category I, defined in Table 6.3.7.2.4-1, in the coverage area when, for a given operation, the horizontal and vertical protection levels are lower than the corresponding alert limits. This is of particular importance for vertically guided operations using SBAS that are not controlled by FAS data block.

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6.2 SBAS coverage area and service areas

6.2.1 It is important to distinguish between the coverage area and service areas for an SBAS. A coverage area typically corresponds to the GEOs footprint areas and comprises one or more service areas, ~~each capable of supporting~~. Service areas are declared by SBAS service providers or by the State or group of States managing the SBAS, for the typical operations defined in Table 6.3.7.2.4-1 (e.g. En-route, APV-I, Category I) where the corresponding accuracy, integrity and continuity requirements are met with a certain availability (e.g. 99 per cent). Some SBAS service providers publish service areas of their systems (e.g. WAAS Performance standard, EGNOS Service Definition Document and AIPs). The service area for En-route may be wider than the service area for APV-I. For the GNSS receiver, the SIS is usable whenever the protection levels are lower than the alert limits for the intended operation (VPL<VAL and HPL<HAL), irrespective of whether or not the GNSS receiver is inside the corresponding service area defined by the SBAS service provider.

6.2.1.1 SBAS systems support operations based on some or all of the SBAS functions defined in CAR-ANS 6.3, 6.3.7.3.4.2. These functions can be related to the operations that are supported as follows:

a) *Ranging*: SBAS provides a ranging source for use with other augmentation(s) (ABAS, GBAS or other SBAS);

b) *Satellite status and basic differential corrections*: SBAS provides en-route, terminal, and non-precision approach service. Different operations (e.g. performance-based navigation operations) may be supported in different service areas;

c) *Precise differential corrections*: SBAS provides APV and precision approach service (i.e. APV-I, APV-II and precision approach may be supported in different service areas).

6.2.2 Satellite-based augmentation services are provided by the Wide Area Augmentation System (WAAS) (North America), the European Geostationary Navigation Overlay Service (EGNOS) (Europe and Africa) ~~and~~, the Multifunction Transport Satellite (MTSAT) Satellite-based Augmentation System (MSAS) (Japan)~~. The~~ and the GPS-aided Geo-augmented Navigation (GAGAN) (India). ~~and the~~ The System of Differential Correction and Monitoring (SDCM) (Russia) and other SBAS systems are also under development to provide these services.

6.2.3 An SBAS may provide accurate and reliable service outside the defined service area(s). The ranging, satellite status and basic differential corrections functions are usable throughout the entire coverage area. The performance of these functions may be technically adequate to support en-route, terminal and non-precision approach operations by providing monitoring and integrity data for core satellite constellations and/or SBAS satellites. ~~The only potential for integrity to be compromised is if there is a satellite ephemeris error that cannot be observed by the SBAS ground network while it creates an unacceptable error outside the service area. For alert limits of 0.3 NM specified for non-precision approach and greater, this is very unlikely.~~ **SBAS mitigates errors which cannot be monitored by its ground network through message types 27 or 28.**

6.2.4 Each State is responsible for ~~defining SBAS service areas and~~ approving SBAS-based operations within its airspace. In some cases, States will field SBAS ground infrastructure linked to an ~~existing~~ SBAS. ~~This would be required to achieve APV or precision approach performance.~~ In other cases, States may simply approve service areas and SBAS-based operations using available SBAS signals. In either case, each State is responsible for ensuring that SBAS meets the requirements of CAR-ANS 6.3, 6.3.7.2.4, within its airspace, and that appropriate operational status reporting and NOTAMs are provided for its airspace.

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6.4 RF characteristics

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6.4.6 *SBAS pseudo-random noise (PRN) codes.* ~~RTCA/DO-229D with Change 1, Appendix A, provides two methods for SBAS PRN code generation.~~ **Receivers compliant with RTCA DO-229D with Change 1 and earlier versions only search for PRN codes in the range 120 to 138 only (out of the full 120 to 158 range in Table B-23), and therefore will not acquire and track SBAS signals identified by a PRN code in the range 139 to 158. Receivers compliant with DO-229E and subsequent versions can acquire and track SBAS signals identified by all PRN codes in Table B-23.**

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7.GROUND-BASED AUGMENTATION SYSTEM (GBAS) AND GROUND-BASED REGIONAL AUGMENTATION SYSTEM (GRAS)

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7.1 System description

7.1.1 GBAS consists of ground and aircraft elements. A GBAS ground subsystem typically includes a single active VDB transmitter and broadcast antenna, referred to as a broadcast station, and multiple reference receivers. A GBAS ground subsystem may include multiple VDB transmitters and antennas that share a single common GBAS identification (GBAS ID) and frequency as well as broadcast identical data. The GBAS ground subsystem can support all the aircraft subsystems within its **service volume**~~coverage~~ providing the aircraft with approach data, corrections and integrity information for GNSS satellites in view. **GBAS ground and aircraft elements are classified according to the types of service they support (as defined in section 7.1.2).** ~~All international aircraft supporting APV should maintain approach data within a database on board the aircraft. The Type 4 message must be broadcast when the ground subsystem supports Category I precision approaches. The Type 4 message must also be broadcast when the ground subsystem supports APV approaches if the approach data is not required by the State to be maintained in the on-board database.~~

~~*Note. Allocation of performance requirements between the GBAS subsystems and allocation methodology can be found in RTCA/DO-245, Minimum Aviation System Performance Standards for the Global Positioning System/Local Area Augmentation System (GPS/LAAS). Minimum Operational Performance Standards for GRAS airborne equipment are under development by RTCA.*~~

7.1.2 GBAS ~~ground sub~~systems may provide two types of services: ~~the~~ approach services and the GBAS positioning service. The approach service provides deviation guidance for FASs ~~in Category I precision approach, APV, and NPA~~ within the ~~operational~~ approach service volume~~coverage area~~. The GBAS positioning service provides horizontal position information to support RNAV operations within the positioning service ~~area~~volume. The two types of services are also distinguished by different performance requirements associated with the particular operations supported (see Table 6.3.7.2.4-1) including different integrity requirements as discussed in 7.5.1.

7.1.2.1 GBAS approach services are further differentiated into multiple types referred to as GBAS approach service types (GAST). A GAST is defined as the matched set of airborne and ground performance and functional requirements that are intended to be used in concert in order to provide approach guidance with quantifiable performance. Four types of approach service, GAST A, GAST B, GAST C and GAST D are currently defined. GAST A, B and C are intended to support typical APV I, APV II and Category I operations, respectively. GAST D has been introduced to support landing and guided take-off operations in lower visibility conditions including Category III operations. Note that provisions for a separate service type to support Category II operations, but not Category I nor Category III, have not been made. Since equipment supporting GAST D will function the same when supporting Category II minima as when supporting Category III minima, GAST D provides one means of supporting Category II operations. Category II operations may potentially be supported using GAST C in conjunction with an appropriate aeroplane level integration. A relevant analogy is the authorization in at least one State of lower than Category I minima based on guidance from a facility performance Category I ILS used in conjunction with a head-up display (HUD). Requirements for the approval of Category II operations using GBAS will be defined by the airworthiness and operational approval authorities within States.

7.1.2.1.1 A GBAS ground subsystem may support multiple service types simultaneously. There are two types of ground subsystems, those that support multiple types of approach service and those that do not. Equipment designed in compliance with earlier versions of these SARPs may only support a single type of approach service, GAST C. Equipment designed in compliance with these SARPs may or may not support multiple types of service on one or more runway ends. The type of services supported for each approach are indicated in the approach performance designation field in a FAS data block within the Type 4 message. The GBAS continuity/integrity designator (GCID) parameter in the Type 2 message indicates whether a GBAS ground subsystem is currently supporting multiple types of approach service. Airborne equipment that can support multiple service types will first check the GCID to determine if the ground segment supports multiple types of service. If it does, the equipment will then check the approach performance designator (APD) field of the selected FAS data block within the Type 4 message to determine which types of service are supported by the ground segment for the approach selected (using the channel selection scheme described in section 7.7 below). The airborne equipment will then determine which approach service to select based on APD, the current status of GCID and the airborne equipment type. Operators should understand that the available operations may be restricted by many factors including pilot qualifications or temporary ANSP limitations which are not reflected in the APD value. Therefore, APD shall not be interpreted as an indication of the availability of any operational use, only as an indication of the service types that are supported for the given runway.

7.1.2.1.2 GBAS airborne equipment may attempt to automatically select the highest type of service supported by both the airborne equipment and the ground segment for the selected approach (as indicated in APD). If the desired type of service is not available, the airborne equipment may select the next lower available type of service and annunciate this appropriately. Therefore, during a GBAS operation, there is the selected service type (SST) and the active service type (AST). The SST is the service type that the airborne equipment would use if it were available, and can be no higher than the highest type of service offered by the ground segment for the selected approach. The AST is the service type that the airborne equipment is actually using at a particular time. The AST may differ from the SST if the SST is unavailable for some reason. The airborne equipment annunciates both the SST and AST so that proper action (e.g. annunciations) may be taken in the context of the airborne integration and operational procedures.

7.1.2.1.3 Service providers shall give consideration to what service type or types are actually required for each runway given the planned operations and encode the availability of the appropriate service types in the APD field of the associated FAS block.

7.1.2.1.4 When the ground subsystem is no longer capable of meeting FAST D requirements there are several options, depending upon which requirements are not met. If the ground subsystem cannot meet all of the FAST D integrity requirements (Appendix 6B, 3.6.7.1.2.1.1.2, 3.6.7.1.2.1.1.3, and 3.6.7.1.2.2.1.1, 3.6.7.3.2) FAST D needs to be removed within the time to alert defined in Appendix 6B, 3.6.7.1.2.1.1.3. If it is still capable of meeting FAST C integrity requirements, the ground subsystem shall only remove FAST D and continue to broadcast in FAST C mode. The procedure for removing FAST D includes two options for reflecting this in the corrections (Appendix 6B, 3.6.7.3.2.1).

7.1.2.1.4.1 When downgrading from FAST D to C, the GCID in the Type 2 message (Appendix 6B, 3.6.7.2.3.2) also needs to change. A FAST D ground subsystem normally broadcasts a GCID of 2, indicating it supports FAST C and FAST D. When the ground subsystem can no longer support FAST D, but can still support FAST C, the GCID shall change to 1. Note that it is assumed here that a FAST D ground subsystem would downgrade to FAST C only, and not to FAST A or B.

7.1.2.1.4.2 Another condition that could result in the ground subsystem no longer being capable of supporting FAST D would be a failure such that FAST D continuity (Appendix 6B, 3.6.7.1.3.1 and 3.6.7.1.3.2) cannot be met (e.g. failure of redundant components). If FAST D integrity requirements are still met, the ground subsystem is not required to remove the corrections in the Type 11 messages. However, the GCID needs to change to 1. Communicating the change in GCID nominally would take 10 seconds, as the minimum update rate for Type 2 messages is 10 seconds. It may take as long as one minute. A change in FAST shall be reflected in the next scheduled broadcast of the Type 2 message. In addition, changes to GCID are ignored by the airborne equipment when the aircraft is in the final stages of the approach. Therefore, GCID changes only affect the FAST for aircraft outside of the final stages of the approach.

7.1.3 A ~~primary~~ significant distinguishing feature for GBAS ground subsystem configurations is whether additional ephemeris error position bound parameters are broadcast. This feature is required for the positioning service, but is optional for some approach services. If the additional ephemeris error position bound parameters are not broadcast, the ground subsystem is responsible for assuring the integrity of ranging source ephemeris data without reliance on the aircraft calculating and applying the ephemeris bound as discussed in 7.5.9.

7.1.4 *GBAS configurations.* There are multiple configurations possible of GBAS ground subsystems conforming to the GNSS Standards, examples of such ~~as~~ configurations are:

a) a configuration that supports ~~Category I precision approach~~ GAST C only;

b) a configuration that supports ~~Category I precision approach and APV~~ GAST A, GAST B, GAST C, and also broadcasts the additional ephemeris error position bound parameters;

c) a configuration that supports ~~Category I precision approach, APV~~ only GAST C and GAST D, and the GBAS positioning service, while also broadcasting the ephemeris error position bound parameters referred to in b); and

d) a configuration that supports ~~APV-~~only GAST A and the GBAS positioning service, and is used within a GRAS.

7.1.4.1 *GBAS facility classification (GFC).* A GBAS ground subsystem is classified according to key configuration options. A GFC is composed of the following elements:

a) facility approach service type (FAST);

b) ranging source types;

c) facility coverage; and

d) polarization.

7.1.4.1.1 *Facility approach service type (FAST).* The FAST is a collection of letters from A to D indicating the service types that are supported by the ground subsystem. For example, FAST C denotes a ground subsystem that meets all the performance and functional requirements necessary to support GAST C. As another example, a FAST ACD designates a ground subsystem that meets the performance and functional requirements necessary to support service types A, C and D.

Note.— The facility classification scheme for GBAS includes an indication of which Service Types the ground subsystem can support. This means the ground subsystem meets all the performance requirements and functional requirements such that a compatible airborne user can apply the information from the ground subsystem and have quantifiable performance at the output of the processing. It does not necessarily mean that the ground subsystem supports all service types on every runway end. Which GBAS approach service types are supported on a given runway end is indicated in the Type 4 message and is included as part of the approach facility designation defined in section 7.1.4.2.

7.1.4.1.2 *Ranging source types*: The ranging source type designation indicates what ranging sources are augmented by the ground subsystem. The coding for this parameter is as follows:

G1 - GPS
G2 - SBAS
G3 - GLONASS
G4 - Reserved for Galileo
G5+ - Reserved for future ranging sources

7.1.4.1.3 *Facility coverage*: The facility coverage designation indicates positioning service capability and maximum use distance. The facility coverage is coded as 0 for ground facilities that do not provide the positioning service. For other cases, the facility coverage indicates the radius of D_{max} expressed in nautical miles.

Note.— The service volume for specific approaches is defined as part of the approach facility designations defined in section 7.1.4.2.

7.1.4.1.4 *Polarization*: The polarization designation indicates the polarization of the VHF data broadcast (VDB) signal. E indicates elliptical polarization and H indicates horizontal polarization.

7.1.4.1.5 *GBAS facility classification examples.* The facility classification for a specific facility is specified by a concatenated series of codes for the elements described in sections 7.1.4.1 through 7.1.4.1.4. The general form of the facility classification is:

GFC = Facility Approach Service Type/Ranging Source Type /Facility Coverage/Polarization.

For example, a facility with the designation of GFC – C/G1/50/H, denotes a ground subsystem that meets all the performance and functional requirements necessary to support service type C on at least one approach, using GPS ranges only, with the GBAS positioning service available to a radius of 50 NM from the GBAS reference position and a VDB that broadcasts in Horizontal polarization only. Similarly, GFC - CD/G1G2G3G4/0/E denotes a ground subsystem that supports at least one approach with a service type of C and D, provides corrections for GPS, SBAS, GLONASS and Galileo satellites, does not support the positioning service and broadcasts on elliptical polarization.

7.1.4.2 *Approach facility designations.* A GBAS ground subsystem may support many approaches to different runway ends at the same airport or even runways at adjacent airports. It is even possible that a GBAS will support multiple approaches to the same runway end with different Types of Service (intended, for example, to support different operational minima). Each approach provided by the ground system may have unique characteristics and in some sense may appear to the user to be a separate facility. Therefore, in addition to the GBAS facility classification, a system for classifying or designating the unique characteristics of each individual approach path is needed. For this purpose a system of approach facility designations is defined. Figure D-10 illustrates the relationship between GBAS facility classifications and approach facility designations. The classification is intended to be used for pre-flight planning and published in the AIP.

7.1.4.2.1 *Approach facility designation elements.* Each approach supported by a GBAS can be characterized by an approach facility designation (AFD). The AFD is composed of the following elements:

GBAS identification: Indicates the GBAS facility identifier that supports the approach (4-character GBAS ID).

Approach identifier: This is the approach identifier associated with the approach in the Message Type 4 data block. It is 4 characters and must be unique for each approach within radio range of the GBAS facility.

Channel number: This is the channel number associated with the approach selection. It is a 5 digit channel number between 20001 and 39999.

Approach service volume: Associated with each published approach, indicates the service volume either by a numerical value in feet corresponding to the minimum decision height (DH) or by the GBAS points as defined below (i.e. GBAS Points A, B, C, T, D, E, or S).

Supported service types: Designates the GBAS service types (A-D) that are supported for the approach by the ground subsystem. This field can never be given a value greater than the facility approach service type for the GBAS ground subsystem that supports the approach.

The GBAS points A, B, C, T, D and E define the same locations relative to the runway as the ILS Points in Attachment 6C, Figure C-1 used to define the ILS localizer course and glide path bend amplitude limits. Point S is a new point defining the stop end of the runway. For GBAS, the points are used to indicate the location along the nominal approach and/or along the runway for which GBAS performance for the supported service type(s) has been verified. When a decision height is used instead to define the approach service volume, the service volume is provided to a height of half the DH as defined in CAR-ANS 6.3, 6.3.7.3.5.3.1. The choice of coding using a DH or GBAS points depends upon the intended operational use of the runway. For example, if the approach identifier corresponds to a Category I instrument approach procedure from which automatic landings are authorized, the approach service volume element is intended to indicate at what point along the runway the performance has been verified. The point definitions are given below:

GBAS Point "A". A point on a GBAS final approach segment measured along the extended runway centre line in the approach direction a distance of 7.5 km (4 NM) from the threshold.

GBAS Point "B". A point on the GBAS final approach segment measured along the extended runway centre line in the approach direction a distance of 1 050 m (3 500 ft) from the threshold.

GBAS Point "C". A point through which the downward extended straight portion of the nominal GBAS final approach segment passes at a height of 30 m (100 ft) above the horizontal plane containing the threshold.

GBAS Point "D". A point 3.7 m (12 ft) above the runway centre line and 900 m (3 000 ft) from the threshold in the direction of the GNSS azimuth reference point (GARP).

GBAS Point "E". A point 3.7 m (12 ft) above the runway centre line and 600 m (2 000 ft) from the stop end of the runway in the direction of the threshold.

GBAS Point "S". A point 3.7 m (12 ft) above the runway centre line at the stop end of the runway.

GBAS reference datum (Point "T"). A point at a height specified by TCH located above the intersection of the runway centre line and the threshold.

7.1.4.2.2 Approach facility designation examples

The approach facility designation consists of the concatenation of the parameters defined in section 7.1.4.2.1 as: GBAS ID/approach ID/ranging sources/approach service volume/required service type. An example application of this concept to a particular approach at the US Washington, DC Ronald Reagan International Airport is:

"KDCA/XDCA/21279/150/CD"

where:

KDCA – indicates the approach is supported by the GBAS installation at DCA
XDCA – indicates the approach ident (echoed to the pilot on approach selection) for this specific approach is "XDCA"
21279 – is the 5-digit channel number used to select the approach
150 – indicates the GBAS coverage has been verified to be sufficient to support a DH as low as 150 ft.
CD – indicates that GBAS approach service types C and D are supported by the ground subsystem for the approach

Another example application of this concept to a particular approach at Boeing Field is:

" KBFI/GBFI/35789/S/C"

where:

KBFI – indicates the approach is supported by the GBAS installation at BFI (with GBAS Station identifier KBFI)
GBFI – indicates the approach ident (echoed to the pilot on approach selection) for this specific approach is "GBFI"
35789 – is the 5-digit channel number used to select the approach.
S – indicates the GBAS service volume extends along the approach and the length of the runway surface (i.e. 12 ft above the runway to the stop end).
C – indicates that GBAS approach service type C is supported by the ground subsystem for this FAS.

7.1.4.3 *GBAS airborne equipment classification (GAEC)*

7.1.4.3.1 GBAS airborne equipment may or may not support multiple types of approach service that could be offered by a specific ground subsystem. The GBAS airborne equipment classifications (GAEC) specifies which subsets of potentially available services types the airborne equipment can support. The GAEC includes the following elements:

Airborne approach service type (AAST): The AAST designation is a series of letters in the range from A to D indicating which GASTs are supported by the airborne equipment. For example, AAST C denotes airborne equipment that supports only GAST C. Similarly, AAST ABCD indicates the airborne equipment can support GASTs A, B, C & D.

Note.— For airborne equipment, designating only the highest GBAS approach service type supported is insufficient as not all airborne equipment is required to support all service types. For example, a particular type of airborne equipment may be classified as AAST CD, meaning the airborne equipment supports GAST C and D (but not A or B).

Ranging source types: This field indicates which ranging sources can be used by the airborne equipment. The coding is the same as for the ground facility classification (see section 7.1.4.1.2).

7.1.4.3.2 *Multiple service type capable equipment.* Ground and airborne equipment designed and developed in accordance with previous versions of these SARPs (Amendment 80) and RTCA DO-253A will only support GAST C. The current version of the Standards has been designed such that legacy GBAS airborne equipment will still operate correctly when a ground subsystem supports multiple types of service. Also, airborne equipment which can support multiple types of service will operate correctly when operating with a ground subsystem that supports only GAST C.

7.1.4.3.3 *GBAS airborne equipment classification examples.* GBAS airborne equipment classifications consist of a concatenated series of codes for the parameters defined in 7.1.4.3. The general form of the GAEC is:

GAEC = (airborne approach service type)/(ranging source type)

For example:

GAEC of C/G1 - denotes airborne equipment that supports only GAST C and uses only GPS ranges.

Similarly:

GAEC of ABC/G1G4 - denotes airborne equipment that supports all GASTs except GAST D and can use both GPS and Galileo ranging sources.

GAEC of ABC/G1G3 - denotes airborne equipment that supports all GASTs except GAST D and can use both GPS and GLONASS ranging sources.

Finally:

GAEC – CD/G1G2G3G4 - denotes airborne equipment that supports GASTs C and D and uses GPS, SBAS, GLONASS and Galileo ranging sources.

7.1.5 *GRAS configurations*. From a user perspective, a GRAS ground subsystem consists of one or more GBAS ground subsystems (as described in 7.1.1 through 7.1.4), each with a unique GBAS identification, providing the positioning service and ~~APV~~ one or more approach service types where required. By using multiple GBAS broadcast stations, and by broadcasting the Type 101 message, GRAS is able to support en-route operations via the GBAS positioning service, while also supporting terminal, departure, and ~~APV~~ operations supported by GAST A or B over a larger coverage region than that typically supported by GBAS. In some GRAS applications, the corrections broadcast in the Type 101 message may be computed using data obtained from a network of reference receivers distributed in the coverage region. ~~This permits detection and mitigation of measurement errors and receiver faults.~~

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7.1.7 Interoperability of the GBAS ground and aircraft elements compatible with RTCA/DO-253~~A~~() is addressed in Appendix 6B, 3.6.8.1. GBAS receivers compliant with RTCA/DO-253A will not be compatible with GRAS ground subsystems broadcasting Type 101 messages. However, GRAS and GBAS receivers compliant with RTCA/DO-310 GRAS MOPS, will be compatible with GBAS ground subsystems. SARPs-compliant GBAS receivers may not be able to decode the FAS data correctly for ~~APV~~ GAST A transmitted from GBAS ground subsystems (i.e. a FAS data block with APD coded as "0"). These receivers will apply the FASLAL and FASVAL as if the active service type is GAST C ~~conducting a Category I precision approach.~~ ANSPs ~~should~~ shall be cognizant of this fact and r~~R~~elevant operational restrictions may have to be applied~~y~~ to ensure the safety of the operation. For GBAS ground subsystems providing GAST D, APD in the FAS data blocks may be coded as values of 1 or 2 (Appendix 6B, 3.6.4.5.1). SARPs compliant GBAS receivers developed in accordance with SARPs prior to Amendment 91 may not be able to use FAS data blocks with APD equal to 2 or above.

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7.1.11 *Availability considerations for GBAS.* A single GBAS ground subsystem may provide multiple types of service to multiple users and service for multiple runway ends simultaneously. These different types of service may have different availability and consequently one type of service may be available when another is not. Furthermore, as some elements of GBAS are optional (e.g. augmentation of multiple constellations or use of SBAS ranging sources), the capabilities of different users will vary. For this reason, it is not practical for the service provider to predict if a given user will find a specific service type to be available at any given time. All that can be known by the service provider is the status of the ground subsystem and satellite constellation. An assessment can be made as to whether the ground subsystem is meeting the allocated requirements for some target service type and further, the availability of service can be predicted based on an assumed level of performance and a nominal user. The definition of the nominal user includes which elements of GNSS are used (core satellite systems, SBAS ranges etc.) and within that, which subset of satellites are used in the position solution. For GBAS supporting GAST D this is further complicated by the fact that certain parameters (e.g. geometry screening thresholds) may be adjusted by the airframe designer to ensure adequate landing performance given the characteristics of the specific aircraft type. ANSPs and air space designers shall be cognizant of the fact that availability of service for GNSS augmentation systems in general is less predictable than conventional navigation aids. Variations in user capabilities will result in times where service may be available to some users and unavailable to others.

7.2 RF characteristics

7.2.1 *Frequency coordination*

7.2.1.1 *Performance factors*

7.2.1.1.1 The geographical separation between a candidate GBAS station, a candidate VOR station and existing VOR or GBAS installations must consider the following factors:

a) the service~~coverage~~ volume, minimum field strength and effective isotropically radiated power (EIRP) of the candidate GBAS including the GBAS positioning service, if provided. The minimum requirements for service volume~~coverage~~ and field strength are found in CAR-ANS 6.3, 6.3.7.3.5.3 and 6.3.7.3.5.4.4, respectively. The EIRP is determined from these requirements;

b) the coverage and service volume, minimum field strength and EIRP of the surrounding VOR and GBAS stations including the GBAS positioning service, if provided. Specifications for coverage and field strength for VOR are found in CAR-ANS 6.3, 6.3.3, and respective guidance material is provided in Attachment 6C;

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h) the four-character GBAS ID to differentiate between GBAS ground subsystems. The GBAS ID is normally identical to the location indicator at the nearest aerodrome. The requirement is found in Appendix 6B, 3.6.3.4.1; and

i) *Slot assignment.* The relative assignment of slots to a GBAS ground subsystem can impact performance in instances where messages in multiple slots need to be received by the airborne subsystem prior to processing. This will occur when using linked messages and/or for a GAST D ground subsystem where correction data is contained in both the Type 1 and Type 11 messages. In these cases slot assignments for all MT 1 and 11 shall be adjacent to avoid unnecessary latency and complexity of design. Non-adjacent assignments may, depending on the design of the ground subsystem, result in a lack of time for the ground subsystem to process fault detections, render some slot combinations unusable and thus result in lower efficiency of spectrum use.

7.2.1.1.2 Nominal link budgets for VDB are shown in Table D-3. The first example in Table D-3 assumes a user receiver height of 3 000 m (10 000 ft) MSL and a transmit antenna designed to suppress ground illumination in order to limit the fading losses to a maximum of 10 dB at VDB coverage edge. In the case of GBAS/E equipment, the 10 dB also includes any effects of signal loss due to interference between the horizontal and vertical components. The second example in Table D-3 provides a link budget for longer range positioning service. It is for a user receiver height sufficient to maintain radio line-of-sight with a multi-path limiting transmitting antenna. No margin is given in Table D-3 for fading as it is assumed that the receiver is at low elevation angles of radiation and generally free from significant null for the distances shown in the table (greater than 50 NM). In practice, installations will experience a fade margin that will be dependent on many parameters including aircraft altitude, distance from transmit antenna, antenna type/design and ground reflectors.

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7.2.1.4 *Example of GBAS/GBAS geographical separation criteria*

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7.2.1.4.2 The geographic separation for co-channel, co-slot GBAS VDB assignments is obtained by determining the distance at which the transmission loss equals 145 dB for receiver altitude of 3 000 m (10 000 ft) above that of the GBAS VDB transmitter antenna. This distance is 318 km (172 NM) using the free-space attenuation approximation and assuming a negligible transmitter antenna height. The minimum required geographical separation can then be determined by adding this distance to the nominal distance between the edge of VDB coverage and the GBAS transmitter 43 km (23 NM). This results in a co-channel, co-slot reuse distance of 361 km (195 NM).

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7.2.1.6 *Guidelines on GBAS/VOR geographical separation criteria.* The GBAS/VOR minimum geographical separation criteria are summarized in Table D-5 based upon the same methodology and the nominal VOR coverage volumes in Attachment 6C.

Table D-3Nominal VDB link budget

VDB link elements					
For approach service			Vertical component at coverage edge		Horizontal component at coverage edge
Required receiver sensitivity(dBm)			-87		-87
Maximum aircraft implementation loss (dB)			11		15
Power level after aircraft antenna (dBm)			-76		-72
Operating margin (dB)			3		3
Fade margin (dB)			10		10
Free space path loss (dB) at 43 km (23 NM)			106		106
Nominal effective isotropically radiated power (EIRP) (dBm)			43		47
For longer range and low radiation angle associated with positioning service			Vertical component		Horizontal component
Required receiver sensitivity (dBm)			-87		-87
Maximum aircraft implementation loss (dB)			11		15
Power level after aircraft antenna (dBm)			-76		-72
Operating margin (dB)			3		3
Fade margin (dB)			0		0
Nominal EIRP (dBm)					
Range (km (NM)	Free space loss (dB)	EIRP (dBm)	EIRP (W)	EIRP (dBm))	EIRP (W)
93(50)	113	39.9	10	43.9	25
185 (100)	119	45.9	39	49.9	98
278(150)	122	49.4	87	53.4	219
390 (200)	125	51.9	155	55.9	389

Notes.—

~~*1. In this table ERP is referenced to an isotropic antenna model.*~~

1~~2~~. It is possible, with an appropriately sited multipath limiting VDB transmitting antenna with an ~~ERP~~ effective radiated power sufficient to meet the field strength requirements for approach service and considering local topographical limitations, to also satisfy the field strength requirements such that positioning service can be supported at the ranges in this table.

2~~3~~. Actual aircraft implementation loss (including antenna gain, mismatch loss, cable loss, etc.) and actual receiver sensitivity may be balanced to achieve the expected link budget. For example, if the aircraft implementation loss for the horizontal component is 19 dB, the receiver sensitivity must exceed the minimum requirement and achieve -91 dBm to satisfy the nominal link budget.

3. The long-range performance estimates may generally be optimistic with the assumption of no fade margin, i.e., link budget performance will generally not be as good as these estimates indicate.

Note 1.— When determining the geographical separation between VOR and GBAS, VOR as the desired signal is generally the constraining case due to the greater protected altitude of the VOR coverage region.

Note 2.— Reduced geographical separation requirements can be obtained using standard propagation models defined in ITU-R Recommendation P.528-2.

7.2.2 The geographical separation criteria for GBAS/ILS and GBAS/VHF communications are under development.

7.2.3 *Compatibility with ILS.* ~~Until compatibility criteria are developed for GBAS VDB and ILS, VDB cannot be assigned to channels below 112.025 MHz. If there is an ILS with a high assigned frequency at the same airport as a VDB with a frequency near 112 MHz, it is necessary to consider ILS and VDB compatibility.~~ Considerations for assignment of VDB channels include the frequency separation between the ILS and the VDB, the distance separation between the ILS coverage area and the VDB, the VDB and ILS field strengths, and the VDB and ILS localizer receiver sensitivity. Until compatibility criteria are developed for GBAS VDB and ILS, VDB can generally not be assigned to channels below 112.025 MHz (i.e. a minimum frequency separation of 75 kHz from the highest assignable ILS localizer frequency).

7.2.3.1 *Inter-airport compatibility.* The minimum geographical separation based on a minimum frequency separation of 75 kHz between ILS localizer and GBAS ground station deployed at different airports is 3 NM between the undesired transmitter antenna location and the edges of the coverage of the desired service that are assumed to be at minimum signal power. Smaller necessary separation distance values may be obtained by taking into account additional information such as the actual desired service field strength and actual undesired service transmit antenna radiation patterns.

Note.— The coverage of the ILS localizer is standardized in CAR-ANS 6.3, section 6.3.1.3.3 and the GBAS service volume is standardized in CAR-ANS 6.3, section 6.3.7.3.5.3, respectively.

7.2.3.2 *Same-airport compatibility.* To analyse the constraints for the deployment of a GBAS ground station at the same airport as ILS, it is necessary to consider ILS and VDB compatibility in detail taking into account information such as the actual desired service field strength and actual undesired service transmit antenna radiation patterns. For GBAS equipment with transmitter power such that the maximum field strength of 0.879 volts per metre (-27 dBW/m^2) for the horizontally polarized signal component is not exceeded in the ILS coverage volume ~~of up to 150 W (GBAS/E, 100 W for horizontal component and 50 W for vertical component) or 100 W (GBAS/H),~~ the 16th channel (and beyond) will be below -100.5~~106~~ dBm in a 25 kHz bandwidth at a distance of ~~200~~80 m from the VDB transmitter, including allow~~ing~~ance for a +5 dB ~~positive reflection~~ increase due to constructive multipath. This -100.5~~106~~ dBm in a 25 kHz bandwidth translates to a signal-to-noise ratio of 21.5 dB (above the assumed minimum signal-to-noise ratio of 20 dB~~) figure assumes~~ for a -79~~86~~ dBm localizer signal which corresponds to an ILS localizer field strength of 90 microvolts per metre (minus 107 dBW/m^2)~~at the ILS receiver input and a minimum 20 dB signal-to-noise ratio.~~

Note.— When deploying GBAS and ILS at the same airport, it is recommended to also analyse the impact of the GBAS VDB transmission on the ILS localizer monitor. Interference may be avoided by installing an appropriate filter.

7.2.4 *Compatibility with VHF communications.* For GBAS VDB assignments above 116.400 MHz, it is necessary to consider VHF communications and GBAS VDB compatibility. Considerations for assignment of these VDB channels include the frequency separation between the VHF communication and the VDB, the distance separation between the transmitters and coverage areas, the field strengths, the polarization of the VDB signal, and the VDB and VHF **communication receiver** sensitivity. Both aircraft and ground VHF communication equipment are to be considered. For GBAS/E equipment with a transmitter maximum power of up to 150 W (100 W for horizontal component and 50 W for vertical component), the 64th channel (and beyond) will be below –112~~0~~ dBm **in a 25 kHz bandwidth** at a distance of 80~~200~~ m from the VDB transmitter including **an allowance**~~allowing for a~~**of** +5 dB ~~positive reflection~~**increase due to constructive multipath.** For GBAS/H equipment with a transmitter maximum power of 100 W, the 32nd channel (and beyond) will be below –1120 dBm in a 25 kHz bandwidth at a distance of 80200 m from the VDB transmitter including **an allowance** ~~allowing for a~~of +5 dB ~~positive reflection~~ **increase due to constructive multipath**, and a 10 dB polarization isolation. It must be noted that due to differences in the GBAS VDB and VDL transmitter masks, separate analysis must be performed to ensure VDL does not interfere with the GBAS VDB.

Table D-4. Typical GBAS/GBAS frequency assignment criteria

Channel of undesired VDB in the same slots	Path loss (dB)	Minimum required geographical separation of Txu = 47 dBm and PD,min = -72 dBm in km (NM)
Co-channel	145	361 (195)
1st adjacent channel (±25 kHz)	101	67 (36)
2ndadjacent channel (±50 kHz)	76	44 (24)
3rd adjacent channel (±75 kHz)	73	No restriction
4th adjacent channel (±100 kHz)	73	No restriction

Note 1.— No geographic transmitter restrictions are expected between co-frequency, adjacent time slots provided the undesired VDB transmitting antenna is located at least 80~~200~~ m from areas where the desired signal is at minimum field strength.

Note 2.— The PD,min of -72 dBm is the output from an ideal isotropic antenna.

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7.2.5 For a GBAS ground subsystem that only transmits a horizontally-polarized signal, the requirement to achieve the power associated with the minimum sensitivity is directly satisfied through the field strength requirement. For a GBAS ground subsystem that transmits an elliptically-polarized component, the ideal phase offset between HPOL and VPOL components is 90 degrees. In order to ensure that an appropriate received power is maintained throughout the GBAS service~~coverage~~ volume during normal aircraft maneuvers, transmitting equipment should be designed to radiate HPOL and VPOL signal components with an RF phase offset of 90 degrees. This phase offset should be consistent over time and environmental conditions. Deviations from the nominal 90 degrees must be accounted for in the system design and link budget, so that any fading due to polarization loss does not jeopardize the minimum receiver sensitivity. System qualification and flight inspection procedures will take into account an allowable variation in phase offset consistent with maintaining the appropriate signal level throughout the GBAS service~~coverage~~ volume. One method of ensuring both horizontal and vertical field strength is to use a single VDB antenna that transmits an elliptically-polarized signal, and flight inspect the effective field strength of the vertical and horizontal signals in the service~~coverage~~ volume.

7.3 Service volume~~Coverage~~

7.3.1 The minimum GBAS service volume~~coverage~~ to support approach services is depicted in Figure D-4. Where practical, it is operationally advantageous to provide valid guidance along the visual segment of an approach. The lateral approach service volume may be different (larger) than the vertical approach service volume. When the additional ephemeris error position bound parameters are broadcast, differential corrections may only be used within the Maximum Use Distance (D_{max}) defined in the Type 2 message. ~~Where practical, it is operationally advantageous to provide valid guidance along the visual segment of an approach.~~ It is also allowable for D_{max} to extend beyond an approach service volume. Reasons why this may be desirable include providing pilots with situational awareness and GBAS status information prior to intercepting the approach procedure, and improving GBAS course capture at the limits of the service volume. In such cases, the potential for reduced protection level, ephemeris bound, and VDB continuity outside the approach service volume shall be considered especially when broadcasting large or unlimited values of D_{max}.

7.3.1.1 If a GBAS installation supports multiple approach service volumes, use of a single omnidirectional data broadcast covering all intended service volumes should be considered to limit complexity, if geographically feasible.

7.3.1.2 In addition, autoland or guided take-off may be used at facilities or runways not intended to support or not currently supporting Category II or III operations using GBAS. Even in Category I or better visual conditions, use of an approved autoland system with GAST C can aid pilots in achieving stabilized approaches and reliable touchdown performance, for Category II or III training, to exercise the airborne system to ensure suitable performance, and for maintenance checks. Use of this capability may also provide pilot workload relief. Similarly, use of an approved guided take-off system will also provide operational benefits. Autoland and guided take-off service volume requirements are contained in CAR-ANS 6.3, 6.3.7.3.5.3.2. VDB reception on the runway surface is significantly affected by the transmit antenna design and its installed height as well as the geography of the airport. Service along all runways at an airport using a single VDB antenna/transmitter location may be difficult. However, where practical, service to support autoland and guided take-off operations shall be provided at suitable runways supporting any precision approach. The approach service volume element of the approach facility designation allows this information to be contained in the AIP (refer to 7.1.4.2.1). A useful autoland capability may be achievable for some aircraft even when the requirements of CAR-ANS 6.3, 6.3.7.3.5.3.2 are not entirely met. Similarly, some aircraft may not be able to conduct automatic landings with only the minimum service volume provided. For approaches with a FAS data path not aligned with the runway centre line, autoland service volume is not required.

7.3.2 An increased signal power (-62.5 dBm) from 36 ft and above, compared to the minimum requirement set for the GBAS service volume at 12 ft above the ground (-72 dBm), is required above the runway surface to accommodate various implementations of airborne VDB antenna. Indeed, VDB antenna height and aircraft implementation loss might not be suitable to meet adequate continuity for autoland under Category III conditions and guided take-off if:

a) aircraft VDB antenna height located above 12 ft may induce more than the expected 15 dB aircraft implementation loss; and

b) aircraft VDB antenna height located below 12 ft may receive a signal power that is below the minimum required value of -72 dBm.

7.3.2.1 To mitigate a lack of adequate VDB link budget, actual aircraft implementation loss (including type of antenna and location of antenna on the fuselage, antenna gain, mismatch loss, cable loss, etc.) and actual receiver sensitivity may be balanced to achieve the expected link budget. The need for additional operational mitigations might be identified and implemented during the aircraft approval process in case of potential loss of VDB along the flight path. It is common practice that a verification flight test is performed by a candidate operator to perform autoland under Category III conditions on a given runway.

7.3.2.2 It is not practical to measure the signal strength at 36 ft. Therefore, two example means of verification are identified below:

- Simplified analysis method: Measure the signal at 12 ft and estimate the signal strength at 36 ft using mathematical tools;

- Complex analysis method: Model the airport configuration and simulate, using a mathematical tool, the signal strength at 12 ft and 36 ft.

Note 1.— There exists an upper limit in the autoland service volume above the runway surface set at 100 ft.

Note 2.— Verification of minimum signal strength at 36 ft is sufficient to ensure compliance above 36 ft.

7.3.2.3 Simplified analysis method.

In order to apply this method, it is assumed the following:

o VDB transmitters are installed above a planar ground with line-of-sight to runways in the desired GBAS service volume as mentioned in Attachment 6D, 7.12.3.

o The analysis methodology consists of:

o Ground subsystem manufacturers and/or service providers perform a generic (non-airport specific) analysis to show that signal strength requirements at both 12 ft and 36 ft can be met based on distance from and height of the VDB antenna at their specific location. Studies have shown that signal strength will increase from the signal strength measured at 12 ft in various airport configurations. When verifying compliance for a specific installation, an acceptable means of compliance is to measure the signal strength at 12 ft and estimate the signal strength by using the following formula:

To estimate the power $P_{h\mathrm{dBm}}$ (in dBm) at a height h (in metres) from the power $P_{h0\mathrm{dBm}}$ at a height $h0$ (in metres), one can use the following expression:

$$P_{h\mathbf{dBm}} = P_{h_0\mathbf{dBm}} + 20\log\left(\sin\left(\frac{2\pi h h_a}{\lambda d}\right)\right) - 20\log\left(\sin\left(\frac{2\pi h_0 h_a}{\lambda d}\right)\right)$$

where

- d is the distance to the transmitter antenna in metres
- h_a is the height of the transmitter antenna phase centre in metres
- $\lambda = c / f$ is the wavelength in metres
- f is the frequency in Hertz
- c is the speed of light

For $h < \frac{\lambda d}{8 h_a}$, the previous formulation can be approximated with an error smaller than 1dB as follows:

$$P_{h\mathbf{dBm}} = P_{h_0\mathbf{dBm}} + 20\log\left(\frac{h}{h_0}\right)$$

Alternatively, converting heights in feet and considering $h_0^{\mathrm{ft}} = 12\mathrm{ft}$, the previous expressions become:

$$P_{h\mathrm{dBm}} = P_{h_0\mathrm{dBm}} + 20\log\left(\sin\left(\frac{0.584\, h^{\mathrm{ft}} h_a^{\mathrm{ft}}}{\lambda d}\right)\right) - 20\log\left(\sin\left(\frac{7 h_a^{\mathrm{ft}}}{\lambda d}\right)\right)$$

and

$$P_{h\mathrm{dBm}} = P_{h_0\mathrm{dBm}} + 20\log\left(h^{\mathrm{ft}}\right) - 21.58\mathrm{dB}$$

The applicability of the above-mentioned formula at different heights above the runway surface may vary with the distance between the VDB transmitter and the intended path on the runway surface and the VDB transmitter antenna height. Some siting constraints may be needed to verify the minimum signal strength is met in the service volume above the runway surface.

7.3.2.4 Complex analysis method.

This method assumes that:

- Airport configuration is so complex that "noise like multipath" (multipath reflections from buildings or aircraft standing or moving) cannot be easily accounted for and must be addressed in the analysis;

and/or

- Line-of-sight between the VDB antenna and runway cannot be maintained.

The analysis methodology consists of:

- The airport configuration includes relevant surfaces such as buildings and metallic fences, and topology of the ground surface is modeled with their electromagnetic characteristics. Radiation pattern of the VDB transmitter antenna is also modeled.

- Signal powers at 12 ft and 36 ft are estimated by simulating radio propagation. One of the acceptable means of the simulation is the ray-tracing method based on geometric optics. Such simulation is available with commercially available software with an intuitive human-machine interface to the airport modeling.

- Effects of small-scale (less than 5-10 wavelengths) structures limit the accuracy of simulation by the ray-tracing method. Therefore, an additional margin to represent such effects may need to be added to the simulation results.

- **The signal power at 12 ft is measured and compared with the simulated one. If the measured and simulated signal powers at 12 ft match well, the simulation can be regarded as being able to model the signal powers at different heights over the runway.**

- **The simulated signal power and the minimum requirement at 36 ft are compared to verify the compliance of the VDB coverage over the runway.**

7.3.~~2~~3 The **service volume**~~coverage~~ required to support the GBAS positioning service is dependent upon the specific operations intended. The optimal **service volume**~~coverage~~ for this service is intended to be omnidirectional in order to support operations using the GBAS positioning service that are performed outside of the ~~precision~~ approach **service**~~coverage~~ volume. Each State is responsible for defining a service **volume** ~~area~~ for the GBAS positioning service and ensuring that the requirements of CAR-ANS 6.3, 6.3.7.2.4 are satisfied. When making this determination, the characteristics of the fault-free GNSS receiver ~~should~~ **shall** be considered, including the reversion to ABAS-based integrity in the event of loss of GBAS positioning service.

7.3.~~3~~4 The limit on the use of the GBAS positioning service information is given by the Maximum Use Distance (D_{max}).~~, which defines the range within which the required integrity is assured and differential corrections can be used for either the positioning service or precision approach. D_{max} also defines the range within which the required integrity is assured for the positioning service~~. D_{max} however does not delineate the coverage area where field strength requirements specified in CAR-ANS 6.3, 6.3.7.3.5.4.4 are **necessarily** met nor matches this area. Accordingly, operations based on the GBAS positioning service can be predicated only in the **service volume**~~coverage area(~~s) (where ~~the field strength~~**performance** requirements are ~~satisfied~~**met**) within the D_{max} range.

7.3.~~4~~5 As the desired **service volume**~~coverage area~~ of a GBAS positioning service may be greater than that which can be provided by a single GBAS broadcast station, a network of GBAS broadcast stations can be used to provide the **service**~~coverage~~. These stations can broadcast on a single frequency and use different time slots (8 available) in neighbouring stations to avoid interference or they can broadcast on different frequencies. Figure D-4A details how the use of different time slots will allow a single frequency to be used without interference subject to guard time considerations noted under Table B-59. For a network based on different VHF frequencies, guidance material in 7.17 should be considered.

7.4 Data structure

A bit scrambler/descrambler is shown in Figure D-5.

Note.— Additional information on the data structure of the VHF data broadcast is given in RTCA/DO-246~~B~~E, GNSS Based Precision Approach Local Area Augmentation System (LAAS) — Signal-in-Space Interface Control Document (ICD).

7.5 Integrity

7.5.1 Different levels of integrity are specified for precision approach operations and operations based on the GBAS positioning service. The signal-in-space integrity risk for ~~Category I~~ approach services is 2×10^{-7} per approach. GBAS ground subsystems that are also intended to support other operations through the use of the GBAS positioning service have to also meet the signal-in-space integrity risk requirement specified for terminal area operations, which is 1×10^{-7}/hour (CAR-ANS 6.3, Table 6.3.7.2.4-1). Therefore, additional measures are necessary to support these more stringent requirements for positioning service. The signal-in-space integrity risk is allocated between the ground subsystem integrity risk and the protection level integrity risk. The ground subsystem integrity risk allocation covers failures in the ground subsystem as well as core constellation and SBAS failures such as signal quality failures and ephemeris failures. For GAST A, B, and C the ~~The~~ protection level integrity risk allocation covers rare fault-free position domain performance risks and the case of failures in one of the reference receiver measurements. In both cases the protection level equations ensure that the effects of the satellite geometry used by ~~the~~ an aircraft fault-free receiver are taken into account. This is described in more detail in the following paragraphs. For GAST D, the position domain integrity is delegated to the aircraft and a FAST D ground subsystem provides additional data and ranging source monitoring for aircraft using this service type.

7.5.1.1 Additional integrity requirements apply for GAST D, which is intended to support precision approach and automatic landing in low visibility conditions with minima less than Category I. The same requirements for bounding the position solution within a protection level that is compared to an alert limit apply, for all error sources except single ground reference receiver faults and errors induced by ionospheric anomalies. Single ground reference receiver faults are mitigated as described in 7.5.11. The responsibility for some errors induced by anomalous ionospheric conditions has been allocated to the airborne equipment. Mitigation of errors due to ionospheric anomalies is described in 7.5.6.1.6. Additional monitoring requirements and design assurance requirements are needed to allow a FAST D GBAS ground subsystem to provide a service that can provide equivalent safety to Category III ILS operations. Some additional monitoring requirements are allocated to the ground subsystem (see 7.5.6.1 to 7.5.6.1.7) and some are allocated to the airborne equipment. The additional monitoring performance requirements for the ground subsystem can be found in Appendix 6B, 3.6.7.3.3.

7.5.1.2 The ground subsystem integrity risk requirement for GAST D (Appendix 6B, section 3.6.7.1.2.1.1.3) limits the probability of a ground subsystem failure resulting in the transmission of erroneous data during a minimum exposure time of "any one landing." Typically the critical period of exposure to failures for vertical guidance in Category III operations is taken to be the period between the Category I Decision Height (200 ft) and the threshold (50 ft height). This is nominally 15 seconds, depending upon the aircraft approach speed. The critical period of exposure to failures for lateral guidance in Category III operations is taken to be the period between the Category I Decision Height and completion of the roll-out, which occurs when the aircraft decelerates to a safe taxi speed (typically less than 30 knots). This is nominally 30 seconds, again depending upon the aircraft approach speed and rate of deceleration. The term "any one landing" is used to emphasize that the time period where faults could occur extends prior to the critical period of exposure. The reason for this is that the fault may develop slowly over time; it could occur earlier in the landing phase and become a hazard during the critical period of exposure.

7.5.1.3 The critical period of exposure to failure for lateral guidance during a guided take-off in low visibility conditions is nominally 60 seconds. Erroneous or loss of guidance during a guided take-off being less critical than for Category III landings, it does not introduce any changes to the ground subsystem integrity requirements.

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7.5.3 The individual error uncertainties described above are used by the receiver to compute an error model of the navigation solution. This is done by projecting the pseudo-range error models to the position domain. General methods for determining that the model variance is adequate to guarantee the protection level integrity risk are described in Section 14. The lateral protection level (LPL) provides a bound on the lateral position error with a probability derived from the integrity requirement. Similarly, the vertical protection level (VPL) provides a bound on the vertical position. For ~~Category I precision approach and APV~~ approach services, if the computed LPL exceeds the lateral alert limit (LAL) or the VPL exceeds the vertical alert limit (VAL), integrity is not adequate to support the selected service type ~~support the operation~~. For the positioning service the alert limits are not defined in the standards, with only the horizontal protection level and ephemeris error position bounds required to be computed and applied. The alert limits will be determined based on the operation being conducted. The aircraft will apply the computed protection level and ephemeris bounds by verifying they are smaller than the alert limits. Two protection levels are defined, one to address the condition when all reference receivers are fault-free (H_0 – Normal Measurement Conditions), and one to address the condition when one of the reference receivers contains failed measurements (H_1 – Faulted Measurement Conditions). Additionally, an ephemeris error position bound provides a bound on the position error due to failures in ranging source ephemeris. For ~~Category I precision approach and APV~~ approach services, a lateral ephemeris error bound (LEB) and a vertical ephemeris error bound (VEB) are defined. For the positioning service a horizontal ephemeris error bound (HEB) is defined.

7.5.3.1 The GBAS signal-in-space integrity risk (Appendix 6B, 3.6.7.1.2.1.1) is defined as the probability that the ground subsystem provides information which when processed by a fault-free receiver, using any combination of GBAS data allowed by the protocols for data application (Appendix 6B, 3.6.5), results in an out-of-tolerance lateral or vertical relative position error without annunciation for a period longer than the maximum time-to-alert. An out-of-tolerance lateral or vertical relative position error is defined as an error that exceeds the GBAS approach services protection level and, if additional data block 1 is broadcast, the ephemeris error position bound. Hence it is the responsibility of the ground subsystem to provide a consistent set of data including the differential corrections, and all parameters that are used by the protocols for data application (e.g, σ_{pr_gnd} and the B values as defined in the Type 1 message), so that the protection levels bound the position error with the required integrity risk. This error bounding process must be valid for any set of satellites that the user might be using. To ensure the computed protection levels actually bound the error with the required probability, it may in some cases be necessary to inflate or otherwise manipulate one or more of the parameters that are used by the protocols for data application. For example, to address the impact of anomalous ionospheric effects one strategy that has been used is to inflate σ_{pr_gnd} and $\sigma_{vert\_iono\_gradient}$ to ensure that airborne equipment that complies with the protocols for data application will be adequately protected.

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7.5.6 *Residual ionospheric errors.* An ionospheric parameter is broadcast in Type 2 messages to model the effects of the ionosphere between the GBAS reference point and the aircraft. This error can be well-characterized by a zero-mean, normal distribution during nominal conditions.

7.5.6.1 *Ionospheric anomalies.* Small scale structures in the ionosphere can result in non-differentially corrected errors in the GBAS position. Such phenomena are typically associated with solar storm activity and may be characterized by steep gradients in the ionospheric delay over a relatively short distance (e.g., a few tens of kilometres). The errors that may be induced by these phenomena result when the airborne receiver and ground subsystem are receiving satellite signals that have different propagation delays. Also, since GBAS uses code-carrier smoothing with a relatively long time constant, biases build up in these filters that are a function of the rate of change of ionospheric delay. If the ground subsystem and airborne receivers experience significantly different delays and rates of change of the ionospheric delays, the biases that build up in these filters will not match and will not be cancelled by the differential processing.

7.5.6.1.1 *Ionospheric anomaly mitigation.* Ionospheric anomalies can produce position errors which are significant (i.e. tens of metres) in the context of approach operations. To mitigate these errors, different strategies are used depending on the GBAS approach service type.

7.5.6.1.2 *Ionospheric anomaly mitigation for GAST A, B and C.* For GAST A, B or C, the ground subsystem is responsible for mitigating the potential impact of ionospheric anomalies. This may be handled through various monitoring schemes (e.g. far-field monitors or integration with a wide area ground network supporting SBAS) which detect the presence of ionosphere anomalies and deny service if the resulting user position errors would be unacceptable. One means to deny service is to inflate some combination of the broadcast integrity parameters: σ_{pr_gnd}, $\sigma_{vert\_iono\_gradient}$, the ephemeris decorrelation parameter (P), the ephemeris missed detection parameters $K_{md\_e,GPS}$ and $K_{md\_e\_,GLONASS}$ such that any geometry that could be used by an airborne user will not be subjected to intolerably large errors (given the intended operational use). This inflation scheme could also be used without the complexity of monitoring the ionosphere during operations by assuming ionosphere anomalies are present. In this case, a model of the possible ionosphere conditions that could occur is used to determine the proper values of the broadcast integrity parameters. Since the extremes of ionosphere conditions vary significantly through the world, the model is location dependent. Such an inflation scheme results in a reduction in availability because it inflates the values even when anomalies are not present.

7.5.6.1.3 *Ionospheric anomaly mitigation for GAST D.* Requirements for monitoring and geometry screening in the airborne equipment have been introduced for GAST D to mitigate the potential impact of ionospheric anomalies. The airborne monitoring consists of monitoring the code-carrier divergence continuously in order to detect large gradients in the ionosphere. In addition, the airborne equipment will screen geometries to ensure that an unacceptably large amplification of residual pseudo-range errors (i.e. errors that may exist after airborne monitoring has been applied) will not occur. Another factor which is useful for the mitigation of errors induced by ionospheric anomalies is the use of the 30-second carrier smoothed pseudo-ranges in a position solution. (The shorter time constant smoothing is inherently less susceptible to filter bias mismatch errors.) Finally, GAST D includes parameters: $K_{md\_e\_D,GLONASS}$, $K_{md\_e\_D,GPS}$, P_D and $\sigma_{vert\_iono\_gradient\_}$ respectively, when the active service type is GAST D. This is done so that if the ground subsystem employs inflation of the parameters $K_{md\_e\_,GLONASS}$, $K_{md\_e,GPS}$, P, and $\sigma_{vert\_iono\_gradient}$ to mitigate the effects of ionospheric anomalies for GAST A, B or C, the GAST D user can be provided with non-inflated parameters for use in GAST D where airborne monitoring is employed to address the ionospheric anomaly errors. This enables GAST D service to have improved availability.

7.5.6.1.4 *Bounding of ionospheric anomaly errors.* As stated above, ionospheric anomalies may be addressed by inflating one or more of the parameters: σ_{pr_gnd}, $\sigma_{vert\_iono\_gradient}$, the ephemeris decorrelation parameter (P), the ephemeris missed detection parameters $K_{md\_e,GPS}$ and $K_{md\_e,GLONASS}$. The ground subsystem is responsible for providing values in these parameters such that the error is appropriately bounded by the VPL and HPL computations at the output of a fault free receiver. In GAST D, responsibility for mitigation of errors due to anomalous ionospheric conditions has been divided between the airborne subsystem and the ground subsystem. Although GAST D still requires the protection levels to bound the errors (as described in 7.5.3.1), they are not required to bound the errors that result from an anomalous ionospheric event as is the case for GAST C. Hence, the protection levels as computed with P_D, $K_{md\_e\_D,GLONASS}$, $K_{md\_e\_D,GPS}$, and $\sigma_{vert\_iono\_gradient\_D}$ must bound the error for all error sources as discussed in 3.6.7.1.2.1.1.2 except for the errors due to anomalous ionospheric conditions. The protections level computations must bound the nominal ionospheric errors.

7.5.6.1.5 *Dual solution ionospheric gradient monitoring.* Another component of the airborne mitigation of errors induced by ionospheric anomalies is by the use of dual position solutions computed simultaneously with two different carrier smoothing time constants (see 7.19.3). This dual solution computation has two purposes. Firstly, taking the difference of two corrected pseudo-range measurements as detection statistics allows the filter build-up errors on each satellite, due to large differences in ionospheric gradients between the ground measurements and airborne measurements, to be directly observable. Hence a threshold can be applied to these detection statistics in order to detect a large portion of the ionospheric anomalies. The second application of the dual solutions is to compute a bound for the 30-second smoothed position (excluding the impact of ionospheric anomalies). The data provided by the ground segment allows a protection level bound to be computed for the 100-second solution. By adding the direct observation of the magnitude of the difference between the 30-second smoothed position and the 100-second smoothed position, to the protection level computation, a protection level is obtained, which is guaranteed to bound the 30-second position solution with the required $1x10^{-7}$/approach. This allows airborne equipment, with an active service type of D to provide equivalent bounding performance, as required for approaches to Category I minima even though the 30-second solution is used to develop the guidance.

7.5.6.1.6 *Requirements for FAST D ground subsystems to support mitigation of errors caused by ionospheric anomalies.* Although much of the responsibility for mitigation of ionospheric errors is allocated to the airborne segment, there is a requirement for FAST D ground subsystems that is necessary to support mitigation of such effects. Appendix 6B, 3.6.7.3.4 specifies that the ground subsystem is responsible for ensuring mitigation of ionospheric spatial delay gradients. The ground subsystem ensures that the value of the maximum corrected pseudo-range error (E_{IG}) computed from the Type 2 data does not exceed 2.75 metres at all LTPs associated with runways that support GAST D procedures. One option available to the manufacturer is to restrict the distance between the GBAS reference point and the LTP.

7.5.6.1.7 *Ionospheric anomaly threat models used for GAST D validation.* As discussed above, the mitigation of errors that could be induced by ionospheric anomalies is accomplished through a combination of airborne and ground system monitoring. The effectiveness of the required monitoring has been demonstrated through simulation and analysis and the maximum errors at the output of the monitoring have been shown to be consistent with airworthiness certification criteria for a range of anomalies described below. This range of anomalies is described in terms of a "standard threat space" consisting of an ionospheric anomaly model which defines physical attributes of the ionospheric anomaly. The model described in 7.5.6.1.7.1 is a conservative rendition of the model developed for the continental United States. This model has been shown to bound the ionospheric threat evaluated in several other mid-latitude regions, relative to the magnetic equator. Recent data collected in some low-latitude regions, relative to the magnetic equator, has shown ionospheric conditions associated with local ionospheric density depletion ("plasma bubbles") that exceed this threat model. Research has resulted, for example, in a reference low-latitude threat model for the Asia-Pacific Region by a dedicated Ionospheric Studies Task Force (APAC ISTF). The threat models define an ionospheric environment for which the standardized monitoring is known to produce acceptable performance on a per-pseudo-range basis. Each service provider shall evaluate whether the standard threat space model described below is appropriate for the ionospheric characteristics in the region where GBAS is intended to support GAST D service. This evaluation shall always be performed, regardless of the latitudes involved. If a service provider determines that the ionospheric behaviour is not adequately characterized by this threat model (e.g., for a region of uniquely severe ionospheric behaviour), that service provider must take appropriate action to ensure the users will not be subjected to ionospheric anomalies with characteristics outside the range of the standard threat space. The service provider may elect to:

1. alter the characteristics of its ground subsystem; and/or

2. introduce additional monitoring (internal or external to the GBAS); and/or

3. introduce other operational mitigations that limit users' exposure to the extreme ionospheric conditions.

Potential ground subsystem changes which could achieve this risk reduction include tighter siting constraints (see 7.5.6.1.6) and improved ground subsystem monitoring performance (Appendix 6B, 3.6.7.3.4). Another mitigation strategy is monitoring of space weather (external to the GBAS system) in conjunction with operational limitations on the use of the system during predicted periods of severely anomalous ionospheric activity. Combinations of these strategies may be used to ensure that the GAST D user is not subjected to ionospheric anomalies outside the standard threat space.

7.5.6.1.7.1 *Ionosphere anomaly model: moving wedge.* This models a severe ionospheric spatial gradient as a moving wedge of constant, linear change in slant ionosphere delay, as shown in Figure D-11. The key parameters of this model are the gradient slope (g) in mm/km, the width (w) of the wedge in km, the amplitude of the change in delay (D) in m, and the speed (v) at which the wedge moves relative to a fixed point on the ground. These values are assumed to remain (approximately) constant over the period in which this wedge affects the satellites tracked by a single aircraft completing a GAST D approach. While the width of the wedge is small, the "length" of the wedge in the East-North coordinate frame (i.e. how far the "ionospheric front" containing the wedge extends) is not constrained.

In this model, the upper bound on g is dependent on wedge speed as specified in Table D-5A. This value is not dependent on satellite elevation angle. Because g is expressed in terms of slant delay, no "obliquity" correction from zenith delay is needed. The width w can vary from 25 to 200 km. The maximum value of D is 50 m. Note that, to make the model consistent, D must equal the product of slope g and width w. In cases where slope and width each fall within their allowed ranges, but their product D exceeds the 50-metre bound, that combination of slope and width is not a valid point within the threat model. For example, both $g = 400$ mm/km and $w = 200$ km are individually allowed, but their product equals 80 metres. Since this violates the constraint on D, a wedge with $g = 400$ mm/km and $w = 200$ km is not included in this threat model.

Note.— In the GAST D validation, it was assumed that each simulated wedge model is applied to the two ranging sources that produced the worst-case position errors. However, the numbers of wedges and impacted ranging sources depend on the ionospheric characteristics in the region where GBAS is intended to support GAST D service.

Table D-5A Upper bound on gradient slope

Propagation speed (v)	Upper bound on gradient slope (g)
$v < 750$ m/s	500 mm/km
$750 \le v < 1500$ m/s	100 mm/km

7.5.6.1.8 *Ionosphere gradient mitigation validation*

7.5.6.1.8.1 Because the mitigation responsibility for spatial ionosphere gradients is shared between the airborne and ground subsystems, this section includes guidance for modeling the critical airborne components (e.g. aircraft motion and monitoring) which will enable a ground manufacturer to validate the mitigation of spatial ionosphere gradients from a total system perspective. The validation can take into account the combination of ground and airborne monitors for the detection of gradients. When accounting for the combination of monitors, the correlation or independence between the monitors needs to be considered. Monitor performance shall also consider the effective time between independent samples of each monitor's test statistic. Modeling of the ionosphere monitoring should include re-admittance criteria for an excluded satellite, as appropriate per the ground subsystem design and DO-253D.

7.5.6.1.8.2 This section also includes test scenario guidance to help ensure all possible airborne position, ground reference point, approach direction, and gradient direction orientations are considered during validation.

7.5.6.1.8.3 *Airborne monitor implementation*

Validation may account for the following airborne monitors:

a) airborne code carrier divergence filtering as described in 2.3.6.11 of DO-253D;

b) differential RAIM used for satellite addition as described in 2.3.9.6.1 of DO-253D; and

c) dual solution pseudo-range ionospheric gradient monitoring as described in 2.3.9.7 of DO-253D.

7.5.6.1.8.3.1 In assessing the probability of missed detection, the contribution of all noise sources to the test statistic used for the airborne code carrier divergence monitor, excluding the effects of the ionosphere, can be assumed to have a normal distribution with a zero mean and a standard deviation of 0.002412 m/s.

7.5.6.1.8.3.2 In assessing the probability of missed detection, the contribution of all noise sources to the test statistic used for the dual solution pseudo-range ionospheric gradient monitor can be assumed to have a normal distribution with a zero mean and a standard deviation of 0.1741 m.

7.5.6.1.8.3.3 Note that the prior probability of the gradient that can be utilized during validation of 3.6.7.3.4 applies for these airborne monitors as well.

7.5.6.1.8.4 *Modeling airborne positioning and speed*

The airborne speed and position can be modeled working backward from the threshold crossing time using the following four values:

a) speed at landing;

b) amount of time at landing speed;

c) deceleration rate; and

d) speed at start of deceleration.

7.5.6.1.8.4.1 Figure D-12 illustrates how these four values are used to define a speed profile and Table D-5B shows the values that define the family of curves to be used in determination of GAST D broadcast parameters for a specific IGM design.

Table D-5B. Airborne speed profile from initial position to LTP

Landing ground speed	Time at landing speed (seconds)	Decelerations rate (knots/s)	Ground speed at start of deceleration (knots)
161	50	1.1	290
148	50	1.1	277
135	50	1.1	264

Note.— Modeling aircraft altitude is not necessary.

7.5.6.1.8.4.2 Figure D-13 shows the approach speed profiles based on the values in Table D-5B in terms of ground speed versus time until the aircraft reaches the landing threshold point.

7.5.6.1.8.5 *Gradient, airborne position, ground reference point, and approach direction considerations*

7.5.6.1.8.5.1 Figure D-14 illustrates the basic anomalous ionospheric scenarios (A-D) that constitute a threat. For a given ground station installation, the ground manufacturer ~~should~~ shall demonstrate valid mitigation for any ionosphere gradient/airborne/approach orientations corresponding to that particular installation.

7.5.6.1.8.5.2 Validation test scenarios shall also address the timing component for each orientation. For example, for a given scenario, an approach shall be executed at least at one minute intervals.

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7.5.9 *Ephemeris error uncertainty*. Pseudo-range errors resulting from ephemeris errors (defined as a discrepancy between the true satellite position and the satellite position determined from the broadcast data) are spatially decorrelated and will therefore be different for receivers in different locations. When users are relatively close to the GBAS reference point, the residual differential error due to ephemeris errors will be small and both the corrections and uncertainty parameters σ_{pr_gnd} sent by the ground subsystem will be valid to correct the raw measurements and compute the protection levels. For users further away from the GBAS reference point, protection against ephemeris failures can be ensured in two different ways:

a) the ground subsystem does not transmit the additional ephemeris error position bound parameters. In this case, the ground subsystem is responsible for assuring integrity in case of satellite ephemeris failures without reliance on the aircraft calculating and applying the ephemeris bound. This may impose a restriction on the distance between the GBAS reference point and the decision altitude/height depending upon the ground subsystem means of detecting ranging source ephemeris failures. One means of detection is to use satellite integrity information broadcast by SBAS; ~~and~~or

b) the ground subsystem transmits the additional ephemeris error position bound parameters which enable the airborne receiver to compute an ephemeris error bound. These parameters are: coefficients used in the ephemeris error position bound equations ($K_{md\_e\_()}$, where the subscript () means either "GPS", "GLONASS", "POS, GPS" or "POS, GLONASS"), ~~the maximum use distance for the differential corrections (D_{max})~~, and the ephemeris decorrelation parameters (P). The ephemeris decorrelation parameter (P) in the Type 1 or Type 101 message characterizes the residual error as a function of distance between the GBAS reference point and the aircraft. The value of P is expressed in m/m. The values of P are determined by the ground subsystem for each satellite. One of the main factors influencing the values of P is the ground subsystem monitor design. The quality of the ground monitor will be characterized by the smallest ephemeris error ~~(or minimum detectable error (MDE))~~ that it can detect. The relationship between the P parameter and the ~~MDE~~ smallest detectable error ε_{ephdet} for a particular satellite, i, can be approximated by $P_i = \varepsilon_{ephdet}$ ~~MDE_i~~$/R_i$ where R_i is the smallest of the predicted ranges from the ground subsystem reference receiver antenna(s) for the period of validity of P_i. ~~Being dependent on satellite geometry geometry~~ Since R_i varies with time, the P parameters values ~~are slowly varying~~ are time dependent as well. However, it is not a requirement for the ground subsystem to dynamically vary P. Static P parameters ~~could~~ can be sent if they properly ensure integrity. In this latter case, the availability would be slightly degraded. Generally, as ~~MDE~~ ε_{ephdet} becomes smaller, overall GBAS availability improves.

7.5.10 *Ephemeris error/failure monitoring.* There are several types of monitoring approaches for detecting ephemeris errors/failures. They include:

a) *Long baseline.* This requires the ground subsystem to use receivers separated by large distances to detect ephemeris errors that are not observable by a single receiver. Longer baselines translate to better performance in ~~MDE~~ smallest detectable error;

b) *SBAS.* Since SBAS augmentation provides monitoring of satellite performance, including ephemeris data, integrity information broadcast by SBAS can be used as an indication of ephemeris validity. SBAS uses ground subsystem receivers installed over very long baselines, therefore this provides optimum performance for ephemeris monitoring and thus makes small errors detectable ~~achieves small MDEs~~; ~~and~~

c) *Ephemeris data monitoring.* This approach involves comparing the broadcast ephemeris over consecutive satellite orbits. ~~There is an assumption~~ This monitoring assumes that the only threat of failure is due to a failure in the ephemeris upload from the constellation ground control network so that the ephemeris is inconsistent with previously broadcast ephemeris; and

d) *Delta-V (change in velocity) monitoring.* ~~Failures due to~~This monitoring covers the cases of uncommanded satellite manoeuvres out of view with unchanged ephemeris~~must be sufficiently improbable to ensure that this approach provides the required integrity.~~

7.5.10.1 The monitor design (for example, its ~~achieved MDE~~ smallest detectable error) is to be based upon the integrity risk requirements and the failure model the monitor is intended to protect against. A bound on the GPS ephemeris failure rate can be determined from the reliability requirements defined in CAR-ANS 6.3, 6.3.7.3.1.3, since such an ephemeris error would constitute a major service failure.

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7.5.11 *Ground reference receiver faults.* A typical GBAS ground subsystem processes measurements from 2 to 4 reference receivers installed in the immediate vicinity of the reference point. ~~The~~ For GAST A, B, C and D, the aircraft receiver is protected against a large error or fault condition in a single reference receiver by computing ~~and applying~~ a protection level based on the B parameters from the Type 1 or Type 101 message ~~to compare data from the various reference receivers~~ and comparing that protection level to the alert limit. Ground subsystem compliance with the GAST A, B, C and D integrity risk (Appendix 6B, 3.6.7.1.2.2.1) is demonstrated taking into account the protocols required of the airborne subsystem (Appendix 6B,3.6.5.5.1.2) and explicit monitoring required in the airborne subsystem. Alternative system architectures with sufficiently high redundancy in reference receiver measurements may employ processing algorithms capable of identifying a large error or fault in one of the receivers. This may apply for a GRAS network with receivers distributed over a wide area and with sufficient density of ionospheric pierce points to separate receiver errors from ionospheric effects. The integrity can then be achieved using only the protection levels for normal measurement conditions (VPL_{H0} and LPL_{H0}), with appropriate values for K_{ffmd} and σ_{pr_gnd}. This can be achieved using the Type 101 message with the B parameters excluded.

7.5.11.1 *GAST D ground reference receiver faults.* For GAST D, there is an additional standardized monitor implemented in the airborne receiver used to maintain the single reference receiver faulted measurement condition integrity regardless of the satellite geometry used in the aircraft. The aircraft receiver computes a position error estimate based on the B parameters and compares that error estimate directly to a threshold set as low as possible consistent with acceptable continuity risk. Although the monitor is mechanized in the airborne subsystem, the ground subsystem must meet specific requirements for the monitor to provide the required protection. The integrity performance depends on the assumed a priori failure rate (Appendix 6B, 3.6.7.1.2.2.1.2) and the probability of missed detection of the monitor. The a priori rate of a single reference receiver providing faulted measurements is required to be less than 1×10^{-5} per 150 seconds. The rate per individual receiver is dependent upon the number of reference receivers in the ground subsystem. For example, with four reference receivers the rate per receiver would be required to be less than 2.5×10^{-6} per 150 seconds. This a priori rate is achieved through a combination of receiver design requirements and proper reference receiver siting and operational constraints. Because conditions during system operation vary, ground subsystems may monitor receiver outputs to verify continued compliance with the requirement. The integrity performance also depends on the probability of missed detection (P_{md}) performance of the monitor implemented in the airborne equipment. The P_{md} performance of this monitor in turn depends on the characteristics of the errors that confound the observability of a reference failure. This is also true for the existing protection level integrity risk equations associated with faulted measurement conditions. The ground subsystem is required to broadcast integrity parameters that bound the errors such that a normal distribution can sufficiently characterize the errors and the P_{md} can be estimated (Appendix 6B, 3.6.7.1.2.2.1.1 and 3.6.7.2.2.4.1).

7.5.11.2 *GAST D ground reference receiver fault magnitude bounding.* Because the airborne subsystem implements the monitor as defined in the MOPS, it is possible to compute the size of the largest error that can result from the failure of a single reference receiver with a probability of greater than 1×10^{-9}. The calculated maximum size of the error will depend on the assumed a priori failure rate (Appendix 6B, 3.6.7.1.2.2.1.1) and the probability of missed detection of the monitor. The monitor P_{md} is dependent on the monitor threshold which is computed by the airborne equipment as a function of the geometry and the error distribution associated with the H_1 hypothesis.

7.5.12 *Range domain monitoring requirements for GAST D.* To support equivalent safety of Category II/III operations, requirements beyond the basic "signal-in-space" requirements defined for GAST A, B and C are necessary. These requirements include performance requirements for monitors implemented to detect pseudo-range errors. Two requirements apply to the post monitoring error in the corrected pseudo-range due to specific ranging source failures (Appendix 6B, 3.6.7.3.3.2 and 3.6.7.3.3.3). In both cases, the requirement applies to the probability of missed detection as a function of the size of an error due to the failure in the 30-second smoothed pseudo-range after the correction is applied.

1) The first requirement constrains the P_{md} performance of the specified ranging source failures without regard for the a priori probability of the ranging source failure. The bound for a ground subsystem's monitor performance defined in Appendix 6B, 3.6.7.3.3.2 is illustrated in Figure D-15. GAEC-D equipment will use the 30-second differential corrections to form the position solution used for deviation guidance. The limits of the constraint region define the minimum P_{md} that the ground subsystem must ensure for any single ranging source failure condition.

Note.— The example compliant P_{md} in Figure D-15 is based on a hypothetical monitor with a threshold set to 0.8 m and monitor noise of 0.123 m. The curve is for illustration purposes only and does not represent the performance of any specific monitor design.

2) The second requirement constrains the conditional probability of the P_{md} performance of the specified ranging source given the a-priori failure probability for the specific ranging source failure. The conditional probability bound, $P_{md} \times P_{apriori}$, for a ground subsystem's monitor performance defined in Appendix 6B, 3.6.7.3.3.3 is illustrated in Figure D-16. The prior probability of each ranging source failure ($P_{apriori}$), used to evaluate compliance, shall be the same value that is used in the analysis to show compliance with the bounding requirements for FAST C and D (see 7.5.3.1).

7.5.12.1 *Verification of ground subsystem compliance with range domain monitoring requirements*

Verifying that a ground system design complies with the monitor requirements provided in Appendix 6B, 3.6.7.3.3.2 and 3.6.7.3.3.3 is achieved by a combination of testing and analysis. The requirements take the form of a constraint on the probability of missed detection as a function of the size of an error in the corrected pseudo-range. The general process that may be used to verify that a specific monitor, included as part of a ground subsystem design, meets the specified performance is as follows:

• Identify the threat space for each fault mode to be considered. (The requirements in section Appendix 6B, 3.6.7.3.3 apply to four specific fault modes). These fault modes (i.e. the threat space), which may be used for evaluating compliance with a ground subsystem design, are provided in 7.5.12.1.3.1 through 7.5.12.1.3.4. These fault modes and fault combinations constitute the threat space. These threat space definitions represent what at least one State has found acceptable as an assumed threat space for each fault mode.

• Identify the airborne configuration space. The airborne system requirements introduce constraints on the design and performance of airborne equipment. These constraints define the range of critical airborne parameters of the configuration space for each fault mode and/or monitor that must be protected by the ground subsystem. For example, the bandwidth and correlator spacing of a compliant airborne receiver will conform to the requirements in sections 8.11.4 through 8.11.7.1. These are two of the critical parameters of the airborne configuration space for the satellite signal deformation fault mode. A critical airborne parameter directly influences how each point in the threat space translates to an error in the differentially corrected pseudo-range.

• An error analysis is done considering the specific monitor design under consideration given the full range of fault characteristics that comprise the threat space. For each characterized fault, the error that would be induced in the corrected pseudo-range (using the 30-second smoothed pseudo-ranges and pseudo-range corrections) is computed given the full range of critical airborne parameters that comprise the airborne configuration space.

• When assessing the compliance of a ground subsystem design, the performance is characterized by relevant statistical measures. Any monitor is subject to noise and therefore the performance may be characterized by the false detection rate and the missed detection probability. Both of these performance metrics are specified in the ground requirements in Appendix 6B by means of a not-to-exceed constraint. The missed detection probability performance is constrained by the requirements in Appendix 6B, 3.6.7.3.3.2 and 3.6.7.3.3.3. The false detection rate performance is constrained by the continuity requirements given in Appendix 6B, 3.6.7.1.3.2. It shall be understood that the ground subsystem must meet all requirements i the Standards. It is possible that the performance of individual monitors may be further constrained by other requirements, such as the ground subsystem integrity risk requirement in Appendix 6B, 3.6.7.1.2.1.1.1. Ground station accuracy performance may have an impact on airborne and ground monitor performance. In the validation of requirement feasibility a GAD C4 performance was assumed to account for instance for single reference receiver faults. Use of lower performance categories may have an availability or continuity impact and shall be investigated in the design process.

7.5.12.1.1 *Compliance of ground subsystem monitoring with continuity requirements.* The compliance with the false detection rate (continuity) may be established based on collected real data combined with analysis and/or simulation. The required number of truly independent samples shall be sufficient to adequately characterize the cumulative distribution function (CDF) of the monitor discriminator, which is compared to the threshold set for the monitor. The fault free noise CDF must be such that for the threshold set in the monitor the false detection probability is smaller than that required to support continuity. An allocation of the continuity to each monitor must be done with consideration given to the overall specified probability of false detection (Appendix 6B, 3.6.7.1.3.2). The achieved probability of false detection is determined by extrapolation of the observed trends in the measured CDF. Additionally, detection events in the ground system may be logged and if, over time, the false detection rates are not maintained at the required levels, thresholds may be adjusted as the result of a maintenance action to correct the problem.

7.5.12.1.2 *Compliance of ground subsystem monitoring with integrity requirements*. The compliance with the missed detection probability (integrity risk) is typically established based on simulation and analysis. (Given the low allowed probability of observing actual faults, collection of enough real data to establish that the probability is met with any statistical significance is impossible.) The threat space for the fault mode is divided into discrete intervals across the relevant parameters that define the fault behavior. The total space of potential faults is represented by a multidimensional grid of discrete points that span the threat space. The airborne configuration space is also discretized i.e. represented by a multidimensional grid of discrete (critical parameter) points. A simulation is used to compute the expected pseudo-range error performance for each point in the threat space, each possible airborne configuration and the ground receiver function with the monitors. The worst-case error in the corrected pseudo-range is computed as a function of the discriminator value for the monitor addressing the threat (assuming no noise at this point). This also makes it possible to determine the discriminator value as a function of the worst-case error in the corrected pseudo-range (the inverse mapping). The missed detection probability is obtained by superimposing noise based on a conservative noise model (using an over bound of the CDF that was generated by the real data), on the discriminator determined from the worst-case differential range. This can be done either analytically or by simulation. The mapping from discriminator to worst-case error in the corrected pseudo-range and the noise levels applied may have further dependencies (for instance satellite elevation), and the established missed detection probability is therefore also a function of a set of parameters that constitute the detection parameter space which is divided into discrete intervals as well, i.e. represented by a multidimensional grid of discrete (detection parameter) points. The final missed detection probability is obtained by searching for the worst case when evaluating all the grid points in the detection parameter space.

7.5.12.1.3 *Threat space and relevant airborne configuration space for each fault mode*

7.5.12.1.3.1 *Code carrier divergence threat*

7.5.12.1.3.1.1 The code carrier divergence threat is a fault condition in a GPS satellite that causes the code and carrier of the broadcast signal to diverge excessively.

7.5.12.1.3.1.2 A code carrier divergence fault may cause a differential ranging error in one or both of the following cases: (1) the aircraft and ground filter designs are not identical, and (2) the aircraft and ground filters start at different times. Both of these cases can result in a difference between the transient responses of the filters in the presence of a CCD event. The critical airborne parameters are:

— The time of initialization of the airborne smoothing filter relative to the fault onset.

— The smoothing filter type (fixed time constant 30 seconds or adjustable time constant equal to time from initialization up to 30 seconds and thereafter fixed).

— The carrier code divergence rate monitoring required in airborne system for GAST D and the associated fault reaction.

— The time period from initialization of the airborne smoothing filter to the incorporation of the measurement in the position solution.

7.5.12.1.3.2 *Excessive acceleration threat*

The excessive acceleration threat is a fault condition in a GPS satellite that causes the carrier (and code in unison) of the broadcast signal to accelerate excessively. The threat space is one-dimensional and corresponds to all possible accelerations including ramps and steps.

7.5.12.1.3.3 *Ephemeris error threat*

The ephemeris error threat is a fault condition that causes the broadcast ephemeris parameters to yield excessive satellite position errors perpendicular to the ground subsystem's line of sight to the satellite. The resultant differential range error is the satellite position error (true compared to broadcast ephemeris) multiplied by the distance between ground subsystem and airborne and scaled by the inverted distance to the satellite. It is bounded by the product of the P parameter (see 7.5.9) and the distance between the user and the ground subsystem. The critical airborne parameter for the ephemeris error threat is therefore the distance between the user and the ground subsystem. Satellite ephemeris faults are categorized into two types, A and B, based upon whether or not the fault is associated with a satellite manoeuvre. There are two subclasses of the type A fault, A1 and A2.

7.5.12.1.3.3.1 *Ephemeris error threat type B*

7.5.12.1.3.3.1.1 The type B threat occurs when the broadcast ephemeris data is anomalous, but no satellite manoeuvre is involved.

7.5.12.1.3.3.1.2 The GBAS ground subsystem can monitor against such faults by comparing current and prior ephemerides. One example of a type B fault: no manoeuvre occurs, an incorrect upload is sent to a satellite, and the satellite subsequently broadcasts an erroneous ephemeris.

7.5.12.1.3.3.2 *Ephemeris error threat type A1*

7.5.12.1.3.3.2.1 The type A1 threat occurs when the broadcast ephemeris data is anomalous following an announced and intentional satellite manoeuvre.

7.5.12.1.3.3.2.2 Prior ephemerides are of limited use in the detection of type A1 failures because of the intervening manoeuvre. The GBAS ground subsystem will need to monitor ranging data directly as part of ephemeris validation. One example of a type A1 fault: a satellite is set unhealthy, a manoeuvre is executed, an incorrect upload is sent to the satellite, the satellite is reset to healthy and subsequently broadcasts an erroneous ephemeris.

7.5.12.1.3.3.3 *Ephemeris error threat type A2*

7.5.12.1.3.3.3.1 The type A2 threat occurs when the broadcast ephemeris data is anomalous following an unannounced or unintentional satellite manoeuvre.

7.5.12.1.3.3.3.2 Prior ephemerides are of limited use in the detection of type A2 failures because of the intervening manoeuvre. The GBAS ground subsystem will need to monitor ranging data directly as part of ephemeris validation. One example of a type A2 fault: a satellite is set healthy, an intentional manoeuvre or unintentional thruster firing occurs, and the satellite continues to broadcast the pre-manoeuvre (now erroneous) ephemeris.

7.5.12.1.3.4 *Signal deformation threat*

7.5.12.1.3.4.1 The signal deformation threat is a fault condition in the GPS satellite that causes the broadcast C/A code to be distorted so that the correlation peaks used for tracking in the airborne system and the ground system are deformed. The extent of the deformation depends on the receiver bandwidth and the resulting tracking error depends on where the correlator points used for code tracking are located (along the correlator peak).

7.5.12.1.3.4.2 The signal deformation monitoring threat space is defined in section 8. There are three fault types A, B, C.

7.5.12.1.3.4.3 Most satellites naturally show some degree of correlator peak deformation and these are referred to as natural (correlator measurement) biases. These natural biases may vary over time.

7.5.12.1.3.4.4 A fault condition (onset) will appear as a step in the raw (unfiltered) code measurement both in the airborne system and in the ground. If both system had exactly the same front end (RF and IF filtering, sampling method), correlator type and correlator spacing the error would be the same in ground and air and no differential error would occur. But typically that is not the case.

7.5.12.1.3.4.5 The step is filtered by the smoothing algorithm in the ground and in the airborne systems and the steady state differential error will gradually manifest itself in a 60 – 90 second time frame when using corrections from message type 11 (or 200 – 300 seconds for message type 1).

7.5.12.1.3.4.6 If a fault (A, B or C) occurs in a satellite it will take about 60 – 90 seconds before the steady state for the error and the monitor discriminator is reached. In essence the fault onset starts a race between the increasing differential error and the monitor discriminator as it moves towards the threshold. This is referred to as the transient state. If the range error reaches the limit that must be protected while the discriminator is not yet past the threshold with sufficient margin to guarantee the required detection probability, the requirement is not met. Both the steady state and the transient state performance must be evaluated.

7.5.12.1.3.4.7 The critical airborne parameters for the signal deformation threat are:

• The time period from initialization of the airborne smoothing filter to incorporation of the measurement in the position solution.

• The parameters that have constraints defined in the GAST D standard (Attachment B) including:

  o Correlator type Early-Late (EL) or Double Delta (DD)

  o Correlator spacing

  o GPS signal bandwidth (from reception at antenna through RF, IF, and A/D conversion)

• Group delay (from reception at antenna through RF, IF, and A/D conversion).

7.5.12.1.3.4.8 Apart from the discrete choice of EL versus DD the configuration space is two-dimensional (correlator spacing and bandwidth). The filters implemented in the airborne system may be of different types (Butterworth, Chebychev, Elliptical, etc.). The group-delay constraints will exclude some of these filters. However the possible variation in receiver design introduces additional dimensions that the ground subsystem manufacturer must consider. The filter types are part of the configuration space to be considered.

7.5.13 *Ground subsystem requirements and airworthiness performance assessment.* Airworthiness certification of autoland systems, for use in Category II/III operations, requires an assessment of landing performance under fault-free and faulted conditions. More information, describing how the technical standards can be used to support an assessment, may be found in RTCA document DO-253D, "Minimum Operational Performance Requirements for Airborne Equipment using the Local Area Augmentation System" Appendix J".

7.5.14 *GBAS signal-in-space time-to-alert.* The GBAS signal-in-space time-to-alert (SIS TTA) is defined below within the context of GBAS based upon the TTA definition in CAR_ANS 6.3, section 6.3.7.1. The GBAS SIS TTA is the maximum allowable time elapsed from the onset of an out-of-tolerance condition at the output of the fault-free aircraft GBAS receiver until the aircraft GBAS receiver annunciates the alert. This time is a never-to-be-exceeded limit and is intended to protect the aircraft against prolonged periods of guidance outside the lateral or vertical alert limits.

7.5.14.1 There are two allocations made to support the GBAS SIS TTA in the Standards.

1) The first allocation, the ground subsystem TTA for SIS requirements, limits the time it takes the ground subsystem to provide an indication that it has detected an out-of-tolerance situation considering the output of a fault-free GBAS receiver. The indication to the aircraft element is either: a) to broadcast Type 1 (and Type 11 if broadcast) or Type 101 messages indicating the condition (in accordance with Appendix 6B, 3.6.7.3.2.1), or b) terminate all VDB transmissions. The ground subsystem is allocated 3 seconds to take either action.

For airborne receivers using GAST C, at least one Type 1 message signaling the out-of-tolerance condition must be received by a fault-free airborne receiver within the message time out to meet the SIS TTA. For airborne receivers using GAST D at least one of each (Type 1 and Type 11) message with the same applicable modified z-count (and the same set of satellites) must be received by a fault-free airborne receiver within the message time out to meet the SIS TTA. Because shutting down the VDB may result in an exposure time longer than the SIS TTA for satellite faults, this option is recommended only under conditions where the VDB transmission does not meet its associated performance requirements (reference Appendix 6B, 3.6.7.3.1.1.).

In addition, for ground subsystems that support GAST D monitoring performance requirements, the ground subsystem is allocated only 1.5 seconds to detect a condition producing out-of-tolerance errors in 30-second corrected pseudo-ranges and to either exclude the ranging source measurements from the broadcast or mark them as invalid. This time-to-detect and broadcast is similar in definition, but not equivalent in function to the ground subsystem TTA, as an out-of-tolerance condition in a single ranging source does not necessarily lead to out-of-tolerance guidance information.

2) The second allocation for the GBAS signal-in-space time-to-alert provides for the possible temporary loss of message reception. Airborne equipment operating with GAST C active will generate an alert if a Type 1 message is not received within 3.5 seconds when on the final stages of approach. When the airborne equipment is below 200 ft height above the runway threshold (HAT), airborne equipment operating with GAST D active will generate an alert or change the active service type if a set of Type 1 and Type 11 messages with the same modified z-count are not received within 1.5 seconds. Note that these time-outs will also dictate the achieved signal-in-space time-to-alert when the ground subsystem ceases VDB transmissions instead of broadcasting messages as an alert to the airborne equipment.

Requirements on how quickly the receiver outputs must be invalidated (so annunciating an alert), as well as additional conditions requiring the outputs to be indicated as invalid, are contained in RTCA DO-253D. For example, there is a requirement for the aircraft GBAS receiver position determination function to use the most recently received message content and reflect the message content in its outputs within 400 ms. The SIS TTA is defined by start and stop events at the same point in the aircraft. Any processing that is common to generating outputs under both normal conditions and alert conditions will not change the achieved SIS TTA. That is, this common period acts like a lag to both the start event and end event and does not affect the total exposure time to the aircraft. Within the GBAS receiver, the outputs under both of these conditions must meet the same latency requirement, so large differences are not expected. SIS TTA will differ from ground subsystem TTA by a value equal to the difference between receiver processing time and receiver time to invalidate outputs.

7.5.14.2 Table D-5C summarizes the time periods that contribute to the GBAS SIS TTA and the range of achieved TTA that can be expected.

7.5.14.3 Figure D-17 illustrates the nominal case with no missed messages and Figure D-18 illustrates the effect of missed messages for GAST D below 200 ft. Above 200 ft, the situation is similar, but the aircraft has a longer missed message allocation, as described above.

7.5.14.3.1 Figure D-18 illustrates the effect on the SIS TTA due to missed messages (upper half) and VDB termination (lower half) using the example of GAST D requirements below 200 ft. The upper time-line shows just two messages being missed, but the third is received, so operations can continue, unless the third message is indicating a fault condition that results in an alert from the receiver. The lower time-line shows the effect of the VDB terminating. The aircraft receiver invalidates its outputs after three messages are missed. The SIS TTA combines the ground TTA and the missed message allocation (See Table D-5B), but it is now displaced by the aircraft receiver processing time. Above 200 ft, the situation is similar, but the aircraft has a longer allocation, as described in RTCA DO-253D.

7.5.14.3.2 For SIS integrity, the diagram indicates that the SIS TTA starting point is where the fault-free airborne receiver outputs out-of-tolerance data. The SIS TTA end event is also at the output of the airborne receiver.

7.5.14.3.3 The start event of the ground subsystem's time-to-alert or time-to-detect and broadcast is the last bit of the first message (Type 1 and Type 11 message pair for GAST D) including the out-of-tolerance data. For ground equipment failures or termination of the VDB signal, this is the first message the ground subsystem broadcasts containing correction, integrity or path information that does not conform to the applicable integrity requirement (e.g. SIS integrity, ground subsystem integrity). For satellite failures, the requirements are out-of-tolerance once differential pseudo-range errors exceed the performance metrics detailed within a certain requirement (e.g. Ranging Source Monitoring). Their end event is the last bit of the first message (message pair for GAST D) removing the out-of-tolerance data or flagging it invalid.

7.5.14.3.4 It shall be noted that, while the Figure D-17 indicates that the SIS and ground subsystem TTAs reference different start and end points in time, an ANSP may assume that they are the same. A ground subsystem shall be evaluated and certified with no credit or penalty for airborne receiver variations due to a specific, approved aircraft implementation. From the ground subsystem perspective, all received messages are assumed to be instantaneously applied or acted upon by the airborne receiver. This effectively results in equivalent SIS and ground subsystem TTA reference points from the ground subsystem's point of view.

7.5.15 *Ground subsystem integrity risk for GAST D.* Appendix 6B, 3.6.7.1.2.1.1.3 specifies a new ground subsystem integrity requirement relating to fail-safe design criteria. This integrity method will ensure that failures within the ground subsystem that might affect the stations functions and result in erroneous information are extremely improbable. The intent of this requirement is to specify the allowable risk that the ground subsystem would internally generate and cause erroneous information to be broadcast. Other requirements specify the required performance of the ground subsystem with respect to detection and mitigation of faults originating outside the ground subsystem (such as ranging source failures). This requirement relates to the probability that the ground subsystem fails to meet the intended function. The intended function for GBAS is defined in CAR-ANS 6.3, 6.3.7.3.5.2. The functions listed in that section and their associated performance requirements characterize the intended function of the system.

Table D-5C. Contributions to signal-in-space time-to-alert

Integrity risk requirements and service types	Ground subsystem TTA *[Note 1]*	Message time-out in aircraft *[Note 5]*	Signal n space TTA (nominal) *[Note 6]*	Signal-in-space TTA (maximum) *[Note 7]*
App B 3.6.7.1.2.1.1.1 and 3.6.7.1.2.2.1 (GAST A, B, C)	3.0 s *[Note 2]*	3.5 s	3.0 s	6.0 s
App B 3.6.7.1.2.1.1.2 and 3.6.7.1.2.2.1 (GAST D)	3.0 s *[Notes 2 and 8]*	3.5s (above 200 ft HAT) 1.5s (below 200 ft HAT)	3.0 s 3.0 s	6.0 s 4.0 s
App B, 3.6.7.1.2.1.1.3 (GAST D)	1.5 s	3.5 s (above 200 ft HAT) 1.5 s (below 200 ft HAT)	1.5 s 1.5 s	4.5 s *[Note 3]* 2.5 s *[Note 3]*
App B, 3.6.7.3.3 (GAST D)	1.5 s*[Note 9]*	3.5.s (above 200 ft HAT) 1.5 s (below 200 ft HAT)	1.5 s 1.5 s	4.5 s *[Note 4]* 2.5 s *[Note 4]*

Note 1.— These ground subsystem TTA requirements apply to a ground subsystem transmitting Type 1 messages. Ground subsystems transmitting Type 101 messages have a 5.5 s TTA as standardized in Appendix 6B, 3.6.7.1.2.1.2.1.2.

Note 2.— These times apply to excluding all ranging sources, marking all ranging sources as invalid in message Type 1 or the cessation of VDB transmission. When a single ranging source is marked invalid or excluded, it may or may not cause the aircraft receiver to generate an alert, depending on the role of that ranging source in the aircraft's position solution.

Note 3.— This design requirement applies to the integrity of internal ground subsystem functions (excluding single reference receiver failures). This includes the ground subsystem ranging source monitoring capability. The table illustrates the exposure time for ground equipment failures that result in the transmission of non-compliant information and that are enunciated to the aircraft using the VDB transmission.

Note 4.— These requirements apply to the integrity monitoring for GNSS ranging sources. When a single ranging source is marked invalid or excluded, it may or may not cause the *aircraft receiver to generate an alert, depending on the role of that ranging source in the aircraft's position solution. The times listed in the table assume the ranging source was critical to determining the position solution.*

Note 5.— The missed message time-out allocation starts with the last received message and not with the first missed message, so is 0.5 s longer than time added to the SIS time-to-alert.

Note 6.— If transmissions continue and there are no missed messages, the "nominal" column is relevant. This value includes the maximum ground subsystem contribution.

Note 7.— The maximum SIS TTA includes the maximum ground subsystem contribution and the possible temporary loss of message reception. When VDB transmissions cease, the maximum SIS TTA is relevant. This time is computed by adding the ground subsystem TTA and the airborne message time out minus 0.5 s (see Note 5).

Note 8.— Although these sections are related to FAST D and the maximum TTA values are larger than those historically associated with Category II/III operations, the TTA values in this line are not relevant for integrity to support Category II/III. These TTA values apply to the bounding conditions (see 7.5.3.1) and therefore are related to the total risk of fault-free error sources and faults exceeding the protection levels. For GAST D, the effects of malfunctions are addressed by the additional requirements in Appendix 6B, 3.6.7.1.2.1.1.3, Appendix 6B, 3.6.7.3.3 and additional airborne requirements as provided in RTCA DO-253D, for example the reference receiver fault monitor. These additional requirements are more constraining and enforce a shorter TTA that is appropriate for Category II/III operations. The existence of the longer TTA values in this line shall not be interpreted to imply that errors near or exceeding the alert limit for up to these longer exposure times can occur with a probability greater than 1 x 10^{-9} in any landing.

Note 9.— This is "time to detect and broadcast"; the other ground system requirements apply in addition.

7.5.15.1 *Verification of compliance with subsystem integrity risk for GAST D.* Verification that a ground subsystem meets the integrity risk requirements of Appendix 6B, 3.6.7.1.2.1.1.3 would typically be accomplished through a combination of analysis and appropriate safety-related design practices/processes. The overall process must ensure that failures within the ground subsystem that might affect the stations intended functions and result in erroneous information are extremely improbable. All ground subsystem component failure conditions must be shown to be sufficiently mitigated through either direct monitoring or through use of an acceptable design assurance development process (such as RTCA/DO-178 and RTCA/DO-254). The methodology should provide assurance of mitigation of component (HW, SW) failures. The integrity method of design assurance, applied in conjunction with fail-safe design concepts and other assurance actions (such as those in SAE ARP 4754) to detect and remove systematic errors in the design, provides safety assurance of the GAST D ground system. Some States have used safety assurance guidance from ICAO's *Safety Management Manual (SMM)* (Doc 9859).

7.6 Continuity of service

7.6.1 ~~*Ground*~~ *GBAS continuity ~~and~~/integrity designator.* The ~~ground~~ GBAS continuity/ ~~and~~ integrity designator (GCID) provides an indication of the current capability ~~classification~~ of GBAS ground subsystems. The ground subsystem meets the performance and functional requirements of GAST A, B or C ~~Category I precision approach or APV~~ when GCID is set to 1. The ground subsystem meets the performance and functional requirements of GAST A, B, C and D when GCID is set to 2. GCID of~~,~~ 3 and 4 are intended to support future operations with an associated service type that has requirements that are more stringent than ~~Category I operations~~ GAST D. The GCID is intended to be an indication of ground subsystem status to be used when an aircraft selects an approach. It is not intended to replace or supplement an instantaneous integrity indication communicated in a Type 1 or Type 101 message. GCID does not provide any indication of the ground subsystem capability to support the GBAS positioning service.

7.6.2 *Ground subsystem continuity of service.* GBAS ground subsystems are required to meet the continuity of service specified in Appendix 6B to CAR-ANS 6.3, 6.3.6.7.1.3 in order to support GAST A, B and C. ~~Category I precision approach and APV.~~ GBAS ground subsystems that are also intended to support other operations through the use of the GBAS positioning service ~~should~~ shall support the minimum continuity required for terminal area operations, which is $1-10^{-4}$/hour (CAR-ANS 6.3, Table 6.3.7.2.4-1). When the GAST A, B or C ~~Category I precision approach or APV~~ required continuity ($1-8 \times 10^{-6}$/15 seconds) is converted to a per hour value it does not meet the $1-10^{-4}$/hour minimum continuity requirement. Therefore, additional measures are necessary to meet the continuity required for other operations. One method of showing compliance with this requirement is to assume that airborne implementation uses both GBAS and ABAS to provide redundancy and that ABAS provides sufficient accuracy for the intended operation.

7.6.2.1 *Ground subsystem continuity of service for GAST D.* A ground segment that supports GAST D must meet the SIS continuity requirement ($1-8.0 \times 10^{-6}$/15 seconds) for a GAST A, B and C system but must also meet the continuity requirements specific to GAST D as defined in Appendix 6B, 3.6.7.1.3.2. The ground subsystem continuity is defined by two requirements. One is the continuity of the ground subsystem that includes failures of all components necessary for the VDB broadcast, including the reference receivers. It also includes loss of service due to integrity failures in the ground subsystem that result in alerts and monitor false alerts. The other allocation is the continuity associated with monitor fault-free detections. The reason for defining the ranging source monitor detections as a separate requirement is because the VDB broadcast portion includes all failures that result in the loss of the SIS, whereas the monitor contribution is related only to exclusion of individual satellites from the broadcast corrections. This does not necessarily result in a loss of the SIS by the airborne receiver. The requirement is defined on a per ranging source basis so that the ground design does not need to account for the actual number of satellites in view or the number considered critical to the user for a specific approach. It is the responsibility of the airborne user to demonstrate the overall continuity achieved when considering the contribution of the satellites and the airborne monitors.

7.7 GBAS channel selection

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7.7.2 A channel number in the range from 20 001 to 39 999 is assigned when the FAS data are broadcast in the Type 4 message. A channel number in the range from 40 000 to 99 999 is assigned when the FAS data associated with ~~an APV~~ GAST A service type are obtained from the on-board database.

7.7.3 Every FAS data block uplinked in a Type 4 message will be associated with a single 5-digit channel number regardless of whether or not the approach is supported by multiple approach service types. For approaches that are supported by multiple approach service types, the approach performance designator field in the Type 4 message is used to indicate the most demanding approach service type supported by the ground subsystem for any specific approach.

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7.10 GBAS identification

The GBAS identification (ID) is used to uniquely identify a GBAS ground subsystem broadcasting on a given frequency within the VDB coverage of the GBAS. The aircraft will navigate using data broadcast from one or more GBAS broadcast stations of a single GBAS ground subsystem (as identified by a common GBAS identification).

7.11 Final approach segment (FAS) path

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7.11.3.1.1 *Lateral deviation reference.* The lateral deviation reference plane is the plane that includes the LTP/FTP, FPAP and a vector normal to the WGS-84 ellipsoid at the LTP/FTP. The rectilinear lateral deviation is the distance of the computed aircraft position from the lateral deviation reference plane. The angular lateral deviation is a corresponding angular displacement referenced to the ~~GBAS~~GNSS azimuth reference point (GARP). The GARP is defined to be beyond the FPAP along the procedure centre line by a fixed offset value of 305 m (1 000 ft).

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7.12 Airport siting considerations

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7.12.3 *Locating the VDB antenna.* The VDB antenna ~~should~~ must be located **to comply with the minimum and maximum field strength requirements within the service volume(s) as defined in CAR-ANS 6.3, 6.3.7.3.5.4.4. Compliance with the minimum field strength for approach services can generally be met if the VDB antenna is located** so that an unobstructed line-of-sight exists from the antenna to any point within the ~~coverage~~service volume for each supported FAS. Consideration ~~should~~ shall also be given to ensuring the minimum transmitter-to-receiver separation so that the maximum field strength is not exceeded. **For the nominal link budget, typically, an 80 m separation is required to avoid exceedance of the maximum field strength requirement. Though it is desirable to apply the separation criteria to any location where an aircraft may operate (including taxiways, ramp areas and gates), it is only necessary to meet the maximum field strength in the service volume(s) (see 6.3.7.3.5.3** for service volume definitions). If the minimum separation cannot be met for all operating aircraft (including taxiways, ramp areas and gates) it must be ensured that the airborne receiver is protected from burn-out in accordance with the RTCA/DO-253 D MOPS. This typically requires a minimum separation of 20 m from the VDB antenna to the aircraft antenna. In order to provide the required coverage for multiple FASs at a given airport, and in order to allow flexibility in ~~VBD~~VDB antenna siting, the actual coverage ~~volume~~ around the transmitter antenna may need to be considerably larger than that required for a single FAS. The ability to provide this coverage is dependent on the VDB antenna location with respect to the runway and the height of the VDB antenna. Generally speaking, increased antenna height may be needed to provide adequate signal strength to users at low altitudes, but may also result in unacceptable multipath nulls within the desired coverage ~~volume~~. A suitable antenna height trade-off must be made based on analysis, to ensure the signal strength requirements are met within the entire ~~volume~~coverage. Consideration ~~should~~ shall also be given to the effect of terrain features and buildings on the multipath environment.

7.12.3.1 In order to ensure that the maximum field strength requirements defined in CAR-ANS 6.3, 6.3.7.3.5.4.4 are not violated, VDB transmitters shall not be located any closer than 80 m to where aircraft are approved to operate based on published procedures using GBAS or ILS guidance information. This applies to aircraft on final approach, departure, and on runways. The 80-metre separation applies to the slant range distance between VDB transmit antennas and the aircraft antenna position. For aircraft on the runway the maximum deviation from the centre line can be assumed to be 19 m. In regions prior to runway thresholds, the maximum lateral course angular deviation from the extended centre line on final approach is plus and minus one sixth of the full course width, which is nominally 210 m (±105 m (±350 ft)) at threshold. The origin of the lateral course shall be assumed to be the GBAS GARP, or the ILS localizer, as appropriate. The maximum vertical deviation is one half of the full scale deflection from the glide path, where full scale deflection is calculated as ±0.25 times the glide path angle. The origin of the glide path shall be assumed to be the GPIP. See 7.11.3 for further guidance on lateral and vertical course width deviation sensitivity.

7.12.4 *Use of multiple transmit antennas to improve VDB coverage.* For some GBAS installations, constraints on antenna location, local terrain or obstacles may result in ground multipath and/or signal blockage that make it difficult to provide the specified field strength at all points within the service volume~~coverage area~~. Some GBAS ground facilities may make use of one or more additional antenna systems, sited to provide signal path diversity such that collectively they meet the service volume ~~coverage area~~ requirements.

7.12.4.1 Whenever multiple antenna systems are used, the antenna sequence and message scheduling must be arranged to provide broadcasts at all points within the service volume~~coverage area~~ that adhere to the specified minimum and maximum data broadcast rates ~~and field strengths,~~ considering ~~without exceeding~~ the receiver's ability to adapt to transmission-to-transmission variations in signal strength in a given slot. Exceedance of the signal power variation requirement in Appendix 6B, 3.6.8.2.2.3 is acceptable for limited areas within the service volume, provided it can be shown based on receiver behaviour as described, for example in RTCA DO-253D and the assumptions listed below, that the resulting performance is acceptable.

7.12.4.1.2 Message transmission and reception rate requirements, and time-to-alert requirements prevent Type 1 and Type 11 messages from being alternated between antennas in the same slot from frame to frame. Only Type 2 and 4 messages (and Type 3 messages as a filler message) are candidates for being alternated. Continuity is maintained as long as a Type 2 message is received at least once per minute. The receiver does not verify repeated reception of Type 4 messages during the final stages of an approach.

7.12.4.1.3 While the signal power variation requirement in Appendix 6B, 3.6.8.2.2.3 applies on the input port of the receiver, the situation for a specific site has to be assessed in the field strength domain. Therefore, the potential variation in aircraft antenna gain must be taken into account. If the area where the signal power variation requirement may be exceeded is so large that it may take one minute or more for an approaching aircraft to pass through it, it may be necessary to address the potential message loss from a probabilistic point of view. In these cases the multiple VDB antenna set-up shall be limited so that in case alternation of messages in the same slot from frame to frame is applied, the alternating pattern shall only involve two transmitter antennas, with a scheduled burst in every frame, and the transmission shall alternate between the antennas every frame, in order to resemble the situation for which the receiver has been tested. This is necessary in order to be able to make assumptions on receiver message failure rates (MFR).

7.12.4.1.4 When analysing the probability of lost messages, the following basic assumptions apply:

1. If all received signal levels are between the receiver minimum design input power (S_{min}) and maximum design input power (S_{max}), and they are within 40 dB of each other, then the analysis can assume 10^{-3} message failure rate (MFR).

2. If all received signals are below S_{min}, then the analysis must assume a MFR of 100 per cent.

3. If any signal exceeds S_{max} it must be assumed that reception in all slots in that frame and any number of subsequent frames is adversely affected (not only those where S_{max} is exceeded), as no receiver recovery time is specified for these conditions.

Furthermore, in the case of a dual antenna set-up with messages alternating in each frame, the following assumptions can be made:

4. If one signal is below S_{min} ($S_{min} - \Delta$) and the second signal is within 40 dB (i.e., $S_{min} - \Delta +$ 40 dB or less), then the analysis must assume that the MFR for the signal below S_{min} is 100 per cent and the MFR for the stronger signal is 10^{-3}.

5. If both signals are within S_{min} to S_{max}, but the variation between the signals is greater than 40 dB, then the analysis must assume a MFR of 60 per cent.

6. If one signal is below S_{min} ($S_{min} - \Delta$) and the second is above S_{min}, and exceeds 40 dB variation ($S_{min} - \Delta + 40$ dB $+ \varepsilon$ or more), then the analysis must assume that the MFR for the signal below S_{min} is 100 per cent and the MFR for the stronger signal is 60 per cent.

7.12.4.1.5 The resulting probability of no Type 2 messages being received for a duration of one minute shall be assessed against the applicable continuity requirement.

Note.— The analysis may have to consider up to 15 dB variation for the aircraft VDB antenna gain variation depending upon the scenario, such that the 40 dB power variation ≤ SIS power variation + up to 15 dB aircraft antenna gain variation.

To avoid receiver processing issues concerning lost or duplicated messages, all transmissions of the Type 1, Type 11 or Type 101 message, or linked pairs of Type 1, Type 11 or Type 101 messages for a given measurement type within a single frame need to provide identical data content.

7.12.4.2 One example of the use of multiple antennas is a facility with two antennas installed at the same location but at different heights above the ground plane. The heights of the antennas are chosen so that the pattern from one antenna fills the nulls in the pattern of the other antenna that result from reflections from the ground plane. The GBAS ground subsystem alternates broadcasts between the two antennas, using one, ~~or~~ two or three assigned slots of each frame for each antenna. Type 1, Type 11 or Type 101 messages as appropriate for the service type supported are broadcast once per frame, per antenna. This allows for reception of one or two Type 1, Type 11 or Type 101 messages per frame, depending on whether the user is located within the null of one of the antenna patterns. Type 2 and 4 messages are broadcast from the first antenna in one frame, then from the second antenna in the next frame. This allows for reception of one each of the Type 2 and 4 messages per one or two frames, depending on the user location.

7.13 Definition of lateral and vertical alert limits

7.13.1 The lateral and vertical alert limits when the active service type is C or D ~~for Category I precision approach~~ are computed as defined in Appendix 6B, Tables B-68 and B-69. In these computations the parameters D and H have the meaning shown in Figure D-8.

7.13.2 The vertical alert limit when the active service type is C or D ~~for Category I precision approach~~ is scaled from a height of 60 m (200 ft) above the LTP/FTP. For a procedure designed with a decision height of more than 60 m (200 ft), the VAL at that decision height will be larger than the broadcast FASVAL.

7.13.3 The lateral and vertical alert limits for ~~APV~~ procedures supported by GAST A service type associated with channel numbers 40 001 to 99 999 are computed in the same manner as ~~for APV procedures using~~ SBAS as given in Attachment 6D, 6.6.~~3.2.8~~.

7.14 Monitoring and maintenance actions

7.14.1 Specific monitoring requirements or built-in tests may be necessary in addition to the monitors defined in Appendix 6B, 3.6.7.3 and ~~should~~ shall be determined by individual States. Since the VDB signal is critical to the operation of the GBAS broadcast station, any failure of the VDB to successfully transmit a usable signal within the assigned slots and over the entire service volume~~coverage area~~ is to be corrected as soon as possible. Therefore, it is recommended that the following conditions be used as a guide for implementing a VDB monitor:

a) *Power*. A significant drop in power is to be detected within ~~3 seconds~~ an appropriate time period.

b) *Loss of message type*. The failure to transmit any scheduled message type(s). This could be based on the failure to transmit a unique message type in succession, or a combination of different message types.

c) *Loss of all message types*. The failure to transmit any message type for an appropriate time period ~~equal to or greater than 3 seconds~~ will be detected.

The appropriate time periods for these monitors depend on the FAST and on whether a back-up transmitter is provided. Where a back-up transmitter is provided, the objective is to switch to the back-up transmitter quickly enough to avoid an alert being generated in the airborne equipment. This means that the appropriate time periods are a maximum of 3 seconds for FAST C and a maximum of 1.5 seconds for FAST D ground systems in order to be consistent with the aircraft equipment message loss requirements. If longer periods than this are implemented, the changeover to the back-up transmitter will cause an alert and must therefore be considered to be a continuity failure. If no back-up transmitter is provided, the time periods for these monitors are not critical.

7.14.2 Upon detection of a failure, and in the absence of a back-up transmitter, termination of the VDB service ~~should~~ shall be considered if the signal cannot be used reliably within the service volume ~~coverage area~~ to the extent that aircraft operations could be significantly impacted. Appropriate actions in operational procedures are to be considered to mitigate the event of the signal being removed from service. These would include dispatching maintenance specialists to service the GBAS VDB or special ATC procedures. Additionally, maintenance actions ~~should~~ shall be taken when possible for all built-in test failures to prevent loss of GBAS service.

7.14.3 The use of a back-up transmitter also applies to the VDB monitoring requirements defined in Appendix 6B, 3.6.7.3.1. The time to switch over to the back-up needs to be taken into account while remaining compliant with the time to detect and terminate transmissions defined in Appendix 6B, 3.6.7.3.1.1 and 3.6.7.3.1.2.

7.15 Examples of VDB messages

7.15.1 Examples of the coding of VDB messages are provided in Tables D-7 through D-10A. The examples illustrate the coding of the various application parameters, including the cyclic redundancy check (CRC) and forward error correction (FEC) parameters, and the results of bit scrambling and D8PSK symbol coding. The engineering values for the message parameters in these tables illustrate the message coding process, but are not necessarily representative of realistic values.

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7.15.4.1 Table D-8B provides an example of Type 2 messages with additional data blocks 1, 3 and 4 coded within a single burst with a Type 3 message that is used to fill the rest of the time slot.

7.15.6 Table D-10 provides an example of a Type 5 message. In this example, source availability durations common to all approaches are provided for two ranging sources. Additionally, source availability durations for two individual approaches are provided: the first approach has two impacted ranging sources and the second approach has one impacted ranging source. ~~The Type 2 message includes additional data block 1.~~

7.15.7 Table D-10A provides an example of a Type 11 message.

. . .

7.17 Type 2 message additional data blocks

. . .

7.17.4 Type 2 message additional data block 3 ~~is reserved for future use~~ contains information necessary to support GAST D. All FAST D ground subsystems are required to transmit a Type 2 message with additional data block 3 properly populated so that the bounding requirements are met.

. . .

Table D-8B . Example of a Type 2 message containing data blocks 1, 3 and 4 and a Type 3 message to fill the remainder of the slot

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
BURST DATA CONTENT					
Power ramp-up and settling	15	-	-	-	000 0000 0000 0000
Synchronization and ambiguity resolution	48	-	-	-	0100 0111 1101 1111 1000 1100 0111 0110 0000 0111 1001 0000
SCRAMBLED DATA					
Station slot identifier	3	-	-	E	100
Transmission length	17	0 to 1824 bits	1 bit	1704	0 0000 0110 1010 1000
Training sequence FEC	5	-	-	-	01000
APPLICATION DATA					
Message Block 1 (Type 2 message)					
Message Block Header					
Message Block identifier	8	-	-	Normal	1010 1010
GBAS ID	24	-	-	Bell	000010 000101 001 100 001100
Message type identifier	8	1 to 101	1	2	0000 0010
Message length	8	10 to 222 bytes	1 byte	~~37~~43	~~00100101~~00101011
Message (Type 2 example)					
GBAS reference receivers	2	2 to 4	1	~~3~~4	~~01~~10
Ground accuracy designator letter	2	-	-	~~B~~C	~~01~~10
Spare	1	-	-	-	0
GBAS continuity/integrity designator	3	0 to 7	1	2	010
Local magnetic variation	11	± 180°	0.25°	E58.0°	000 1110 1000
Reserved ~~Spare~~	5	-	-zero	-	0000 0
$\sigma_{vert\_iono\_gradient}$					0010 1000

	8	0 to 25.5 x 10^{-6}m/m	0.1x10^{-6} m/m	4 x 10^{-6}	
Refractivity index	8	16 to 781	3	379	1111 1001
Scale height	8	0 to 25 500m	100m	100 m	0000 0001
Refractivity uncertainty	8	0 to255	1	20	0001 0100
Latitude	32	± 90.0°	0.0005 arcsec	N45°40'32" (+164432")	0001 0011 1001 1010 0001 0001 0000 0000
Longitude	32	± 180.0°	0.0005 arcsec	W93°25'13" (-336313")	1101 0111 1110 1000 1000 1010 1011 0000
Ellipsoid height	24	± 83886.07 m	0.01 m	892.55 m	0000 0001 0101 1100 1010 0111
Additional Data Block 1					
Reference station data selector	8	0 to 48	1	5	0000 0101
Maximum use distance (D_{max})	8	2 to 510 km	2 km	50 km	0001 1001
$K_{md\_e\_POS,GPS}$	8	0 to 12.75	0.05	6	0111 1000
Kmd_ e G,GPS	8	0 to 12.75	0.05	5	0110 0100
$K_{md\_e\_POS,GLONASS}$	8	0 to 12.75	0.05	0	0000 0000
Kmd_ e G,GLONASS	8	0 to 12.75	0.05	0	0000 0000
Additional Data Block 4					
Additional Data Block length	8	3	1 byte	3	0000 0011
Additional Data block number	8	4	1	4	0000 0100
Slot group definition	8	-	-	E+F	0011 0000
Additional Data Block 3					
Additional Data Block Length	**8**	**6**	**1 byte**	**6**	0000 0110
Additional Data Block Number	**8**	**3**	**1**	**3**	0000 0011
$K_{md\_e\_D,GPS}$	**8**	**0 to 12.75**	**0.05**	**5.55**	0110 1111
$K_{md\_e\_D,GLONASS}$	**8**	**0 to 12.75**	**0.05**	**0**	0000 0000
$\sigma_{vert\_iono\_gradient\_D}$	**8**	**0 – 25.5 x 10^{-6} m/m**	**0.1 x 10^{-6} m/m**	**4x 10^{-6}**	0010 1000
~~Spare~~	~~8~~	-	-	-	~~0000 0000~~
Y_{EIG}	**5**	**0 to 3.0 m**	**0.1**	**1**	0 1010
M_{EIG}	**3**	**0 to 0.7 m/km**	**0.1**	**0.3**	011
Message Block 1 CRC	32	-	-	-	~~1100 0101 1110 0000 0010 0110 1100 1011~~ ~~0000 0010 0111 0000 1111 1111 1111 0011~~ 0011 1100 1110 0001 1000 0100 1011 1011
Message Block 2 (Type 3 message)					
Message Block Header					
Message Block identifier	8	-	-	Normal	1010 1010
GBAS ID	24	-	-	Bell	000010 000101 001100 001100
Message Type identifier	8	1 to 101	1	3	0000 0011
Message length	8	N/A	1 byte	~~170~~ 164	~~1010 1010~~ 1010 0100
Message (Type 3 example)					
Filler	~~1280~~ 1232	-	-	-	1010 1010……1010 1010
Message Block 2 CRC	32	-	-	-	~~1001 0000 1110 1100 1101 1001 1011 1010~~ 0110 1101 1011 1001 1110 0100 1110 0100
Application FEC	48	-	-	-	~~0000 1000 0010 0011 1100 1011 1101 0000~~ ~~1101 0110 1011 0101~~ ~~1101 0010 1001 0000 1111 0000 1011 1010~~ ~~1000 1111 0110 0010~~ 1111 0110 0011 0100 1101 1001 1110 0010 1110 0011 1111 1101
Input to a bit scrambling (Note 2)	~~0 45 58 02 55 30 CA 10 40 A4 A2 17 00 14 9F 80 28 00 88 59 C8 0D 51 17 EB E5 3A 80 A0 98 1E 26 00 00 C0 20 0C D3 64 07 A3 55 30 CA 10 C0 55 5D 9B 37 09 AD 6B 0B D3 C4 100 45 58 02 55 30 CA 10 40 D4 A2 17 00 14 9F 80 28 00 88 59 C8 0D 51 17 EB E5 3A 80 A0 98 1E 26 00 00 C0 20 0C 60 C0 F6 00 14 00 CF FF 0E 40 55 30 CA 10 C0 25 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55~~				

	~~55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55~~ ~~55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55~~ ~~55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55~~ ~~55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55~~ ~~55 55 55 55 55 55 55 55 55 55 27 27 9D B6 46 F1 5D 0F 09 4B~~ 0 45 58 02 55 30 CA 10 40 D4 52 17 00 14 9F 80 28 00 88 59 C8 0D 51 17 EB E5 3A 80 A0 98 1E 26 00 00 C0 20 0C 60 C0 F6 00 14 56 DD 21 87 3C 55 30 CA 10 C0 25 55 27 27 9D B6 BF C7 47 9B 2C 6F				
Output from the bit scrambling (Note 3)	~~0 63 6F 8A 1F 2F D2 3B 9F 3E 77 CE 32 C8 D9 50 DE C1 C1 5A D4 09 7E E7 81 5A 5C D4 28~~ ~~56 00 CE 29 60 A3 5F 77 87 C0 C9 D2 42 73 01 15 DB A6 8F EF 8C F3 88 DC 78 B6 C7 D0 93~~ ~~58 5D 46 B5 6F D5 0C AA 77 FE D3 30 A2 27 E1 EC E4 F7 17 2D AD F4 0B 29 82 04 61 96 E4~~ ~~50 E9 58 FA B8 C0 38 99 C7 BB 6C 3D 09 CA 7B 7E C2 CF 60 8D 18 75 B9 2B C5 FC 94 C8 57~~ ~~79 52 C5 5F 6A B2 FF DF 33 4D DD 74 B5 28 2A 06 01 91 9B A4 43 E9 63 05 1D 95 B4 54 29 56~~ ~~05 51 95 5B AA BC 00 36 66 2E EE 0F 0E 72 71 21 25 E5 EB 14 FD A8 CB F8 83 38 62 39 1E~~ ~~3A 4E 3E 8E 30 71 D9 24 BA 17 C1 AC 9B F7 BC D3 C8 A3 78 1D 39 B5 C4 2B 69 FD 04 CA 68~~ ~~81 07 9A 64 8F 6B 39 7D 2A 34 D0 6F EA0 63 6F 8A 1F 2F D2 3B 9F 4E 77 CE 32 C8 D9 50 DE~~ ~~C1 C1 5A D4 09 7E E7 81 5A 5C D4 28 56 00 CE 29 60 A3 5F 77 34 64 38 71 03 43 04 FA 15 B3~~ ~~8F 8A 13 B6 1D AC 78 B6 C7 D0 93 58 5D 46 B5 6F D5 0C AA 77 FE D3 30 A2 27 E1 EC E4 F7~~ ~~17 2D AD F4 0B 29 82 04 61 96 E4 50 E9 58 FA B8 C0 38 99 C7 BB 6C 3D 09 CA 7B 7E C2 CF~~ ~~60 8D 18 75 B9 2B C5 FC 94 C8 57 79 52 C5 5F 6A B2 FF DF 33 4D DD 74 B5 28 2A 06 01 91~~ ~~9B A4 43 E9 63 05 1D 95 B4 54 29 56 05 51 95 5B AA BC 00 36 66 2E EE 0F 0E 72 71 21 25 E5~~ ~~EB 14 FD A8 CB F8 83 38 62 39 1E 3A 4E 3E 8E 30 71 D9 24 BA 17 C1 AC 9B F7 BC D3 C8 A3~~ ~~78 1D 39 B5 C4 2B 69 FD 04 CA 68 81 07 9A 1E 33 C1 86 96 B0 62 0C A2 B1~~ 0 63 6F 8A 1F 2F D2 3B 9F 4E 87 CE 32 C8 D9 50 DE C1 C1 5A D4 09 7E E7 81 5A 5C D4 28 56 00 CE 29 60 A3 5F 77 34 64 38 71 03 15 16 24 9C CF 8F 8A 13 B6 1D AC 78 B6 C7 D0 93 58 5D 46 B5 6F D5 0C AA 77 FE D3 30 A2 27 E1 EC E4 F7 17 2D AD F4 0B 29 82 04 61 96 E4 50 E9 58 FA B8 C0 38 99 C7 BB 6C 3D 09 CA 7B 7E C2 CF 60 8D 18 75 B9 2B C5 FC 94 C8 57 79 52 C5 5F 6A B2 FF DF 33 4D DD 74 B5 28 2A 06 01 91 9B A4 43 E9 63 05 1D 95 B4 54 29 56 05 51 95 5B AA BC 00 36 66 2E EE 0F 0E 72 71 21 25 E5 EB 14 FD A8 CB F8 83 38 62 39 1E 3A 4E 3E 8E 30 71 D9 24 BA 17 C1 AC 9B F7 BC D3 C8 A3 78 1D 39 B5 C4 2B 69 FD 04 CA 68 81 07 9A 1E 33 C1 86 6F 86 78 98 87 95				
Fill bits	0 to 2	—	—	~~2~~12	00
Power ramp-down	9	—	—	—	000 000 000
D8PSK Symbols (Note 4)	~~00000035 11204546 31650102 46331130 13067746 52605627 35467122 62533573 77100603~~ ~~75554273 01666461 41203311 42111340 14733657 27302663 77076361 44301001 17175104~~ ~~35263707 43007132 40135774 07012022 52546153 57425454 25413051 54022547 01622754~~ ~~12302141 24615265 50476225 56622615 23311312 51275055 11132570 45242065 63665236~~ ~~04052447 35155017 73303745 61650521 06765616 04756006 16264736 30530735 02426407~~ ~~53610061 12111501 04147002 72512117 74672621 42254251 12533720 37475054 44460104~~ ~~57516674 46523401 22503075 25125742 03431633 22607072 37230050 35463673 43300570~~ ~~12353363 77140357 42715724 03470633 30354042 67720645 27225703 50111005 40736127~~ ~~14021742 36572477 13042222 216750066 17666015 61400324 74057621 34465623 33767665~~ ~~26561513 24117724 20704065 73460227 32345355 05071406 02750707 50746304 07355072~~ ~~34155207 45635474 57140510 03721550 01155140 56644645 04520300 44465023 70575310~~ ~~16110561 37305772 60400342 26636270 14103054 31210141 37201331 41517261 63063260~~ ~~35751732 06143314 45444034 37472335 25045442 27125154 75507504 45066253 62720307~~ ~~77713437 02041127 71056734 55036320 50450275 36764166 55132325 62563303 60716126~~ ~~76633023 45606616 22473602 75240257 36723166 63607375 12253170 52550236 03444330~~ ~~73230046 22446140 65512232 00600777 7~~ 00000035 11204546 31650102 46331130 13067746 52652552 60712455 15066026 22433136 20007526 34111714 74536644 75444673 47266102 52635407 12243401 11561037 01237127 60553360 64340421 37024663 76701711 41435042 46314343 14302740 43711436 70511643 01271030 13504154 47365114 45511504 12200201 40164744 00021467 34131754 52554125 73741336 24044706 62272634 50547410 75654505 73645775 05153625 27427624 71315376 42507750 01000470 73036771 61401006 63561510 31143140 01422617 26364743 33357073 46405563 35412370 11472764 14014631 72320522 11576761 26127747 24352562 32277467 01242252 66037246 31604613 72367522 27243731 56617534 16114672 47000774 37674402 66002316 56521466 56347666 6				

Notes

1. *The rightmost bit is the LSB of the binary parameter value and is the first bit transmitted or sent to the bit scrambler. All data fields are sent in the order specified in the table.*
2. *This field is coded in hexadecimal with the first bit to be sent to the bit scrambler as its MSB. The first character represents a single bit.*
3. *In this example, fill bits are not scrambled.*
4. *This field represents the phase, in units of $\pi/4$(e.g. a value of five represents a phase of $5\pi/4$ radians), relative to the phase of the first symbol.*

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Table D-10A. Example of a Type 11 VDB message

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
BURST DATA CONTENT					
Power ramp up and setting	15				000 0000 0000 0000
Synchronization and ambiguity resolution	48				0100 0111 1101 1111 1000 1100 0111 0110 0000 0111 1001 0000
SCRAMBLED DATA					
STATION SLOT IDENTIFIER(SSID)	3	-	-	E	100
TRANSMISSION LENGTH (BITS)	17	0 TO 1 824 bits	1 bit	440	0 0000 0001 1011 1000
TRAINING SEQUENCE FEC	5	—	—	—	0 0000 0001 1011 1000
APPLICATION DATA MESSAGE BLOCK					
Message Block 1 (Type 11 message)					
Message Block Header					
Message block identifier	8	—	—	Normal	1010 1010
GBAS ID	24	—	—	BELL	0000 1000 0101 0011 0000 1100
Message type identifier	8	1 to 101	1	11	0000 1011
Message length	8	10 to 222 bytes	1 byte	49	0011 0001
Message (Type 11 example)					
Modified Z-count	14	0 to 1 199.9 s	0.1 s	100 s	00 0011 1110 1000
Additional message flag	2	0 to 3	1	0	00
Number of measurements	5	0 to 18	1	5	0 0101
Measurement type	3	0 to 7	1	C/A L1	00
Ephemeris Decorrelation Parameter (P_D)	8	0 to 1.275 $\times 10^{-3}$m/m	5×10^{6}m/m	1×10^{-4}	0001 0100
Measurement Block 1					
Ranging source ID	8	1 to 255	1	12	0000 1100
Pseudo-range correction (PRC30)	16	±327.67 m	0.01 m	+1.04 m	0000 0000 0110 1000

Range rate correction (RRC30)	16	±32.767 m	0.001 m/s	−0.18 m/s	1111 1111 0100 1100
σpr_gnd,D	8	0 to 5.08 m	0.02 m	0.96 m	0011 0000
σpr_gnd,30	8	0 to 5.08 m	0.02 m	1.00 m	0011 0010
Measurement Block 2					
Ranging source ID	8	1 to 255	1	4	0000 0100
Pseudo-range correction (PRC30)	16	±327.67 m	0.01 m	−1.08 m	1111 1111 1001 0100
Range rate correction (RRC30)	16	±32.767 m	0.001 m/s	−0.18 m/s	0000 0000 1011 0100
σpr_gnd,D	8	0 to 5.08 m	0.02 m	0.24 m	0000 1100
σpr_gnd,30	8	0 to 5.08 m	0.02 m	0.6 m	0001 1110
Measurement Block 3					
Ranging source ID	8	1 to 255	1	2	0000 0010
Pseudo-range correction (PRC30)	16	±327.67 m	0.01 m	+1.2 m	0000 0000 0111 1000
Range rate correction (RRC30)	16	±32.767 m	0.001 m/s	0.3 m/s	0000 0001 0010 1100
σpr_gnd,D	8	0 to 5.08 m	0.02 m	0.64 m	0010 0000
σpr_gnd,30	8	0 to 5.08 m	0.02 m	0.74m	0010 0101
Measurement Block 4					
Ranging source ID	8	1 to 255	1	23	0001 0111
Pseudo-range correction (PRC30)	16	±327.67 m	0.01 m	−2.64 m	1111 1110 1111 1000
Range rate correction (RRC30)	16	±32.767 m	0.001 m/s	−0.51 m/s	1111 1110 0000 0010
σpr_gnd,D	8	0 to 5.08 m	0.02 m	0.08 m	0000 0100
σpr_gnd,30	8	0 to 5.08 m	0.02 m	0.14 m	0000 0111

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
Measurement Block 5					
Ranging source ID	8	1 to 255	1	122	0111 1010
Pseudo-range correction (PRC_{30})	16	±327.67 m	0.01 m	+0.8 m	0000 0000 0101 0000
Range rate correction (RRC_{30})	16	±32.767 m	0.001 m/s	−0.25 m/s	1111 1111 0000 0110
σpr_gnd,D	8	0 to 5.08 m	0.02 m	0.92 m	0010 1110
σpr_gnd,30	8	0 to 5.08 m	0.02 m	1.08 m	0011 0110
Message Block CRC	32	—	—	—	0010 1111 0000 0101 1101 1001 0000 1100
APPLICATION FEC	48	—	—	—	1001 0011 1110 0111 1101 1100 0100 0001 0100 0101 1011 1110
Input to the bit scrambling (Note 2)	0 47 60 1A 55 30 CA 10 D0 8C 17 C0 A0 28 30 16 00 32 FF 0C 4C 20 29 FF 2D 00 30 78 40 1E 00 34 80 04 A4 E8 1F 7F 40 7F 20 E0 5E 0A 00 60 FF 74 6C 30 9B A0 F4 7D A2 82 3B E7 C9				
Output from the bit scrambling (Note 3)	0 61 57 92 1F 2F D2 3B 0F 16 C2 19 92 F4 76 C6 F6 F3 B6 0F 50 24 06 0F 47 BF 56 2C C8 D0 1E DC A9 64 C7 97 64 2B E4 B1 51 F7 1D C1 05 7B 0C AE D6 E9 3D 7D 7D 50 41 10 BE 21 C4				
Fill bits	0 to 2	—	—	0	
Power ramp-down	9	—	—	—	000 000 000
D8PSK Symbols (Note 4)	00000035 11204546 31650101 42701130 13067746 60457114 40234621 31760262 76357705 07725551 13760416 17615700 43341354 25047116 53736646 34577501 64015223 34742121 71757170 16162053 65544366 41033007 777				

Notes.-

1. *The rightmost bit is the LSB of the binary parameter value and is the first bit transmitted or sent to the bit scrambler. All data fields are sent in the order specified in the table.*
2. *This field is coded in hexadecimal with the first bit to be sent to the bit scrambler as its MSB. The first character represents a single bit.*
3. *In this example, fill bits are not scrambled.*
4. *This field represents the phase, in units of $\pi/4$(e.g. a value of five represents a phase of $5\pi/4$ radians), relative to the phase of the first symbol.*

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7.19 Airborne processing for GBAS approach service types

Note.— In order to ensure the required performance and functional objectives for GAST D are achieved, it is necessary for the airborne equipment to meet defined performance and functional standards. The relevant minimum operational performance standards (MOPS) are detailed in RTCA DO-253D.

7.19.1 *Differential position solution for the GBAS positioning service.* The position solution used to provide position, velocity and time outputs is based on 100-second smoothed pseudo-ranges corrected with corrections obtained from Message Type 1 or Message Type 101.

7.19.2 *Differential position solution for approach service GAST A, B and C.* When the active approach service type is A, B or C, the position solution used to generate deviations is based on 100-second smoothed pseudo-ranges corrected with corrections obtained from Message Type 1 or Message Type 101. The projection matrix, S, used to compute the position solution (Appendix 6B, 3.6.5.5.1.1.2) is computed based on σ_i computed using $\sigma_{pr\_gnd}[i]$ from Message Type 1 or Message Type 101 and $\sigma_{iono,i}$ based on $\sigma_{vert\_iono\_gradient}$ from message Type 2.

7.19.3 *Differential position solutions for approach service GAST D.* When GAST D is the active approach service type, the airborne equipment will compute two different position solutions, one based on 30-second smoothed pseudo-ranges and the other based on 100-second smoothed pseudo-ranges. The following characterizes the standard processing required by the MOPS:

a) the position solution used to develop deviations is based on 30-second smoothed pseudo-ranges corrected with corrections obtained from message Type 11;

b) the projection matrix, S, used for both position solutions is computed based on $\sigma w,i$ computed using $\sigma_{pr\_gnd\_30s}$ from Message Type 11 and $\sigma_{iono,i}$ based on $\sigma_{vert\_iono\_gradient\_D}$ from Message Type 2 Additional Data Block 3;

c) a second position solution is computed using the projection matrix from b) and the 100-second smoothed pseudo-ranges corrected with corrections obtained from message Type 1; and

d) both position solutions are based on the same set of satellites as used for the position solution defined in a) above.

Additional information regarding the intended use of these dual position solutions is given in 7.5.6.1 of this attachment.

7.20 Type 11 message

A Type 11 message is required for FAST D ground subsystems. The Type 11 message contains differential corrections derived from pseudo-range data that has been carrier smoothed with a time constant of 30 seconds. The Type 11 message also includes alternative parameters for integrity bounding and for optimal weighting of measurements. Additional information regarding the standard processing of parameters in the Type 11 message is given in 7.19.

7.21 Slot occupancy

The slot occupancy requirement in Appendix 6B, 3.6.7.4.1.3 is for ground subsystems that support authentication. The slot occupancy is the length of a burst divided by the length of a single time slot. In more detail and expressed in number of bits:

slot occupancy = (88 bits + up to 1 776 bits application data + 57 to 59 bits for application FEC, fill bits and ramp down) / 1 968.75 bits

The numerator in the formula sums all bits that are included in a single burst of the ground subsystem. These are the first 88 bits from ramp up to training sequence FEC, up to 1 776 application data bits, 48 application FEC bits, 0 to 2 fill bits and 9 bits for ramp down. For the denominator 1 968.75 bits are the calculated number of bits that can be transmitted in 62.5 ms (Appendix 6B, 3.6.3.1) using the data rate of 31 500 bits/s (Appendix 6B, 3.6.2.5).

8. Signal quality monitor (SQM) design

8.1 The objective of the signal quality monitor (SQM) is to detect satellite signal anomalies in order to prevent aircraft receivers from using misleading information (MI). MI is an undetected aircraft pseudo-range differential error greater than the maximum error (MERR) that can be tolerated. For GAST D equipment, additional requirements are in place to assure detection before the differential pseudo-range error reaches a specified value (see Appendix 6B, 3.6.7.3.3). These large pseudo-range errors are due to C/A code correlation peak distortion caused by satellite payload failures. If the reference receiver used to create the differential corrections and the aircraft receiver have different measurement mechanizations (i.e. receiver bandwidth and tracking loop correlator spacing), the signal distortion affects them differently. The SQM must protect the aircraft receiver in cases when mechanizations are not similar. SQM performance is further defined by the probability of detecting a satellite failure and the probability of incorrectly annunciating a satellite failure.

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8.11.4.2 For GBAS airborne equipment class D (GAEC D) receivers using early-late correlators and tracking GPS satellites, the precorrelation bandwidth of the installation, the correlator spacing and the differential group delay are within the ranges defined in Table D-11, regions 2, 3 or 4 only. In addition, in region 2 the range of average correlator spacing is 0.045 – 0.12 chips, and the instantaneous correlator spacing is 0.04 – 0.15 chips.

8.11.4.~~2~~3 For SBAS airborne equipment using early-late correlators and tracking GPS satellites, the precorrelation bandwidth of the installation, the correlator spacing and the differential group delay (including the contribution of the antenna) are within the ranges of the first three regions defined in Table D-11.

...

8.11.5.1 For GBAS airborne equipment class D (GAEC D) aircraft receivers using early-late correlators and tracking GLONASS satellites, the precorrelation bandwidth of the installation, the correlator spacing, and the differential group delay are within the ranges as defined in Table D-12, regions 2 and 3 only. In addition, in region 2 the range of average correlator spacing is 0.05 – 0.1 chips, and the instantaneous correlator spacing is 0.045 – 0.11 chips.

...

8.11.6.1 For GBAS airborne equipment class D (GAEC D) receivers using double-delta correlators and tracking GPS satellites, the precorrelation bandwidth of the installation, the correlator spacing and the differential group delay are within the ranges defined in Table D-13, regions 2 and 3 only.

...

8.11.7.1 For GBAS airborne equipment class D (GAEC D) receivers using the early-late or double-delta correlators and tracking SBAS satellites, the precorrelation bandwidth of the installation, the correlator spacing and the differential group delay are within the ranges defined in Table D-14, region 2 only. In addition, for GAEC D receivers using early-late correlators and tracking SBAS satellites, the average correlator spacing is 0.045 – 0.12 chips, and the instantaneous correlator spacing is 0.04 – 0.15 chips.

. . .

12. GNSS PERFORMANCE ASSESSMENT

12.1 GNSS performance assessment is a periodic offline activity that may be performed by a State or delegated entity, aiming to verify that GNSS performance parameters conform to the relevant Annex 10 Standards. This activity can be done for the core constellation, the augmentation system or a combination of both.

Note.— Additional guidance material on GNSS performance assessment is provided in the Global Navigation Satellite System (GNSS) Manual *(Doc 9849).*

12.2 The data described in Section 11 may also support ~~periodic confirmation of~~ GNSS performance assessment ~~in the service area.~~

. . .

14. MODELLING OF RESIDUAL ERRORS

. . .

14.2 One method of ensuring that the protection level risk requirements are met is to define the model variance (σ^2), such that the cumulative error distribution satisfies the conditions:

$$\int_{y}^{\infty} f(x)dx \leq Q\left(\frac{y}{\sigma}\right) \text{ for all } \left(\frac{y}{\sigma}\right) \geq 0 \text{ and}$$

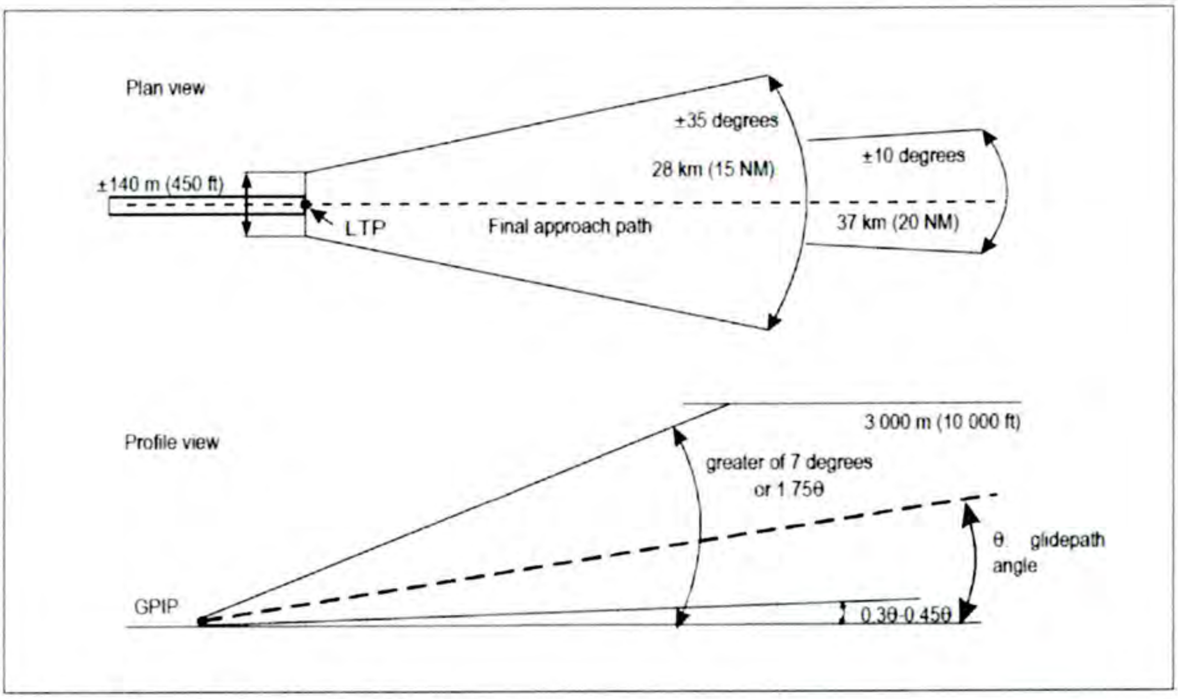
$$\int_{-\infty}^{-y} f(x)dx \leq Q\left(\frac{y}{\sigma}\right) \text{ for all } \left(\frac{y}{\sigma}\right) \geq 0 \text{ and}$$

where

f(x) = probability density function of the residual aircraft pseudo-range error component; and

$$Q(x) = \frac{1}{\sqrt{2\pi}}\int_{x}^{\infty} e^{-\frac{t^2}{2}} dt.$$

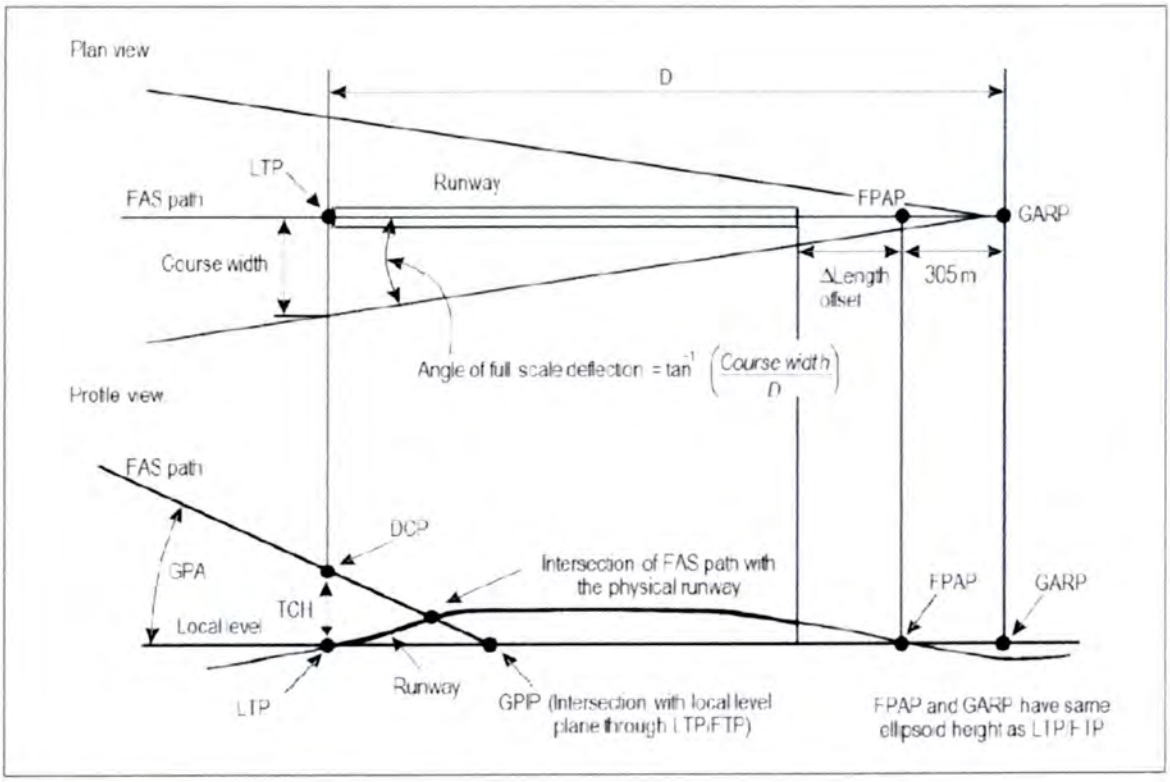
. . .



GPIP – glide path intersection point

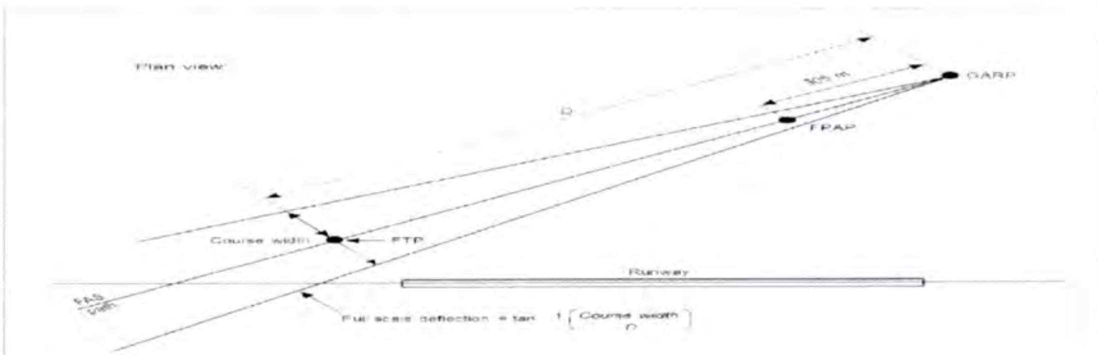
LTP – landing threshold point

Figure D-4. Minimum GBAS ~~coverage~~service volume



DCP—datum crossing point
FAS—final approach segment
FPAP—flight path alignment point
FTP—fictitious threshold point (see Figure D-7)
GARP—~~GBAS~~GNSS azimuth reference point
GPA—glide path angle
GPIP—glide path intersection point
LTP—landing threshold point
TCH—threshold crossing height

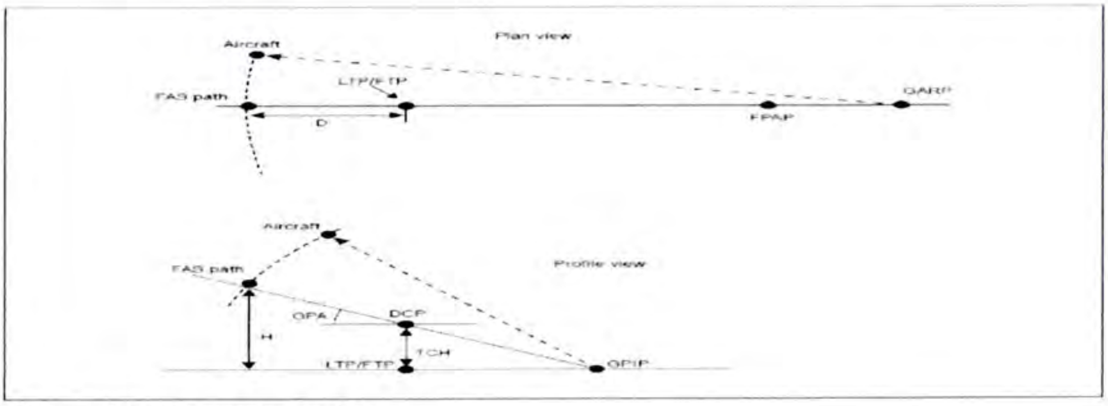
Figure D-6. FAS path definition



FAS — final approach segment

FPAP — flight path alignment point
FTP — fictitious threshold point
GARP — ~~GBAS~~GNSS azimuth reference point

Figure D-7. FAS path definition for approaches not aligned with the runway



DCP — datum crossing point
FAS — final approach segment
FPAP — flight path alignment point
FTP — fictitious threshold point (see Figure D-7)
GARP — ~~GBAS~~GNSS azimuth reference point
GPA — glide path angle
GPIP — glide path intersection point
LTP — landing threshold point
TCH — threshold crossing height

Figure D-8. Definition of D and H parameters in alert limit computations

. . .

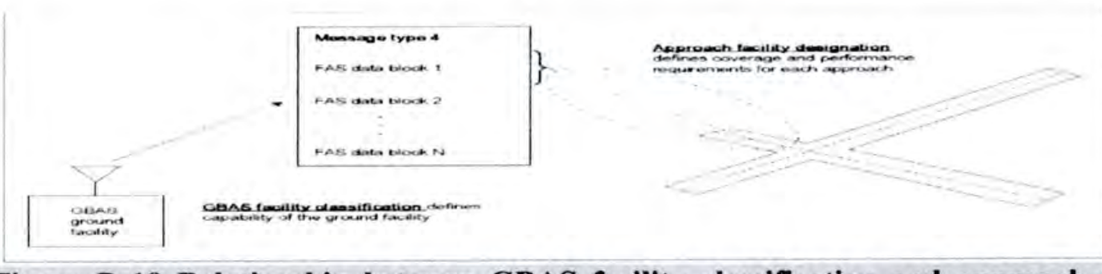


Figure D-10 Relationship between GBAS facility classification and approach facility designation

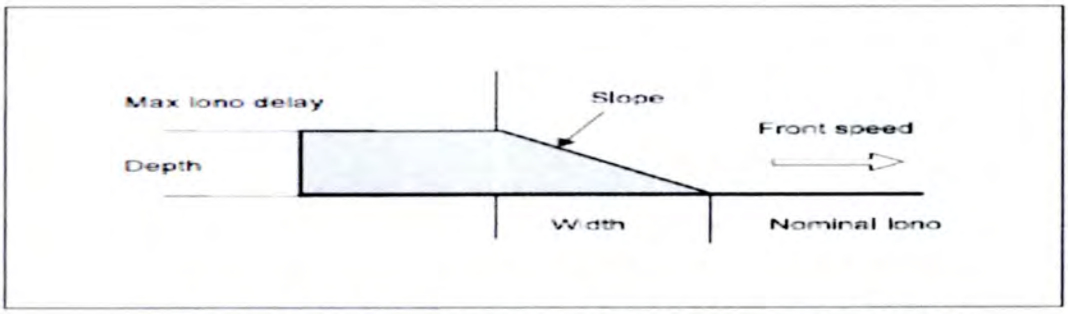


Figure D-11. Moving wedge ionospheric anomaly model

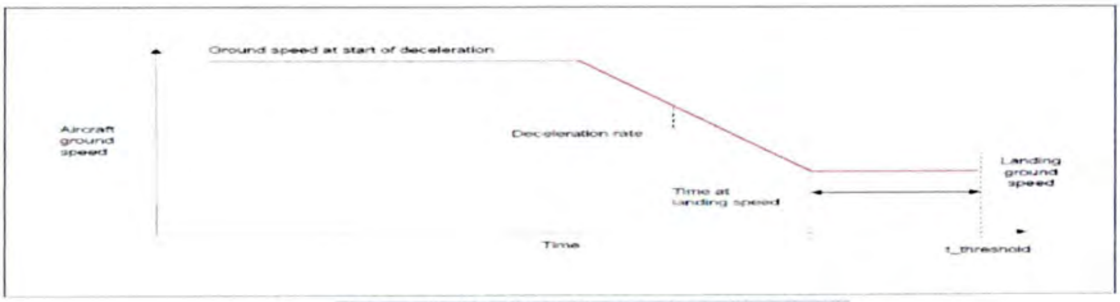


Figure D-12. Aircraft speed profile model

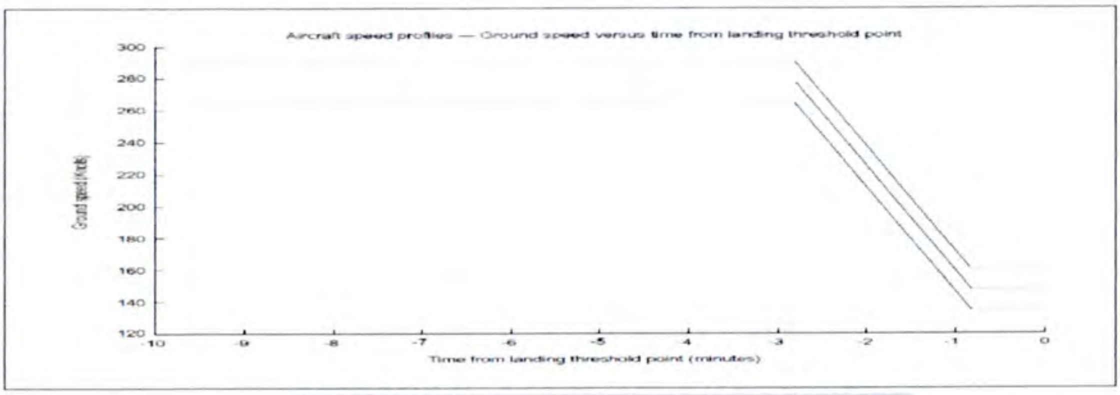


Figure D-13. Family of aircraft speed profiles

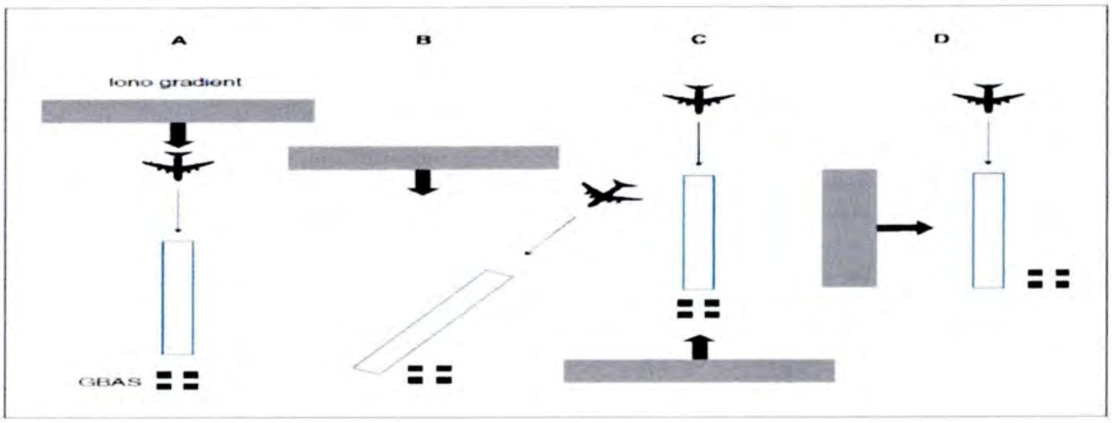


Figure D-14. Ionospheric gradient air/ground/approach orientations

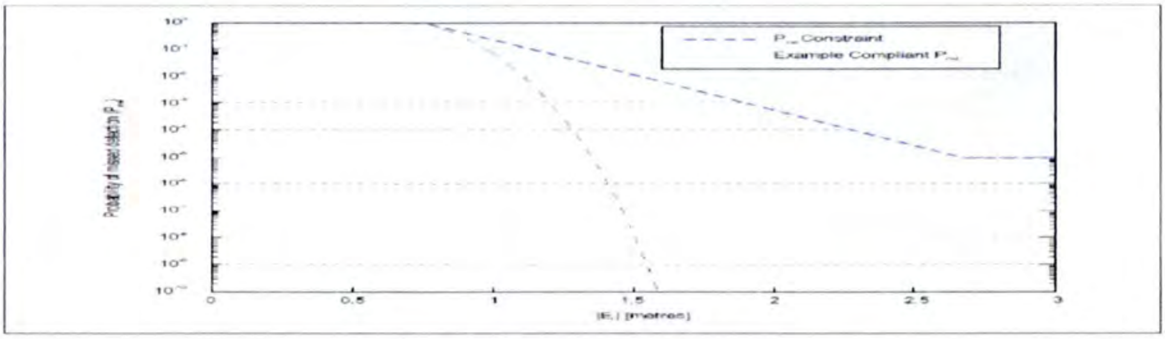


Figure D-15. Example P_{md_limit} constraint region

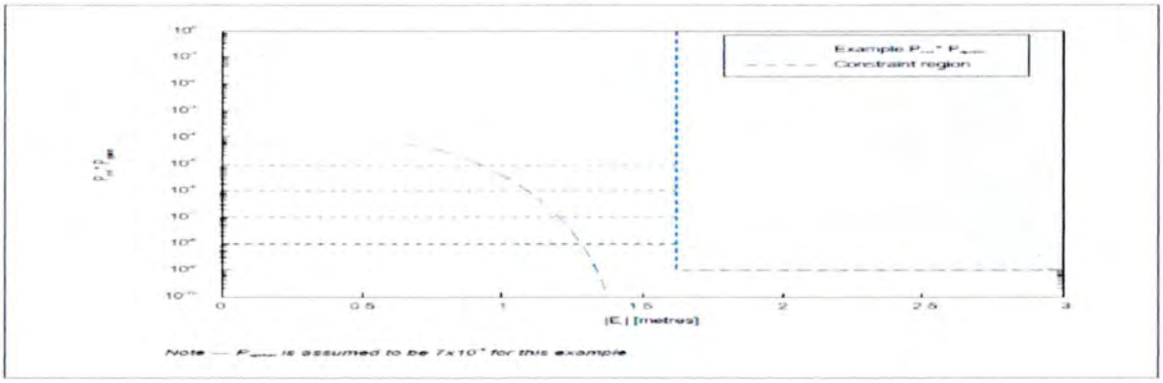


Figure D-16. Example P_{md_limit} constraint with a priori probability

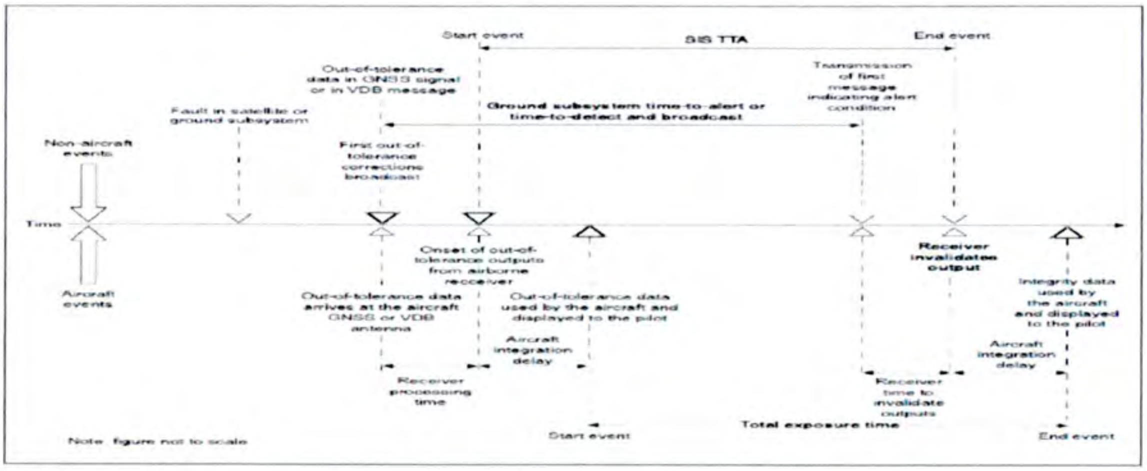


Figure D-17. Nominal GBAS time-to-alert illustration

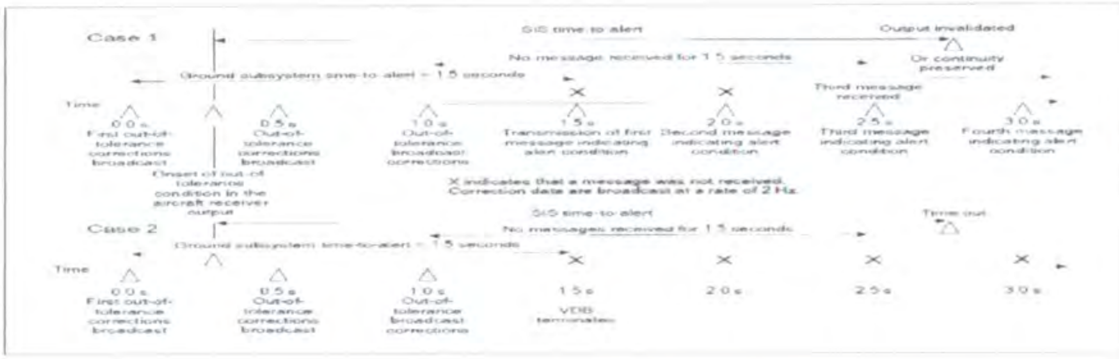


Figure D-18. Effect of missed messages on the GAST D GBAS time-to-alert below 200 ft Case 1 describes the situation for missed messages, Case 2 the one for VDB termination

NEW/AMENDED REGULATIONS:

6.2. GENERAL PROVISIONS FOR RADIO NAVIGATION AIDS

6.2.1 Standard radio navigation aids

...

6.2.1.4 GNSS-specific provisions

...

6.2.1.4.2 A State that approves GNSS-based operations shall ensure that GNSS data relevant to those operations are recorded.

Note 1.— These recorded data can support accident and incident investigations. They may also support periodic analysis to verify the GNSS performance parameters detailed in the relevant Standards in this CAR-ANS.

Note 2.— Guidance material on the recording of GNSS parameters and on GNSS performance assessment is contained in Attachment 6D, 11 and 12.

...

6.3. SPECIFICATIONS FOR RADIO NAVIGATION AIDS

Note.— Specifications concerning the siting and construction of equipment and installations on operational areas aimed at reducing the hazard to aircraft to a minimum are contained in CAAP MOS - Aerodromes, Chapter 11.

6.3.1 Specification for ILS

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6.3.1.2 Basic requirements

. . .

6.3.1.2.7.1 At those locations where two separate ILS facilities serve opposite ends of a single runway and where a Facility Performance Category I — ILS is to be used for auto-coupled approaches and landings in visual conditions an interlock shall ensure that only the localizer serving the approach direction in use radiates, providing the other localizer is not required for simultaneous operational use.

Note.— If both localizers radiate there is a possibility of interference to the localizer signals in the threshold region. Additional guidance material is contained in 2.1.8 of Attachment 6C.

6.3.1.2.7.2 At locations where ILS facilities serving opposite ends of the same runway or different runways at the same airport use the same paired frequencies, an interlock shall ensure that only one facility shall radiate at a time. When switching from one ILS facility to another, radiation from both shall be suppressed for not less than 20 seconds.

Note.— Additional guidance material on the operation of localizers on the same frequency channel is contained in CAR-ANS Part 13, Chapter 4.

6.3.1.3 VHF localizer and associated monitor

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6.3.1.3.3.3 Above 7 degrees, the signals shall be reduced to as low a value as practicable.

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Note 2.— Guidance material on significant airborne receiver parameters is given in 2.2.2 of Attachment 6C.

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6.3.1.3.4 Course structure

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Note 2.— Guidance material relevant to the localizer course structure is given in 2.1.3, 2.1.5, 2.1.6 and 2.1.9 of Attachment 6C.

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6.3.1.3.6 Course alignment accuracy

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Note 3.— Guidance material on measurement of localizer course alignment is given in 2.1.3 of Attachment 6C. Guidance material on protecting localizer course alignment is given in 2.1.9 of Attachment 6C.

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6.3.1.3.10 Siting

Note.— Guidance material relevant to siting localizer antennas in the runway and taxiway environment is given in 2.1.9 of Attachment 6C.

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6.3.1.5 UHF glide path equipment and associated monitor

. . .

6.3.1.5.1.2.1 The glide path angle shall be adjusted and maintained within:

. . .

Note 3.— Guidance material relevant to protecting the ILS glide path course structure is given in 2.1.9 of Attachment 6C.

. . .

6.3.1.5.4 ILS glide path structure

. . .

Note 3.— Guidance material relevant to the ILS glide path course structure is given in 2.1.4 of Attachment 6C. Guidance material relevant to protecting the ILS glide path course structure is given in 2.1.9 of Attachment 6C.

. . .

6.3.1.5.7 Monitoring

6.3.1.5.7.1 The automatic monitor system shall provide a warning to the designated control points and cause radiation to cease within the periods specified in 6.3.1.5.7.3.1 if any of the following conditions persist:

. . .

Note 1.— The value of 0.7475 θ from horizontal is intended to ensure adequate obstacle clearance. This value was derived from other parameters of the glide path and monitor specification. Since the measuring accuracy to four significant figures is not intended, the value of 0.75 θ may be used as a monitor limit for this purpose. Guidance on obstacle clearance criteria is given in the Procedures for Air Navigation Services — Aircraft Operations (PANS-OPS) (Doc 8168).

Note 2.— Subparagraphs f) and g) are not intended to establish a requirement for a separate monitor to protect against deviation of the lower limits of the half-sector below 0.7475 θ from horizontal

Note 3.— At glide path facilities where the selected nominal angular displacement sensitivity corresponds to an angle below the ILS glide path which is close to or at the maximum limits specified in 3.1.5.6, it may be necessary to adjust the monitor operating limits to protect against sector deviations below 0.7475 θ from horizontal.

Note 4.— Guidance material relating to the condition described in g) appears in Attachment 6C, 2.4.11.

6.3.7 Requirements for the Global Navigation Satellite System (GNSS)

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6.3.7.2 General

. . .

6.3.7.2.4 Signal-in-space performance

6.3.7.2.4.1 The combination of GNSS elements and a fault-free GNSS user receiver shall meet the signal-in-space requirements defined in Table 6.3.7.2.4-1 (located at the end of section 6.3.7).

Note 1.— The concept of a fault-free user receiver is applied only as a means of defining the performance of combinations of different GNSS elements. The fault-free receiver is assumed to be a receiver with nominal accuracy and time-to-alert performance. Such a receiver is assumed to have no failures that affect the integrity, availability and continuity performance.

Note 2.— For GBAS approach service (as defined in Attachment 6D, 7.1.2.1) intended to support approach and landing operations using Category III minima, performance requirements are defined that apply in addition to the signal-in-space requirements defined in Table 6.3.7.2.4-1.

. . .

6.3.7.3.4 *Satellite-based augmentation system (SBAS)*

6.3.7.3.4.1 *Performance.* SBAS combined with one or more of the other GNSS elements and a fault-free receiver shall meet the requirements for system accuracy, integrity, continuity and availability for the intended operation as stated in 6.3.7.2.4, throughout the corresponding service area (see 6.3.7.3.4.3)

. . .

6.3.7.3.4.1.1 SBAS combined with one or more of the other GNSS elements and a fault-free receiver shall meet the requirements for signal-in-space integrity as stated in 6.3.7.2.4, throughout the SBAS coverage area.

Note.— Message Types 27 or 28 can be used to comply with the integrity requirements in the coverage area. Additional guidance on the rationale and interpretation of this requirement is provided in Attachment 6D, 3.3.

. . .

6.3.7.3.4.3 *Service area.* An SBAS service area for any approved type of operation shall be a declared area within the SBAS coverage area where SBAS meets the corresponding requirements of 6.3.7.2.4.

Note 1.— An SBAS system can have different service areas corresponding to different types of operation (e.g. APV-I, Category I, etc.).

Note 2.— The coverage area is that area within which the SBAS broadcast can be received (i.e. the geostationary satellite footprints).

Note 3.— SBAS coverage and service areas are discussed in Attachment 6D, 6.2.

. . .

6.3.7.3.5 Ground-based augmentation system (GBAS) and ground-based regional augmentation system (GRAS)

Note.— Except where specifically annotated, GBAS Standards and Recommended Practices apply to GBAS and GRAS.

6.3.7.3.5.1 *Performance.* GBAS combined with one or more of the other GNSS elements and a fault-free GNSS receiver shall meet the requirements for system accuracy, continuity, availability and integrity for the intended operation as stated in 6.3.7.2.4 within the service volume for the service used to support the operation as defined in 6.3.7.3.5.3.

Note.— GBAS is intended to support all types of approach, landing, guided take-off, departure and surface operations and may support en-route and terminal operations. GRAS is intended to support en-route, terminal, non-precision approach, departure, and approach with vertical guidance. The following SARPs are developed to support all categories of precision approach, approach with vertical guidance, and a GBAS positioning service.

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6.3.7.3.5.3 *Service volume*

6.3.7.3.5.3.1 *General requirement for approach services.* The minimum GBAS approach service volume shall be as follows, except where topographical features dictate and operational requirements permit:

a) laterally, beginning at 140 m (450 ft) each side of the landing threshold point/fictitious threshold point (LTP/FTP) and projecting out ±35 degrees either side of the final approach path to 28 km (15 NM) and ±10 degrees either side of the final approach path to 37 km (20 NM); and

b) vertically, within the lateral region, up to the greater of 7 degrees or 1.75 promulgated glide path angle (GPA) above the horizontal with an origin at the glide path interception point (GPIP) to an upper bound of 3 000 m (10 000 ft) height above threshold (HAT) and 0.45 GPA above the horizontal or to such lower angle, down to 0.30 GPA, as required, to safeguard the promulgated glide path intercept procedure. The lower bound is half the lowest decision height supported or 3.7 m (12 ft), whichever is larger.

Note 1.— LTP/FTP and GPIP are defined in Appendix 6B, 3.6.4.5.1.

Note. 2 — Guidance material concerning the approach service volume is provided in Attachment 6D, 7.3.

6.3.7.3.5.3.2 *Approach services supporting autoland and guided take-off.* The minimum additional GBAS service volume to support approach operations that include automatic landing and roll-out, including during guided take-off, shall be as follows, except where operational requirements permit:

a) Horizontally, within a sector spanning the width of the runway beginning at the stop end of the runway and extending parallel with the runway centre line towards the LTP to join the minimum service volume as described in 6.3.7.3.5.3.1.

b) Vertically, between two horizontal surfaces one at 3.7 m (12 ft) and the other at 30 m (100 ft) above the runway centre line to join the minimum service volume as described in 6.3.7.3.5.3.1.

Note.— Guidance material concerning the approach service volume is provided in Attachment 6D, 7.3.

6.3.7.3.5.3.3 *GBAS positioning service.* The service volume for the GBAS positioning service shall be where the data broadcast can be received and the positioning service meets the requirements of 6.3.7.2.4 and supports the corresponding approved operations.

Note.— Guidance material concerning the positioning service volume is provided in Attachment 6D, 7.3.

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6.3.7.3.5.4.4 Data broadcast RF field strength and polarization

Note 1.— GBAS can provide a VHF data broadcast with either horizontal (GBAS/H) or elliptical (GBAS/E) polarization that employs both horizontal polarization (HPOL) and vertical polarization (VPOL) components. Aircraft using a VPOL component will not be able to conduct operations with GBAS/H equipment. Relevant guidance material is provided in Attachment 6D, 7.1.

Note 2.— The minimum and maximum field strengths are consistent with a minimum distance of 80 m (263 ft) from the transmitter antenna for a range of 43 km (23 NM).

Note 3.— When supporting approach services at airports with challenging VDB transmitter siting constraints, it is acceptable to adjust the service volume when operational requirements permit (as stated in the service volume definition sections 6.3.7.3.5.3.1 and 6.3.7.3.5.3.2). Such adjustments of the service volume may be operationally acceptable when they have no impact on the GBAS service outside a radius of 80 m (263 ft) from the VDB antenna, assuming a nominal effective isotropically radiated power of 47dBm (Attachment 6D, Table D-3).

6.3.7.3.5.4.4.1 GBAS/H

. . .

6.3.7.3.5.4.4.1.2 The effective isotropically radiated power (EIRP) shall provide for a horizontally polarized signal with a minimum field strength of 215 microvolts per metre (–99 dBW/m^2) and a maximum field strength of 0.879 volts per metre (–27 dBW/m^2) within the GBAS service volume as specified in 6.3.7.3.5.3.1. The field strength shall be measured as an average over the period of the synchronization and ambiguity resolution field of the burst.

Within the additional GBAS service volume, as specified in 6.3.7.3.5.3.2, the effective isotropically radiated power (EIRP) shall provide for a horizontally polarized signal with a minimum field strength of 215 microvolts per metre (–99 dBW/m^2) below 36 ft and down to 12 ft above the runway surface and 650 microvolts per metre (-89.5 dBW/m^2) at 36 ft or more above the runway surface.

Note.— Guidance material concerning the approach service volume is provided in Attachment 6D, 7.3.

6.3.7.3.5.4.4.2 *GBAS/E*

...

6.3.7.3.5.4.4.2.2 When an elliptically polarized signal is broadcast, the horizontally polarized component shall meet the requirements in 6.3.7.3.5.4.4.1.2, and the effective isotropically radiated power (EIRP) shall provide for a vertically polarized signal with a minimum field strength of 136 microvolts per metre (–103 dBW/m^2) and a maximum field strength of 0.555 volts per metre (–31 dBW/m^2) within the GBAS service volume. The field strength shall be measured as an average over the period of the synchronization and ambiguity resolution field of the burst.

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Table 6.3.7.2.4-1 Signal-in-space performance requirements

Typical operation	Accuracy horizontal 95% (Notes 1 and 3)	Accuracy vertical 95% (Notes 1 and 3)	Integrity (Note 2)	Time-to-alert (Note 3)	Continuity (Note 4)	Availability (Note 5)
En-route	3.7 km (2.0 NM)	N/A	$1 - 1 \times 10^{-7}$/h	5 min	$1 - 1 \times 10^{-4}$/h to $1 - 1 \times 10^{-8}$/h	0.99 to 0.99999
En-route, Terminal	0.74 km (0.4 NM)	N/A	$1 - 1 \times 10^{-7}$/h	15 s	$1 - 1 \times 10^{-4}$/h to $1 - 1 \times 10^{-8}$/h	0.99 to 0.99999
Initial approach, Intermediate approach, Non-precision approach (NPA), Departure	220 m (720 ft)	N/A	$1 - 1 \times 10^{-7}$/h	10 s	$1 - 1 \times 10^{-4}$/h to $1 - 1 \times 10^{-8}$/h	0.99 to 0.99999
Approach operations with vertical guidance (APV-I) (Note 8)	16.0 m (52 ft)	20 m (66 ft)	$1 - 2 \times 10^{-7}$ in any approach	10 s	$1 - 8 \times 10^{-6}$ per 15 s	0.99 to 0.99999
Approach operations with vertical guidance (APV-II) (Note 8)	16.0 m (52 ft)	8.0 m (26 ft)	$1 - 2 \times 10^{-7}$ in any approach	6 s	$1 - 8 \times 10^{-6}$ per 15 s	0.99 to 0.99999
Category I precision approach (Note 7)	16.0 m (52 ft)	6.0 m to 4.0 m (20 ft to 13 ft) (Note 6)	$1 - 2 \times 10^{-7}$ in any approach	6 s	$1 - 8 \times 10^{-6}$ per 15 s	0.99 to 0.99999

NOTES.—

1. The 95th percentile values for GNSS position errors are those required for the intended operation at the lowest height above threshold (HAT), if applicable. Detailed requirements are specified in Appendix B and guidance material is given in Attachment 6D, 3.2.

. . .

7. GNSS performance requirements intended to support Category II and III precision approach operations necessitate lower level requirements in the technical appendix (Appendix 6B section 3.6) to be applied in addition to these signal-in –space requirements (see Attachment 6D, 7.5.1).

. . .

APPENDIX 6B. TECHNICAL SPECIFICATIONS FOR THE GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS)

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3.5 Satellite-based augmentation system (SBAS)

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Table B-23. SBAS PRN codes

PRN code number	G2 delay (chips)	First 10 SBAS chips (Leftmost bit represents first transmitted chip, binary)
120	145	0110111001
121	175	0101011110
122	52	1101001000
123	21	1101100101
124	237	0001110000
125	235	0111000001
126	886	0000001011
127	657	1000110000
128	634	0010100101
129	762	0101010111
130	355	1100011110
131	1 012	1010010110
132	176	1010101111
133	603	0000100110
134	130	1000111001
135	359	0101110001
136	595	1000011111
137	68	0111111000
138	386	1011010111
139	797	1100111010
140	456	0001010100
141	499	0011110110
142	883	0001011011
143	307	0100110101
144	127	0111001111
145	211	0010001111
146	121	1111100010
147	118	1100010010
148	163	1100100010
149	628	0101010011
150	853	0111011110
151	484	1110011101
152	289	0001011110
153	811	0010111011
154	202	1000010110
155	1021	0000000011
156	463	1110111000
157	568	0110010100
158	904	0010011101

3.5.4.1 *PRN mask parameters*. PRN mask parameters shall be as follows:

PRN code number: a number that uniquely identifies the satellite PRN code and related assignments as shown in Table B-25.

. . .

Table B-25. PRN code number assignments

PRN code number	Assignment
1 – 37	GPS
38 – 61	GLONASS slot number plus 37
62 – 119	Spare
120 – 158	SBAS
159 – 210	Spare

. . .

3.6 Ground-based augmentation system (GBAS) and ground-based regional augmentation system (GRAS)

3.6.1 GENERAL

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3.6.1.1 *GBAS service types.* A GBAS ground subsystem shall support either the positioning service, approach service or both types of service.

Note 1. - Service types refers to a matched set of ground and airborne functional and performance requirements that ensure that quantifiable navigation performance is achieved by the airborne equipment. Guidance material concerning service types is given in Attachment 6D, 7.1.

Note 2.— GBAS ground facilities are characterized by a GBAS facility classification (GFC). Many GBAS performance and functional requirements depend on the GFC. These SARPs are organized according to which requirements apply for a given facility classification element (i.e. the facility approach service type (FAST) letter, the facility polarization, etc.). Guidance material concerning facility classifications is given in Attachment 6D, 7.1.4.1.

3.6.1.2 All GBAS ground subsystems shall comply with the requirements of 3.6.1, 3.6.2, 3.6.3, 3.6.4, 3.6.6 and 3.6.7, unless otherwise stated. A FAST D ground subsystem shall comply with all FAST C requirements in addition to the specific FAST D requirements.

3.6.2 RF CHARACTERISTICS

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3.6.2.6 *Emissions in unassigned time slots.* Under all operating conditions, the maximum power over a 25 kHz channel bandwidth, centred on the assigned frequency, when measured over any unassigned time slot, shall not exceed –105 dBc referenced to the authorized transmitter power.

Note.— The –105 dBc may not protect reception of emissions in a slot assigned to another desired transmitter for receivers within 80 metres from the undesired transmitting antenna.

. . .

3.6.4 DATA CONTENT

. . .

3.6.4.2.1 The Type 1 message shall provide the differential correction data for individual GNSS ranging sources (Table B-70). The message shall contain three sections:

. . .

Note 1.— Transmission of the low-frequency data for SBAS ranging sources is optional.

Note 2.— All parameters in this message type apply to 100-second carrier-smoothed pseudo-ranges.

...

Table B-63 GBAS VHF data broadcast messages

Message Type Identifier	Message name
0	Spare
1	Pseudo-range corrections
2	GBAS-related data
3	Null message
4	Final approach segment (FAS) data
5	Predicted ranging source availability
6	Reserved
7	Reserved for national applications
8	Reserved for test applications
9 to 10	Spare
11	Pseudo-range-corrections-30-second smoothed pseudo-ranges
12 to 100	Spare
101	GRAS pseudo-range corrections
102-255	Spare

Note.- See 3.6.6 for message formats.

. . .

3.6.4.2.4 The measurement block parameters shall be as follows:

Ranging source ID: the identity of the ranging source to which subsequent measurement block data are applicable.

. . .

Coding:
1 to 36 = GPS satellite IDs (PRN)

37 = reserved
38 to 61 = GLONASS satellite IDs (slot number plus 37)
62 to 119 = spare
120 to 158 = SBAS satellite IDs (PRN)
159 to 255 = spare
. . .

B_1 through B_4: are the integrity parameters associated with the pseudo-range corrections provided in the same measurement block. For the i^{th} ranging source these parameters correspond to $B_{i,1}$ through $B_{i,4}$ (3.6.5.5.1.2, 3.6.5.5.2.2 and 3.6.7.2.2.4). During continuous operation, the indices "1-4" correspond to the same physical reference receiver for every epoch transmitted from a given ground subsystem with the following exception: the physical reference receiver tied to any of the indices 1 to 4 can be replaced by any other physical reference receiver (including a previously removed one) that has not been used for transmissions during the last 5 minutes.

Coding: 1000 0000 = Reference receiver was not used to compute the pseudo-range correction.

Note 1.— A physical reference receiver is a receiver with an antenna at a fixed location.

Note 2. — Some airborne inertial integrations may expect a largely static correspondence of the reference receivers to the indices. Refer to RTCA/DO-253D, Appendix L

. . .

GBAS continuity/integrity designator (GCID): numeric designator indicating the operational status of the GBAS.

Coding: 0 = spare
1 = GCID 1
2 = GCID 2
3 = GCID 3
4 = GCID 4
5 = spare
6 = spare
7 = unhealthy

Note 1.— The values of GCID, 3 and 4 are specified in order to ensure compatibility of equipment with future GBAS.

Note 2.— The value of GCID 7 indicates that all approach services supported by the ground facility are unavailable.
. . .

3.6.4.3.1 *Additional data block 1 parameters.* Additional data block 1 parameters shall be as follows:

. . .

MAXIMUM USE DISTANCE (D_{max}): the maximum distance (slant range) from the GBAS reference point within which pseudo-range corrections are applied by the aircraft element.

Note.— This parameter does not indicate a distance within which VHF data broadcast field strength requirements are met.

Coding: 0 = distance limitation

GPS EPHEMERIS MISSED DETECTION PARAMETER, GBAS Positioning Service ($K_{md\_e\_POS,GPS}$): the multiplier for computation of the ephemeris error position bound for the GBAS positioning service derived from the probability of missed detection given that there is an ephemeris error in a GPS satellite.

For GBAS ground subsystems that do not broadcast corrections for GPS ranging sources or that do not provide the GBAS positioning service, this parameter shall be coded as all zeros.

GPS EPHEMERIS MISSED DETECTION PARAMETER, GBAS approach service types A, B or C ($K_{md\_e,GPS}$): the multiplier for computation of the ephemeris error position bound for GBAS approach service types A, B and C derived from the probability of missed detection given that there is an ephemeris error in a GPS satellite.

For GBAS ground subsystems that do not broadcast corrections for GPS ranging sources, this parameter shall be coded as all zeros

GLONASS EPHEMERIS MISSED DETECTION PARAMETER, GBAS Positioning Service ($K_{md\_e,\_POS,GLONASS}$): the multiplier for computation of the ephemeris error position bound for the GBAS positioning service derived from the probability of missed detection given that there is an ephemeris error in a GLONASS satellite.

For GBAS ground subsystems that do not broadcast corrections for GLONASS ranging sources or that do not provide positioning service, this parameter shall be coded as all zeros.

GLONASS EPHEMERIS MISSED DETECTION PARAMETER, GBAS approach service types A, B or C ($K_{md\_e\_,GLONASS}$): the multiplier for computation of the ephemeris error position bound for GBAS approach service types A, B and C derived from the probability of missed detection given that there is an ephemeris error in a GLONASS satellite

. . .

3.6.4.3.2 *Additional data blocks.* For additional data blocks other than additional data block 1, the parameters for each data block shall be as follows:

. . .

ADDITIONAL DATA BLOCK NUMBER: the numerical identifier of the type of additional data block.

Coding :	0-1	= Reserved
	2	= additional data block 2, GRAS broadcast stations
	3	= **additional data block 3, GAST D parameters**
	4	= additional data block 4, VDB authentication Parameters
	5 to 255	= Spare

. . .

3.6.4.3.2.2 GAST D parameters

Parameters for additional data block 3 shall include parameters (Table B-65B) to be used when the active service type is GAST D as follows:

Kmd_e_D,GLONASS ($K_{md\_e\_D,GLONASS}$): is the multiplier for computation of the ephemeris error position bound for GAST D derived from the probability of missed detection given that there is an ephemeris error in a GLONASS satellite. For GBAS ground subsystems that do not broadcast corrections for GLONASS ranging sources, this parameter is coded as all zeros.

Note.— This parameter, Kmd_e_D,GLONASS, may be different than the ephemeris decorrelation parameter Kmd_e_GLONASS provided in additional data block 1 of the Type 2 message. Additional information regarding the difference in these parameters is given in Attachment 6D, 7.5.6.1.2 and 7.5.6.1.3.

Kmd_e_D,GPS ($K_{md\_e\_D,GPS}$): is the multiplier for computation of the ephemeris error position bound for GAST D derived from the probability of missed detection given that there is an ephemeris error in a GPS satellite. For GBAS ground sub-systems that do not broadcast corrections for GPS ranging sources, this parameter is coded as all zeros.

Note.— This parameter, Kmd_e_D,GPS, may be different than the ephemeris decorrelation parameter Kmd_e_GPS provided in additional data block 1 of the Type 2 message. Additional information regarding the difference in these parameters is given in Attachment 6D, 7.5.6.1.2 and 7.5.6.1.3.

Sigma_vert_iono_gradient_D ($\sigma_{vert\_iono\_gradient\_D}$): is the standard deviation of a normal distribution associated with the residual ionospheric uncertainty due to spatial decorrelation. This parameter is used by airborne equipment when its active approach service type is D.

Note.— This parameter, Sigma_vert_iono_gradient_D, may be different than the ionospheric decorrelation parameter Sigma_vert_iono_gradient provided in the Type 2 message. Additional information regarding the difference in these parameters is given in Attachment 6D, 7.5.6.1.2 and 7.5.6.1.3.

Y_{EIG}: is the maximum value of E_{IG} at zero distance from the GBAS reference point. This parameter is used by airborne equipment when its active approach service type is D.

M_{EIG}: is the slope of maximum E_{IG} versus distance from the GBAS reference point. This parameter is used by airborne equipment when its active approach service type is D.

3.6.4.3.2.3 *VDB authentication parameters*

Additional data block 4 includes information needed to support VDB authentication protocols (Table B-65C).

Slot group definition: This 8-bit field indicates which of the 8 slots (A-H) are assigned for use by the ground station. The field is transmitted LSB first. The LSB corresponds to slot A, the next bit to slot B, and so on. A "1" in the bit position indicates the slot is assigned to the ground station. A "0" indicates the slot is not assigned to the ground station.

3.6.4.4 *TYPE 3 MESSAGE — NULL MESSAGE*

. . .

3.6.4.5 *Type 4 message — Final approach segment (FAS).* Type 4 message shall contain one or more sets of FAS data, each defining a single precision approach (Table B-72). Each Type 4 message data set shall include the following:

. . .

FAS data block: the set of parameters to identify an approach and define its associated approach path.

. . .

FASLAL/approach status: the value of the parameter FASLAL as used in 3.6.5.6.

Coding: 1111 1111 = Do not use approach.

Note.— The Procedures for Air Navigation Services — Aircraft Operations *(PANS-OPS) (Doc 8168), Volume II, specifies conventions to be used by procedure designers when applying the FAS data block definitions and codings below to encode procedures.*

Table B-65B Additional Data Block 3 GAST D Parameters

Data content	Bits used	Range of values	Resolution
$K_{md\ e\ D,GPS}$	8	0 to 12.75	0.05
$K_{md\ e\ D,GLONASS}$	8	0 to 12.75	0.05
$\sigma_{vert\ iono\ gradient\ D}$	8	0 to 25.5 × 10^{-6} m/m	0.1 × 10^{-6} m/m
Y_{EIG}	5	0 to 3.0 m	0.1
M_{EIG}	3	0 to 0.7 m/km	0.1

Table B-65C. VDB authentication parameters

Data content	Bits used	Range of values	Resolution
Slot group definition	8	-	-

3.6.4.5.1 *FAS data block.* The FAS data block shall contain the parameters that define a single GAST A, B, C or D approach. The FAS path is a line in space defined by the landing threshold point/fictitious threshold point (LTP/FTP), flight path alignment point (FPAP), threshold crossing height (TCH) and glide path angle (GPA). The local level plane for the approach is a plane perpendicular to the local vertical passing through the LTP/FTP (i.e. tangent to the ellipsoid at the LTP/FTP). Local vertical for the approach is normal to the WGS-84 ellipsoid at the LTP/FTP. The glide path intercept point (GPIP) is where the final approach path intercepts the local level plane. FAS data block parameters shall be as follows:

. . .

Note.— Offset procedures are straight-in procedures and coded as "0".

. . .

Approach performance designator: the general information about the approach design.

Coding:
0 = GAST A or B
1 = GAST C
2 = GAST C and GAST D
3 = GAST C, GAST D and an additional approach service type to be defined in the future
4 = GAST C, GAST D and two additional approach service types to be defined in the future
5 to 7 = spare

. . .

3.6.4.10 *TYPE 101 MESSAGE —GRAS PSEUDO-RANGE CORRECTIONS*

3.6.4.10.1 The Type 101 message shall provide the differential correction data for individual GNSS ranging sources (Table B-70A). The message shall contain three sections:

. . .

c) satellite data measurement blocks.

Note.— All parameters in this message type apply to 100-second carrier-smoothed pseudo-ranges.

. . .

3.6.4.11 *TYPE 11 MESSAGE — PSEUDO-RANGE CORRECTIONS —30-SECOND SMOOTHED PSEUDO-RANGES*

3.6.4.11.1 The Type 11 message shall provide the differential correction data for individual GNSS ranging sources (Table B-70B) with 30-second carrier-smoothing applied. The message shall contain three sections:

a) message information (time of validity, additional message flag, number of measurements and the measurement type);

b) low-frequency information (ephemeris decorrelation parameter); and

c) satellite data measurement blocks.

Note.— Transmission of the low-frequency data for SBAS ranging sources is optional.

3.6.4.11.2 Each Type 11 message shall include the ephemeris decorrelation parameter for one satellite ranging source. The ephemeris decorrelation parameter shall apply to the first ranging source in the message.

Note.— The ephemeris CRC and source availability duration parameters are not included in the Type 11 message because they are provided in the Type 1 message.

3.6.4.11.3 Pseudo-range correction parameters for the Type 11 message shall be as follows:

Modified Z-count: as defined in 3.6.4.2.3.

Additional message flag: an identification of whether the set of measurement blocks in a single frame for a particular measurement type is contained in a single Type 11 message or a linked pair of messages.

Coding: 0	=	All measurement blocks for a particular measurement type are contained in one Type 11 message.
1	=	This is the first transmitted message of a linked pair of Type 11 messages that together contain the set of all measurement blocks for a particular measurement type.
2	=	Spare
3	=	This is the second transmitted message of a linked pair of Type 11 messages that together contain the set of all measurement blocks for a particular measurement type.

Number of measurements: the number of measurement blocks in the message.

Measurement type: as defined in 3.6.4.2.3.

Ephemeris decorrelation parameter D (P_D): a parameter that characterizes the impact of residual ephemeris errors due to decorrelation for the first measurement block in the message.

Note.— This parameter, P_D, may be different than the ephemeris decorrelation parameter P provided in the Type 1 message. Additional information regarding the difference in these parameters is given in Attachment 6D, 7.5.6.1.3 and 7.5.6.1.4.

For an SBAS geostationary satellite, the ephemeris decorrelation parameter, if transmitted, shall be coded as all zeros.

3.6.4.11.4 The measurement block parameters shall be as follows:

Ranging source ID: as defined in 3.6.4.2.3.

Pseudo-range correction (PRC_{30}): the correction to the ranging source pseudo-range based on 30-second carrier smoothing.

Range rate correction (RRC_{30}): the rate of change of the pseudo-range correction based on 30-second carrier smoothing.

Sigma_PR_gnd_D ($\sigma_{pr\_gnd\_D}$): the standard deviation of a normal distribution associated with the signal-in-space contribution of the pseudo-range error in the 100-second smoothed correction in the Type 1 message at the GBAS reference point (3.6.5.5.1 and 3.6.7.2.2.4).

Note.— The parameter $\sigma_{pr\_gnd\_D}$ differs from $\sigma_{pr\_gnd\_}$ for the corresponding measurement in the Type 1 message in that $\sigma_{pr\_gnd\_D}$ shall include no inflation to address overbounding of decorrelated ionospheric errors.

Coding: 1111 1111 = Ranging source correction invalid.

Sigma_PR_gnd_30 ($\sigma_{pr\_gnd\_30}$): the standard deviation of a normal distribution that describes the nominal accuracy of corrected pseudo-range smoothed with a time constant of 30 seconds at the GBAS reference point.

Note.— The normal distribution N(0, $\sigma_{pr\_gnd\_D}$) is intended to be an appropriate description of the errors to be used in optimizing the weighting used in a weighted least squares position solution. The distribution need not bound the errors as described in 3.6.5.5.1 and 3.6.7.2.2.4.

Coding: 1111 1111 = Ranging source correction invalid.

3.6.5 DEFINITIONS OF PROTOCOLS FOR DATA APPLICATION

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3.6.5.1 *Measured and carrier smoothed pseudo-range.* The broadcast correction is applicable to carrier smoothed code pseudo-range measurements that have not had the satellite broadcast troposphere and ionosphere corrections applied to them. The carrier smoothing is defined by the following filter:

. . .

where

P_{CSCn} = the smoothed pseudo-range;
P_{CSCn-1} = the previous smoothed pseudo-range;
P = the raw pseudo-range measurement where the raw pseudo-range measurements are obtained from a carrier driven code loop, first order or higher and with a one-sided noise bandwidth greater than or equal to 0.125 Hz;

λ = the L1 wavelength;
ϕ_n = the carrier phase;
ϕ_{n-1} = the previous carrier phase; and
α = the filter weighting function equal to the sample interval divided by the smoothing time constant. For GBAS pseudo-range corrections in message Type 1 and message Type 101, the smoothing time constant is 100 seconds, except as specified in 3.6.8.3.5.1 for airborne equipment. For GBAS pseudo-range corrections in message Type 11, the smoothing time constant is 30 seconds.

3.6.5.2 *Corrected pseudo-range.* The corrected pseudo-range for a given satellite at time *t* is:

$$PR_{corrected} = P_{CSC} + PRC + RRC \times (t - \text{tz-count}) + TC + c \times (\Delta t_{sv})_{L1}$$

where

P_{CSC} = the smoothed pseudo-range (defined in 3.6.5.1);

PRC = the pseudo-range correction from the appropriate message:

a) for 100-second smoothed pseudo-ranges, PRC is taken from message Type 1 or Type 101 defined in 3.6.4.2; and

b) for 30-second smoothed pseudo-ranges, PRC is PRC_{30} taken from message Type 11 defined in 3.6.4.11;

RRC = the pseudo-range correction rate from the appropriate message:

a) for 100-second smoothed pseudo-ranges, RRC is taken from message Type 1 or Type 101 defined in 3.6.4.2; and

b) for 30-second smoothed pseudo-ranges, RRC is RRC30 taken from message Type 11 defined in 3.6.4.11;

t = the current time;

tz-count = the time of applicability derived from the modified Z-count of the message containing PRC and RRC;

TC = the tropospheric correction (defined in 3.6.5.3); and
c and $(\Delta t_{sv})_{L1}$ are as defined in 3.1.2.2 for GPS satellites.

3.6.5.3 TROPOSPHERIC DELAY

. . .

3.6.5.4 *Residual ionospheric uncertainty.* The residual ionospheric uncertainty for a given satellite is:

$$\sigma_{iono} = F_{pp} \times \sigma_{vig} \times (x_{air} + 2 \times \tau \times v_{air})$$

where

F_{pp} = the vertical-to-slant obliquity factor for a given satellite (3.5.5.5.2);

σ_{vig} = is dependent on the active GAST. For GAST A, B or C, $\sigma_{vig} = \sigma_{vert\_iono\_gradient}$ (as defined in 3.6.4.3); For GAST D, $\sigma_{vig} = \sigma_{vert\ iono\ gradient\ D}$ (as defined in 3.6.4.3.2.2);

x_{air} = the distance (slant range) in metres between current aircraft location and the GBAS reference point indicated in the Type 2 message;

τ = is dependent on the active GAST.
For GAST A, B or C, τ =100 seconds (time constant used in 3.6.5.1); and For GAST D, the value of τ depends on whether σ_{iono} is applied in measurement weighting or in integrity bounding. τ = 100 seconds when σ_{iono} is used for integrity bounding (per section.3.6.5.5.1.1.1) and τ = 30 seconds when σ_{iono} is used for measurement weighting (per section 3.6.5.5.1.1.2);

v_{air} = the aircraft horizontal approach velocity (metres per second).

3.6.5.5 *PROTECTION LEVELS*

3.6.5.5.1 *Protection levels for all GBAS approach service types.* The signal-in-space vertical and lateral protection levels (VPL and LPL) are upper confidence bounds on the error in the position relative to the GBAS reference point defined as:

$$VPL = MAX\{VPL_{HO}, VPL_{H1}\}$$

$$LPL = MAX\{LPL_{HO}, LPL_{H1}\}$$

3.6.5.5.1.1 *Normal measurement conditions*

3.6.5.5.1.1.1 The vertical protection level (VPL_{H0}) and lateral protection level (LPL_{H0}), assuming that normal measurement conditions (i.e. no faults) exist in all reference receivers and on all ranging sources, is calculated as:

$$VPL_{H0} = K_{ffmd}\sigma_{vert} + D_V$$

$$LPL_{H0} = K_{ffmd}\sigma_{lat} + D_L$$

where

$$\sigma_{vert} = \sqrt{\sum_{i=1}^{N} s\_vert_i^2 \times \sigma_i^2}$$

$$\sigma_{lat} = \sqrt{\sum_{i=1}^{N} s\_lat_i^2 \times \sigma_i^2}$$

$$\sigma_i^2 = \sigma^2_{pr\_gnd,i} + \sigma^2_{tropo,i} + \sigma^2_{pr\_air,i} + \sigma^2_{iono,i};$$

and

$\sigma_{pr\_gnd,i}$ is dependent on the active GAST.
For GAST A, B or C: $\sigma_{pr\_gnd,i} = \sigma_{pr\_gnd}$ for the i^th ranging source as defined in 3.6.4.2;
For GAST D: $\sigma_{pr\_gnd,i} = \sigma_{pr\_gnd\_D}$ for the i^th ranging source (3.6.4.11);
$\sigma^2_{tropo,i}$, $\sigma^2_{pr\_air,i}$ and $\sigma^2_{iono,i}$ are as defined in section 3.6.5.5.1.1.2;

K_{ffmd} = the multiplier derived from the probability of fault-free missed detection;

$s\_vert_i = s_{v,i} + s_{x,i} \times \tan(GPA)$;

$s\_lat_i = s_{y,i}$;

$s_{x,i}$ = the partial derivative of position error in the x-direction with respect to pseudo-range error on the i^th satellite;

$s_{y,i}$ = the partial derivative of position error in the y-direction with respect to pseudo-range error on the i^th satellite;

$s_{v,i}$ = the partial derivative of position error in the vertical direction with respect to pseudo-range error on the i^th satellite;

GPA = the glidepath angle for the final approach path (3.6.4.5.1);

N = the number of ranging sources used in the position solution; and

i = the ranging source index for ranging sources used in the position solution;

D_V = an airborne determined parameter depending on the active GAST. For GAST A, B or C: $D_V = 0$;
For GAST D: D_V is calculated as the magnitude of the vertical projection of the difference between the 30-second and 100-second position solutions;

D_L = an airborne determined parameter depending on the active GAST. For GAST A, B or C: $D_L = 0$; For GAST D: D_L is calculated as the magnitude of the lateral projection of the difference between the 30-second and 100-second position solutions.

Note 1.— The airborne 30-second and 100-second position solutions, D_V and D_L are defined in RTCA MOPS DO-253D.

Note 2.— The coordinate reference frame is defined such that x is along track positive forward, y is crosstrack positive left in the local level tangent plane and v is the positive up and orthogonal to x and y.

3.6.5.5.1.1.2 For a general-least-squares position solution, the projection matrix S is defined as:

$$S \equiv \begin{bmatrix} S_{x,1} & S_{x,2} & \cdots & S_{x,N} \\ S_{y,1} & S_{y,2} & \cdots & S_{y,N} \\ S_{v,1} & S_{v,2} & \cdots & S_{v,N} \\ S_{t,1} & S_{t,2} & \cdots & S_{t,N} \end{bmatrix} = (G^T \times W \times G)^{-1} \times G^T \times W$$

where

G_i = $[-\cos El_i \cos Az_i \; -\cos El_i \sin Az_i \; -\sin El_i \; 1]$ = i^{th} row of G; and

$$W = \begin{bmatrix} \sigma_{w,1}^2 & 0 & \dots & 0 \\ 0 & \sigma_{w,2}^2 & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & \sigma_{w,N}^2 \end{bmatrix}^{-1}$$

where $\sigma^2_{w,i} = \sigma^2_{pr\_gnd,i} + \sigma^2_{tropo,i} + \sigma^2_{pr\_air,i} + \sigma^2_{iono,i}$.

where

σ_{pr_gnd},i = is dependent on the active GAST.

For GAST A, B or C or the GBAS positioning service: $\sigma_{pr\_gnd},i = \sigma\ p_{r\_gnd}$ for the i^{th} ranging source as defined in (3.6.4.2);

For GAST D: $\sigma_{pr\_gnd,i} = \sigma_{pr\_gnd\_30}$ for the ith ranging source (3.6.4.11);

$\sigma_{tropo,i}$=the residual tropospheric uncertainty for the i[th] ranging source (3.6.5.3);

$\sigma_{iono,i}$= the residual ionospheric delay (due to spatial decorrelation) uncertainty for the i[th] ranging source (3.6.5.4); and

$\sigma_{pr\_air,i}$ = $\sqrt{\sigma^2_{receiver}(El_i) + \sigma^2_{multipath}(El_i)}$, the standard deviation of the aircraft contribution to the corrected pseudo-range error for the i[th] ranging source. The total aircraft contribution includes the receiver contribution (3.6.8.2.1) and a standard allowance for airframe multipath.

. . .

3.6.5.5.1.2 *Faulted measurement conditions.* When the Type 101 message is broadcast without B parameter blocks, the values for VPL_{H1} and LPL_{H1} are defined as zero. Otherwise, the vertical protection level (VPL_{H1}) and lateral protection level (LPL_{H1}), assuming that a latent fault exists in one, and only one reference receiver, are:

$$VPLH1 = \max\,[VPLj] + D_V$$
$$LPLH1 = \max\,[LPLj] + D_L$$

where VPL_j and LPL_j for $_j$ = 1 to 4 are

$VPL_j = |B\_vert_j| + K_{md}\,\sigma_{vert,H1}$; and
$LPLj = |B\_lat_j| + K_{md}\,\sigma_{lat,H1}$;
D_V = an airborne determined parameter depending on the active GAST (3.6.5.5.1.1.1);
D_L = an airborne determined parameter depending on the active GAST (3.6.5.5.1.1.1);
and

B_vert_j = $\sum_{i=1}^{N}(s\_vert_i \times B_{i,j})$;
B_lat_j = $\sum_{i=1}^{N}(s\_lat_i \times B_{i,j})$;
$B_{i,j}$ = the broadcast differences between the broadcast pseudo-range corrections and the corrections obtained excluding the j[th] reference receiver measurement for the i[th] ranging source.
K_{md} = the multiplier derived from the probability of missed detection given that the ground subsystem is faulted.
$\sigma^2_{vert,H1}$ = $\sum_{i=1}^{N}(s\_vert_i^2 \times \sigma\_H1_i^2)$
$\sigma^2_{lat,H1}$ = $\sum_{i=1}^{N}(s\_lat_i^2 \times \sigma\_H1_i^2)$;
$\sigma\_H1_i^2$ = $\left(\frac{M_i}{U_i}\right)\sigma^2_{pr\_gnd,i} + \sigma^2_{pr\_air,i} + \sigma^2_{tropo,i} + \sigma^2_{iono,i}$.
$\sigma_{pr\_gnd,i}$ is dependent on the active GAST
For GAST A, B or C: $\sigma_{pr\_gnd,i} = \sigma_{pr\_gnd}$ for the i[th] ranging source as defined in (3.6.4.2);
For GAST D: $\sigma_{pr\_gnd,i} = \sigma_{pr\_gnd\_D}$ for the i[th] ranging source (3.6.4.11).
$\sigma^2_{tropo,i}$, $\sigma^2_{pr\_air,i}$ and $\sigma^2_{iono,i}$ are as defined in section 3.6.5.5.1.1.2;
M_i = the number of reference receivers used to compute the pseudo-range corrections for the i[th] ranging source (indicated by the B values); and
U_i = the number of reference receivers used to compute the pseudo-range corrections for the i[th] ranging source, excluding the j[th] reference receiver

Note.— A latent fault includes any erroneous measurement(s) that is not immediately detected by the ground subsystem, such that the broadcast data are affected and there is an induced position error in the aircraft subsystem.

3.6.5.5.1.3 *Definition of K multipliers for GBAS approach services.* The multipliers are given in Table B-67.

Table B-67. K-multipliers for GBAS approach services

	M_i			
Multiplier	1 note	2	3	4
K_{ffmd}	6.86	5.762	5.81	5.847
K_{md}	Not used	2.935	2.898	2.878

Note. – For GAST A supported by Type 101 message broadcast without the B parameter block.

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3.6.5.5.2 *GBAS positioning service.* The signal-in-space horizontal protection level is an upper confidence bound on the horizontal error in the position relative to the GBAS reference point defined as:

$$HPL = MAX\{HPL_{H0}, HPL_{H1}, HEB\}$$

...

3.6.5.5.2.2 *Faulted measurement conditions.*

...

$HPLj = |B\_horzj| + K_{md\_POS}\, d_{major,H1}$

...

3.6.5.6 *ALERT LIMITS*

Note 1.— Guidance concerning the calculation of alert limits, including approaches associated with channel numbers 40 000 to 99 999, is provided in Attachment 6D, 7.13.

Note 2. — Computation of alert limits depends on the active service type.

3.6.5.6.1 *GAST C and D alert limits.* The alert limits are defined in Tables B-68 and B-69. For aircraft positions at which the lateral deviation exceeds twice the deviation at which full-scale lateral deflection of a course deviation indicator is achieved, or vertical deviation exceeds twice the deviation at which full-scale fly-down deflection of a course deviation indicator is achieved, both the lateral and vertical alert limits are set to the maximum values given in the tables.

3.6.5.6.2 *GAST A and B alert limits.* The alert limits are equal to the FASLAL and FASVAL taken from the Type 4 message for approaches with channel numbers in the range of 20 001 to 39 999. For approaches with channel numbers in the range 40 000 to 99 999, the alert limits are stored in the on-board database.

3.6.5.7 *Channel number.* Each GBAS approach transmitted from the ground subsystem is associated with a channel number in the range of 20 001 to 39 999. If provided, the GBAS positioning service is associated with a separate channel number in the range of 20 001 to 39 999. The channel number is given by:

Channel number = 20 000 + 40(F – 108.0) + 411(S)

where

F = the data broadcast frequency (MHz)
S = RPDS or RSDS

and

RPDS = the reference path data selector for the FAS data block (as defined in 3.6.4.5.1)
RSDS = the reference station data selector for the GBAS ground subsystem (as defined in 3.6.4.3.1)

Table B-68. GAST C and D lateral alert limit

Horizontal distance of aircraft position from the LTP/FTP as translated along the final approach path (metres)	Lateral alert limit (metres)
$D \leq 873$	FASLAL
$873 < D \leq 7\,500$	0.0044D (m) + FASLAL -3.85
$D > 7\,500$	FASLAL + 29.15

Table B-69. GAST C and D vertical alert limit

Height above LTP/FTP of aircraft position translated onto the final approach path (feet)	Vertical alert limit (metres)
$H \leq 200$	FASVAL
$200 < H \leq 1\,340$	0.02925H (ft) + FASVAL – 5.85
$H > 1\,340$	FASVAL + 33.35

For channel numbers transmitted in the additional data block 2 of Type 2 message (as defined in 3.6.4.3.2.1), only RSDS are used.

Note 1.— When the FAS is not broadcast for an approach supported by GAST A or B, the GBAS approach is associated with a channel number in the range 40 000 to 99 999.

Note 2.— Guidance material concerning channel number selection is provided in Attachment 6D, 7.7.

3.6.5.8 *EPHEMERIS ERROR POSITION BOUND*

. . .

3.6.5.8.1 *GBAS approach.* The vertical and lateral ephemeris error position bounds are defined as:

$$VEB = \underset{j}{MAX}\{VEB_j\} + D_V$$

$$LEB = \underset{J}{MAX}\{LEB_j\} + D_L$$

The vertical and lateral ephemeris error position bounds for the j[th] core satellite constellation ranging constellation ranging source used in the position solution are given by:

$$VEB_j = \left|s\_vert_j\right| x_{air} P_{ej} + K_{md\_ej} \sqrt{\sum_{i=1}^{N} s\_vert_i^2 \times \sigma_i^2}$$

$$LEB_j = \left|s\_lat_j\right| x_{air} P_{ej} + K_{md\_ej} \sqrt{\sum_{i=1}^{N} s\_lat_i^2 \times \sigma_i^2}$$

where:

D_V = an airborne determined parameter depending on the active GAST (3.6.5.5.1.1.1);
D_L = an airborne determined parameter depending on the active GAST (3.6.5.5.1.1.1);
$s\_vert_{i\ or\ j}$ is defined in 3.6.5.5.1.1;
$s\_lat_{i\ or\ j}$ is defined in 3.6.5.5.1.1;
x_{air} is defined in 3.6.5.4;
N is the number of ranging sources used in the position solution;
σ_i is defined in 3.6.5.5.1.1;
P_{ej} is the broadcast ephemeris decorrelation parameter for the j^{th} ranging source. The source of this parameter depends on the active GBAS approach service type:
GAST A, B or C: $P_{ej} = P$ from the Type 1 or Type 101 Message corresponding to the j^{th} ranging source. (section 3.6.4.2.3);
GAST D: $P_{ej} = P_D$ from the Type 11 Message corresponding to the j^{th} ranging source (section 3.6.4.11.3).
$K_{md\_e,j}$ is the broadcast ephemeris missed detection multiplier for GAST A-C associated with the satellite constellation for the j^{th} ranging source. The source of this parameter depends on the active GBAS approach service type:
GAST A, B or C: $K_{md\_e,j} = K_{md\_e,GPS}$ or $K_{md\_e,GLONASS}$ as obtained from the Type 2 Message Additional Data block 1 (section 3.6.4.3.1);
GAST D: $K_{md\_e,j} = K_{md\_e\_D,GPS}$ or $K_{md\_e\_D,GLONASS}$ as obtained from the Type 2 Message Additional Data block 3 (section 3.6.4.3.2.2).

3.6.5.8.2 GBAS positioning service. The horizontal ephemeris error position bound is defined as:

$$HEB = \underset{j}{MAX}\{HEB_j\}$$

The horizontal ephemeris error position bound for the j^{th} core satellite constellation ranging source used in the position solution is given by:

$$HEB_j = |s_{horz,j}|x_{air}P_j + K_{md\_e\_POS}d_{major}$$

where:

$$s_{horz,j}^2 = s_{xj}^2 + s_{yj}^2$$

$s_{x,j}$ is as defined in 3.6.5.5.2.1

$s_{y,j}$ is as defined in 3.6.5.5.2.1

x_{air} is defined in 3.6.5.4

P_j is the broadcast ephemeris decorrelation parameter for the j^{th} ranging source. The source of this parameter does not depend on the active GBAS approach service type. In all cases, P_j=P from the Type 1 or Type 101 Message (section 3.6.4.2.3) corresponding to the j^{th} ranging source.

$K_{md\_e\_POS}$ is the broadcast ephemeris missed detection multiplier for the GBAS positioning service associated with the satellite constellation for the jth ranging source ($K_{md\ e\ POS,GPS}$ or $K_{md\ e\ POS,GLONASS}$)

d_{major} is as defined in 3.6.5.5.2.1

3.6.5.9 *Ionospheric gradient error*

The maximum undetected 30-second smoothed corrected pseudo-range error due to an ionospheric gradient (E_{IG}) is calculated based on the broadcast parameters Y_{EIG} and M_{EIG}, as:

$E_{IG} = Y_{EIG} + M_{EIG} \times D_{EIG}$

where

Y_{EIG} = maximum value of E_{IG} (metres) in the Type 2 message;
M_{EIG} = slope of maximum E_{IG} (m/km) in the Type 2 message;
D_{EIG} = the distance in kilometres between the LTP location for the selected approach broadcast in the Type 4 Message and the GBAS reference point in the Type 2 message.

3.6.6 MESSAGE TABLES

Each GBAS message shall be coded in accordance with the corresponding message format defined in Tables B-70 through B-73.

Note.— Message type structure is defined in 3.6.4.1

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Table B-70B. Type 11 pseudo-range corrections (30-second smoothed pseudo-ranges) message

Data content	Bits used	Range of values	Resolution
Modified Z-count	14	0-1199.9 sec	0.1 sec
Additional message flag	2	0-3	1
Number of measurements	5	0-18	1
Measurement type	3	0-7	1
Ephemeris decorrelation parameter D (P_D) (Notes1,3)	8	0-1.275 x 10^{-3} m/m	5 x 10^{-6} m/m
For N measurement blocks:			
Ranging source ID	8	1-255	1
Pseudo-range correction (PRC_{30})	16	±327.67 m	0.01 m
Range rate correction (RRC_{30})	16	±32.767 m/s	0.001 m/s
Sigma_PR_gnd_D($\sigma_{pr\_gnd\_D}$)(Note 2)	8	0-5.08 m	0.02m
Sigma_PR_gnd_D($\sigma_{pr\_gnd\_30}$)	8	0-5.08 m	0.02 m

Notes:

1. *For SBAS satellites, the parameter is set to all zeros.*
2. *1111 1111 indicates the source is invalid.*
3. *Parameter is associated with the first transmitted measurement block*

...

Table B-71A. Type 2 GBAS-related data message

Data content	Bits used	Range values	Resolution
GBAS reference receivers	2	2 to 4	-
Ground accuracy designator letter	2	-	-
Spare	1	-	-
GBAS continuity/integrity designator	3	0 to 7	1
Local magnetic variation	11	± 180°	0.25°
Reserved and set to zero(00000)	5	-	-
$\sigma_{vert\ iono\ gradient}$	8	0 to 25.5 x 10^{-6} m/m	0.1 x 10^{-6}m/m
Refractivity index	8	16 to 781	3
Scale height	8	0 to 25 500 m	100 m
Refractivity uncertainty	8	0 to 255	1
Latitude	32	± 90°	0.0005 arcsec
Longtitude	32	± 180°	0.0005 arcsec
GBAS reference point height	24	± 83 886.07 m	0.01 m
Additional data block 1 (if provided)			
Reference station data selector	8	0 to 48	1
Maximum use distance (D_{max})	8	2 to 510 km	2 km
$K_{md\ e\ POS\ GPS}$	8	0 to 12.75	0.05
$K_{md\ e\ GPS}$	8	0 to 12.75	0.05
$K_{md\ e\ POS,GLONASS}$	8	0 to 12.75	0.05
$K_{md\ e\ GLONASS}$	8	0 to 12.75	0.05
Additional data blocks (repeated for all provided)			
Additional data block length	8	2 to 255	1
Additional data block number	8	2 to 255	1
Additional data parameters	Variable	-	-

Note.- Multiple additional data blocks may be appended to a Type 2 message.

...

Table B-72. Type 4 FAS data message

Data content	Bits used	Range of value	Resolution
For N data sets			
Data set length	8	2 to 212	1 byte
FAS data block	304	-	-
FAS vertical alert limit /approach status	8		
(1.)when associated approach performance designator (APD) is coded as 0		0 to 50.8 m	0.2m
(2.) when associated approach performance designator(APD) is not coded as 0		0 to 25.4m	0.1m
FAS lateral approach alert limit/approach status	8	0 to 50.8 m	0.2 m

...

3.6.7 NON-AIRCRAFT ELEMENTS

3.6.7.1 *PERFORMANCE*

3.6.7.1.1 Accuracy

3.6.7.1.1.1 The root-mean-square (RMS) (1 sigma) of the ground subsystem contribution to the corrected 100-second smoothed pseudo-range accuracy for GPS and GLONASS satellites shall be:

...

Note 1.— The GBAS ground subsystem accuracy requirement is determined by the GAD letter and the number of reference receivers.

Note 2.— The ground subsystem contribution to the corrected 100-second smoothed pseudo-range error specified by the curves defined in Tables B-74 and B-75 and the contribution to the SBAS satellites do not include aircraft noise and aircraft multipath.

3.6.7.1.1.2 The RMS of the ground subsystem contribution to the corrected 100-second smoothed pseudo-range accuracy for SBAS satellites shall be:

...

3.6.7.1.2 Integrity

3.6.7.1.2.1 GBAS ground subsystem integrity risk

3.6.7.1.2.1.1 *Ground subsystem integrity risk for GBAS approach services*

3.6.7.1.2.1.1.1 *Ground subsystem signal-in-space integrity risk for GBAS approach service types A, B or C.* For a GBAS ground subsystem classified as FAST A, B or C, the integrity risk shall be less than 1.5×10^{-7} per approach.

Note 1.— The integrity risk assigned to the GBAS ground subsystem is a subset of the GBAS signal-in-space integrity risk, where the protection level integrity risk (3.6.7.1.2.2.1) has been excluded and the effects of all other GBAS, SBAS and core satellite constellations failures are included. The GBAS ground subsystem integrity risk includes the integrity risk of satellite signal monitoring required in 3.6.7.3.3.

Note 2.— GBAS signal-in-space integrity risk is defined as the probability that the ground subsystem provides information which when processed by a fault-free receiver, using any GBAS data that could be used by the aircraft in the service volume, results in an out-of-tolerance lateral or vertical relative position error without annunciation for a period longer than the maximum signal-in-space time-to-alert. An out-of-tolerance lateral or vertical relative position error is defined as an error that exceeds the GBAS approach services protection level and, if additional data block 1 is broadcast, the ephemeris error position bound.

3.6.7.1.2.1.1.2 *Ground subsystem signal-in-space integrity risk for GBAS approach service type D.* For a GBAS ground subsystem classified as FAST D the integrity risk for all effects other than errors induced by anomalous ionospheric conditions shall be less than 1.5×10^{-7} per approach.

Note 1.— The integrity risk assigned to the GBAS ground subsystem classified as FAST D is a subset of the GBAS signal-in-space integrity risk, where the protection level integrity risk (3.6.7.1.2.2.1) has been excluded and the effects of all other GBAS, SBAS and core satellite constellations failures are included.

Note 2.— For GAST D the GBAS signal-in-space integrity risk is defined as the probability that the ground subsystem provides information which when processed by a fault-free receiver, using any GBAS data that could be used by the aircraft in the service volume, in the absence of an ionospheric anomaly results in an out-of-tolerance lateral or vertical relative position error without annunciation for a period longer than the maximum signal-in-space time-to-alert. An out-of-tolerance lateral or vertical relative position error is defined as an error that exceeds the GBAS approach services protection level and the ephemeris error position bound. For GAST D, out of tolerance conditions caused by anomalous ionospheric errors are excluded from this integrity risk as the risk due to ionospheric anomalies has been allocated to and is mitigated by the airborne segment.

3.6.7.1.2.1.1.3 *Ground subsystem integrity risk for GAST D.* For a GBAS ground subsystem classified as FAST D, the probability that the ground subsystem internally generates and transmits non-compliant information for longer than1.5 seconds shall be less than 1×10^{-9} in any one landing.

Note 1.— This additional integrity risk requirement assigned to FAST D GBAS ground subsystems is defined in terms of the probability that internal ground subsystem faults generate non-compliant information. Non-compliant information in this context is defined in terms of the intended function of the ground subsystem to support landing operations in Category III minima. For example, non-compliant information includes any broadcast signal or broadcast information that is not monitored in accordance with the standard.

Note 2.— Environmental conditions (anomalous ionosphere, troposphere, radio frequency interference, GNSS signal multipath, etc.) are not considered faults; however, faults in ground subsystem equipment, used to monitor for or mitigate the effects of these environmental conditions, are included in this requirement. Similarly, the core satellite constellation ranging source faults are excluded from this requirement; however, the ground subsystem's capability to provide integrity monitoring for these ranging sources is included. Monitoring requirements for ranging source faults and ionosphere environmental conditions are separately specified in 3.6.7.3.3.2, 3.6.7.3.3.3 and.3.6.7.3.4.

Note 3.— Faults that occur in ground receivers used to generate the broadcast corrections are excluded from this requirement if they occur in any one, and only one, ground receiver at any time. Such faults are constrained by the requirement in 3.6.7.1.2.2.1.2 and the associated integrity risk requirements in 3.6.7.1.2.2.1 and 3.6.7.1.2.2.1.1.

3.6.7.1.2.1.2 *Ground subsystem time-to-alert for GBAS approach services*

3.6.7.1.2.1.2.1 *Maximum time-to-alert for approach services*

3.6.7.1.2.1.2.1.1 For a ground segment classified as FAST A, B, C or D, the GBAS ground subsystem maximum time-to-alert shall be less than or equal to 3 seconds for all signal-in-space integrity requirements (see Appendix 6B, 3.6.7.1.2.1.1.1, 3.6.7.1.2.1.1.2, 3.6.7.1.2.2.1) when Type 1 messages are broadcast.

Note 1.— The ground subsystem time-to-alert above is the time between the onset of the out of tolerance lateral or vertical relative position error and the transmission of the last bit of the message that contains the integrity data that reflects the condition (see Attachment 6D, 7.5.14)
Note 2.— For FAST D ground subsystems, additional range domain monitoring requirements apply as defined in section 3.6.7.3.3.2, 3.6.7.3.3.3 and 3.6.7.3.4. In these sections, time limits are defined for the ground system to detect and alert the airborne receiver of out-of-tolerance differential pseudo-range errors

3.6.7.1.2.1.2.1.2 For a ground segment classified as FAST A, the GBAS ground subsystem maximum signal-in-space time-to-alert shall be less than or equal to 5.5 seconds when Type 101 messages are broadcast.

3.6.7.1.2.1.3 Ground subsystem FASLAL and FASVAL

3.6.7.1.2.1.3.1 For message Type 4 FAS data blocks with APD coded as 1, 2, 3 or 4, the value FASLAL for each FAS block, as defined in the FAS lateral alert limit field of the Type 4 message shall be no greater than 40 metres, and the value FASVAL for each FAS block, as defined in the FAS vertical alert limit field of the Type 4 message, shall be no greater than 10 metres.

3.6.7.1.2.1.3.2 For message Type 4 FAS data blocks with APD coded as zero, the value FASLAL and FASVAL shall be no greater than the lateral and vertical alert limits given in CAR-ANS 6.3.7.2.4 for the intended operational use.

3.6.7.1.2.1.4 *Ground subsystem signal-in-space integrity risk for GBAS positioning service.* For GBAS ground subsystem that provides the GBAS positioning service, integrity risk shall be less than 9.9×10^{-8} per hour.

Note 1.— The integrity risk assigned to the GBAS ground subsystem is a subset of the GBAS signal in-space integrity risk, where the protection level integrity risk (3.6.7.1.2.2.2) has been excluded and the effects of all other GBAS, SBAS and core satellite constellations failures are included. The GBAS ground subsystem integrity risk includes the integrity risk of satellite signal monitoring required in 3.6.7.3.3.

...

3.6.7.1.2.1.4.1 *Time-to-alert for GBAS positioning service.* The GBAS ground subsystem maximum time-to-alert shall be less than or equal to 3 seconds when Type 1 messages are broadcast and less than or equal to 5.5 seconds when Type 101 messages are broadcast.

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3.6.7.1.2.2 *Protection level integrity risk*

3.6.7.1.2.2.1 For a GBAS ground subsystem that provides GBAS approach services, the protection level integrity risk shall be less than 5×10^{-8} per approach.

Note.— For approach services, the protection level integrity risk is the integrity risk due to undetected errors in the 100- second smoothed position solution relative to the GBAS reference point greater than the associated protection levels under the two following conditions:

a) normal measurement conditions defined in 3.6.5.5.1.1 with D_V and D_L set to zero; and

b) faulted measurement conditions defined in 3.6.5.5.1.2 with D_V and D_L set to zero.

Note.— The ground subsystem bounding of the 100-second smoothed GAST D position solution will ensure that the 30 smoothed GAST D position solution is bounded

3.6.7.1.2.2.1.1 *Additional bounding requirements for FAST D ground subsystems.* The σ_{vert} (used in computing the protection level VPL_{H0}) and σ_{lat} (used in computing the protection level LPL_{H0}) for GAST D formed, based on the broadcast parameters (defined in 3.6.5.5.1.1.1) and excluding the airborne contribution, shall satisfy the condition that a normal distribution with zero mean and a standard deviation equal to σ_{vert} and σ_{lat} bounds the vertical and lateral error distributions of the combined differential correction errors as follows:

$$\int_{y}^{\infty} f_n(x)dx \leq Q\left(\frac{y}{\sigma}\right) \text{ for all } \frac{y}{\sigma} \geq 0 \text{ and}$$

$$\int_{-\infty}^{-y} f_n(x)dx \leq Q\left(\frac{y}{\sigma}\right) \text{ for all } \frac{y}{\sigma} \geq 0$$

where

$f_n(x)$ = probability density function of the differential vertical or lateral position error excluding the airborne contribution, and

$$Q(x) \quad = \frac{1}{\sqrt{2\pi}} \int_{x}^{\infty} e^{-\frac{t^2}{2}} dt$$

The $\sigma_{vert,H1}$ (used in computing the protection level VPL_{H1}) and $\sigma_{lat,H1}$ (used in computing the protection level LPL_{H1}) for GAST D formed, based on the broadcast parameters (defined in 3.6.5.5.1.2) and excluding the airborne contribution, shall bound the combined differential correction errors (as defined above) formed by all possible subsets with one reference receiver excluded.

Note 1.— The airborne contribution is addressed in 3.6.8.3.2.1 in combination with the use of the standard airborne multipath model defined in 3.6.5.5.1.1.2

Note 2.— The combined differential correction errors refer to code-carrier-smoothed corrections based on 100-second smoothing time constant.

3.6.7.1.2.2.1.2 For a GBAS ground subsystem classified as FAST D, the rate of faulted measurements from any one, and only one, reference receiver shall be less than 1×10^{-5} per 150 seconds.

Note.— Faulted measurements can occur from faults within the receiver or from environmental conditions unique to a single reference receiver location

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3.6.7.1.3 *Continuity of service*

3.6.7.1.3.1 *Continuity of service for approach services.* The GBAS ground subsystem continuity of service shall be greater than or equal to $1 - 8.0 \times 10^{-6}$ per 15 seconds.
...

3.6.7.1.3.2 *Additional continuity of service requirements for FAST D.* The probability of a GBAS ground subsystem failure or false alert, excluding ranging source monitoring, causing an unscheduled interruption of service for a period equal to or greater than 1.5 seconds shall not exceed 2.0×10^{-6} during any 15 second interval. The probability that the ground subsystem excludes any individual fault-free ranging source from the Type 1 or Type 11 corrections due to a false detection by the ground integrity monitors shall not exceed 2.0×10^{-7} during any 15 second interval

Note 1.— Loss of service includes failures resulting in loss of the VHF data broadcast, failure to meet the VHF data broadcast field strength, failures resulting in transmission of out-of-tolerance VHF broadcast data, and alert due to an integrity failure. Guidance material on the potential causes of loss of service and monitor false detections are contained in Attachment 6D, 7.6.2.1

Note 2. – Continuity for FAST D is defined as the probability that the ground subsystem continues to provide the services associated with the intended ground subsystem functions. Total aircraft continuity of navigation system performance in the position domain must be evaluated in the context of a specific satellite geometry and aeroplane integration. Evaluation of position domain navigation service continuity is the responsibility of the airborne user for GAST D. Additional information regarding continuity is given in Attachment 6D, 7.6.2.1.

3.6.7.1.3.3 Continuity of service for positioning service

Note.— For GBAS ground subsystems that provide the GBAS positioning service, there may be additional continuity requirements depending on the intended operations.

3.6.7.2 *FUNCTIONAL REQUIREMENTS*

3.6.7.2.1 *General*

3.6.7.2.1.1 *Data broadcast requirements.*

3.6.7.2.1.1.1 A GBAS ground subsystem shall broadcast message types as defined in Table B-75A according to the service types supported by the ground subsystem.

3.6.7.2.1.1.2 Each GBAS ground subsystem shall broadcast Type 2 messages with additional data blocks as required to support the intended operations.

Note.— Guidance material concerning usage of the Type 2 message additional data blocks is provided in Attachment 6D, 7.17.

3.6.7.2.1.1.3 Each GBAS ground subsystem which supports GBAS approach service type (GAST) B, C or D shall broadcast FAS blocks in Type 4 messages for these approaches. If a GBAS ground subsystem supports any approach using GAST A or B and does not broadcast FAS blocks for the corresponding approaches, it shall broadcast additional data block 1 in the Type 2 message.

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Note.— FAS blocks for APV procedures may be held within a database on board the aircraft. Broadcasting additional data block 1 allows the airborne receiver to select the GBAS ground subsystem that supports the approach procedures in the airborne database. FAS blocks may also be broadcast to support operations by aircraft without an airborne database. These procedures use different channel numbers as described in Attachment 6D, 7.7.

3.6.7.2.1.1.4 When the Type 5 message is used, the ground subsystem shall broadcast the Type 5 message at a rate in accordance with Table B-76.

3.6.7.2.1.1.5 *Data broadcast rates.* For all message types required to be broadcast, messages meeting the field strength requirements of CAR-ANS 6.3, 6.3.7.3.5.4.4.1.2 and 6.3.7.3.5.4.4.2.2 and the minimum rates shown in Table B-76 shall be provided at every point within the service volume. The total message broadcast rates from all antenna systems of the ground subsystem combined shall not exceed the maximum rates shown in Table B-76.

Note.— Guidance material concerning the use of multiple antenna systems is provided in Attachment 6D, 7.12.4.

3.6.7.2.1.2 *Message block identifier.* The MBI shall be set to either normal or test according to the coding given in 3.6.3.4.1.

Table B-75A. GBAS message types for supported service types

Message type	GAST A – Note 1	GAST B – Note 1	GAST C – Note 1	GAST D – Note 1
MT 1	Optional – Note 2	Required	Required	Required
MT 2	Required	Required	Required	Required
MT2-ADB 1	Optional – Note 3	Optional – Note 3	Optional – Note 3	Required
MT2-ADB 2	Optional – Note 4	Optional – Note 4	Optional – Note 4	Optional
MT2-ADB 3	Not used	Not used	Not used	Required
MT2-ADB 4	Recommended	Recommended	Recommended	Required
MT3-Note 5	Recommended	Recommended	Recommended	Required
MT 4	Optional	Required	Required	Required
MT 5	Optional	Optional	Optional	Optional
MT11 – Note 6	Not used	Not used	Not used	Required
MT 101	Optional – Note 2	Not allowed	Not allowed	Not allowed

Note 1.— Definition of terms:

- *Required: Message needs to be transmitted when supporting the service type;*
- *Optional: Message transmission is optional when supporting the service type (not used by some or all airborne subsystems);*
- *Recommended: Use of the message is optional, but recommended, when supporting the service type;*
- *Not used: Message is not used by airborne subsystems for this service type;*
- *Not allowed: Message transmission is not allowed when supporting the service type.*

Note 2.— Ground subsystems supporting GAST A service types may broadcast Type 1 or 101 Messages, but not both. Guidance material concerning usage of the Type 101 message is provided in Attachment 6D, 7.18.

Note 3.— MT2-ADB1 is required if positioning service is offered.

Note 4.— MT2-ADB2 is required if GRAS service is offered.

Note 5.— MT3 is recommended (GAST A, B, C) or required (GAST-D) to be used only in order to meet slot occupancy requirements in 3.6.7.4.1.3.

Note 6.— Guidance material concerning usage of the Type 11 message is provided in Attachment 6D, 7.20.

Table B-76. GBAS VHF data broadcast rates

Message Type	Minimum broadcast rate	Maximum broadcast rate
1 or 101	For each measurement type: All measurement blocks once per frame (Note)	For each measurement type: All measurement blocks once per slot
2	Once per 20 consecutive frames	Once per frame (except as stated in 3.6.7.4.1.2)
3	Rate depends on message length and scheduling of other messages (see section 3.6.7.4.1.3)	Once per slot and eight times per frame
4	All FAS blocks once per 20 consecutive frames	All FAS blocks once per frame
5	All impacted sources once per 20 consecutive frames:	All impacted sources once per 5 consecutive frames
11	For each measurement type: All measurement blocks once per frame(see Note)	For each measurement type: All measurement blocks once per slot

Note.— One Type 1, Type 11 or Type 101 message or two Type 1, Type 11 or Type 101 messages that are linked using the additional message flag described in 3.6.4.2, 3.6.4.10.3 or 3.6.4.11.3.

3.6.7.2.1.3 *VDB authentication*

3.6.7.2.1.3.1 All GBAS ground subsystems shall support VDB authentication (see 3.6.7.4).

3.6.7.2.1.3.2 All ground subsystems classified as FAST D shall support VDB authentication (see 3.6.7.4).

3.6.7.2.2 *Pseudo-range corrections*

3.6.7.2.2.1 *Message latency.* The time between the time indicated by the modified Z-count and the last bit of the broadcast Type 1, Type 11 or Type 101 message shall not exceed 0.5 seconds.

3.6.7.2.2.2 *Low-frequency data.* Except during an ephemeris change, the first ranging source in the Type 1, Type 11 or Type 101 message shall sequence so that the ephemeris decorrelation parameter, ephemeris CRC and source availability duration for each core satellite constellation's ranging source are transmitted at least once every 10 seconds. During an ephemeris change, the first ranging source shall sequence so that the ephemeris decorrelation parameter, ephemeris CRC and source availability duration for each core satellite constellation's ranging source are transmitted at least once every 27 seconds. When new ephemeris data are received from a core satellite constellation's ranging source, the ground subsystem shall use the previous ephemeris data from each satellite until the new ephemeris data have been continuously received for at least 2 minutes but shall make a transition to the new ephemeris data before 3 minutes have passed. When this transition is made to using the new ephemeris data for a given ranging source, the ground subsystem shall broadcast the new ephemeris CRC and associated low-frequency information, notably P and P_D for all occurrences of that ranging source in the low-frequency information of Type 1, Type 11 or Type 101 message in the next 3 consecutive frames. For a given ranging source, the ground subsystem shall continue to transmit data corresponding to the previous ephemeris data until the new CRC ephemeris is transmitted in the low-frequency data of Type 1, Type 11 or Type 101 message (see *Note*). If the ephemeris CRC changes and the IOD does not, the ground subsystem shall consider the ranging source invalid.

Note.— The delay before the ephemeris transition allow sufficient time for the aircraft subsystem to collect new ephemeris data.

...

3.6.7.2.2.3 *Broadcast pseudo-range correction.* Each broadcast pseudo-range correction shall be determined by combining the pseudo-range correction estimates for the relevant ranging source calculated from each of the reference receivers. For each satellite, the measurements used in this combination shall be obtained from the same ephemeris data. The corrections shall be based on smoothed code pseudo-range measurements for each satellite using the carrier measurement from a smoothing filter and the approach service type specific smoothing parameters in accordance with Appendix 6B, section 3.6.5.1.

3.6.7.2.2.4 *Broadcast signal-in-space integrity parameters.* The ground subsystem shall provide σ_{pr_gnd} and B parameters for each pseudo-range correction in Type 1 message such that the protection level integrity risk requirements defined in 3.6.7.1.2.2 for GAST A, B, and C are satisfied. At least two B values that are not using the special coding (as defined in section 3.6.4.2.4) shall be provided with each pseudo-range correction. The ground subsystem shall provide σ_{pr_gnd} and, if necessary, B parameters for each pseudo-range correction in Type 101 message such that the protection level integrity risk requirements defined in 3.6.7.1.2.2 are satisfied.

Note.— Broadcast of the B parameters are optional for Type 101 messages. Guidance material regarding the B parameters in Type 101 messages is contained in Attachment 6D, 7.5.11.

3.6.7.2.2.4.1 *Broadcast signal-in-space integrity parameters for FAST D ground subsystems.* Ground subsystems that support GAST D shall provide Sigma_PR_gnd_D in the Type 11 message and B parameters for each pseudo-range correction in the Type 1 message, such that the protection level integrity risk requirement defined in 3.6.7.1.2.2.1 is satisfied.

3.6.7.2.2.4.2 For FAST D systems broadcasting the Type 11 message, if σ_{pr_gnd} is coded as invalid in the Type 1 message, then the Sigma_PR_gnd_D for the associated satellite in the Type 11 message shall also be coded as invalid.

...

3.6.7.2.2.6 *Repeated transmission of Type 1, Type 2, Type 11 or Type 101 messages.* For a given measurement type and within a given frame, all broadcasts of Type 1, Type 2, Type 11 or Type 101 messages or linked pairs from all GBAS broadcast stations that share a common GBAS identification, shall have identical data content.

...

3.6.7.2.2.9 *Linked pair of Type 1, Type 11 or Type 101 messages.* If a linked pair of Type 1, Type 11 or Type 101 messages is transmitted then,

...

d) the two messages shall be broadcast in different time slots;

e) the order of the B values in the two messages shall be the same;

f) for a particular measurement type, the number of measurements and low-frequency data shall be computed separately for each of the two individual messages;

g) in the case of FAST D, when a pair of linked Type 1 messages are transmitted, there shall also be a linked pair of Type 11 messages; and

h) if linked message types of Type 1 or Type 11 are used, the satellites shall be divided into the same sets and order in both Type 1 and Type 11 messages.

Type 11 messages. Airborne processing is not possible for satellites included in the Type 11 message, but also not included in the associated Type 1 message.

3.6.7.2.2.9.1 Linked messages shall only be used when there are more pseudo-range corrections to transmit than will fit in one Type 1 message.

3.6.7.2.2.10 *Modified Z-count requirements*

3.6.7.2.2.10.1 *Modified Z-count update.* The modified Z-count for Type 1, Type 11 or Type 101 messages of a given measurement type shall advance every frame.

3.6.7.2.2.10.2 If message Type 11 is broadcast, the associated Type 1 and Type 11 messages shall have the same modified Z-count

3.6.7.2.2.11 *Ephemeris decorrelation parameters*

3.6.7.2.2.11.1 *Ephemeris decorrelation parameter for approach services.* For ground subsystems that broadcast the additional data block 1 in the Type 2 message, the ground subsystem shall broadcast the ephemeris decorrelation parameter in the Type 1 message for each core satellite constellation ranging source such that the ground subsystem integrity risk of 3.6.7.1.2.1.1.1 is met.

3.6.7.2.2.11.2 *Ephemeris decorrelation parameter for GAST D.* Ground subsystems classified as FAST D shall broadcast the ephemeris decorrelation parameter in the Type 11 message for each core satellite constellation ranging source such that the ground subsystem signal-in-space integrity risk of 3.6.7.1.2.1.1.2 is met.

3.6.7.2.2.11.3 *GBAS positioning service.* For ground subsystems that provide the GBAS positioning service, the ground subsystem shall broadcast the ephemeris decorrelation parameter in the Type 1 message for each core satellite constellation's ranging source such that the ground subsystem signal-in-space integrity risk of 3.6.7.1.2.1.4 is met.

...

3.6.7.2.3 *GBAS-related data*

...

3.6.7.2.3.2 *GCID indication*

3.6.7.2.3.2.1 *GCID indication for FAST A, B or C.* If the ground subsystem meets the requirements of. 3.6.7.1.2.1.1.1, 3.6.7.1.2.2.1, 3.6.7.1.3.1,.3.6.7.3.2 and 3.6.7.3.3.1 but not all of 3.6.7.1.2.1.1.2, 3.6.7.1.2.1.1.3,.3.6.7.1.2.2.1.1, and 3.6.7.1.3.2 the GCID shall be set to 1, otherwise it shall be set to 7.

Note.— Some of the requirements applicable to FAST D are redundant with the FAST A, B and C requirements. The phrase "not all of" refers to the condition where a ground subsystem may meet some of the requirements applicable to FAST D but not all of them. Therefore, in that condition, the GCID would be set to 1, indicating that the ground subsystem meets only FAST A, B or C.

3.6.7.2.3.2.2 *GCID indication for FAST D.* If the ground subsystem meets the requirements of 3.6.7.1.2.1.1.1, 3.6.7.1.2.1.1.2, 3.6.7.1.2.1.1.3, 6.3.6.7.1.2.2.1.1, 3.6.7.1.2.2.1, 3.6.7.1.3.1, 3.6.7.1.3.2, .3.6.7.3.2 and 3.6.7.3.3, the GCID shall be set to 2, otherwise it shall be set in accordance with 3.6.7.2.3.2.1.

3.6.7.2.3.2.3 GCID values of 3 and 4 are reserved for future service types and shall not be used.

...

3.6.7.2.3.5 *Ionospheric uncertainty estimate parameter*

3.6.7.2.3.5.1 *Ionospheric uncertainty estimate parameter for all ground subsystems.* The ground subsystem shall broadcast an ionospheric delay gradient parameter in the Type 2 message such that the protection level integrity risk requirements defined in 3.6.7.1.2.2 are satisfied.

3.6.7.2.3.5.2 *Ionospheric uncertainty estimate parameter for FAST D ground subsystems.* The ground subsystem shall broadcast an ionospheric delay gradient parameter in the Type 2 message, additional data block 3, such that the protection level integrity risk requirements defined in 3.6.7.1.2.2 are satisfied.

Note.— Guidance material concerning FAST D position domain error bounding for ionospheric errors may be found in Attachment 6D, 7.5.6.1.3 and 7.5.6.1.4.

...

3.6.7.2.3.8.1 *Maximum use distance.* The ground subsystem shall provide the maximum use distance (D_{max}). When the positioning service is provided the ground subsystem integrity risk in 3.6.7.1.2.1.4 and the protection level integrity risk in 3.6.7.1.2.2.2 shall be met within D_{max}. When approach service is provided, the maximum use distance shall at least encompass all approach service volumes supported.

...

3.6.7.2.4.4 *LTP/FTP for FAST D.* For an approach that supports GAST D, the LTP/FTP point in the corresponding FAS definition shall be located at the intersection of the runway centre line and the landing threshold.

Note.— Airborne systems may compute the distance to the landing threshold using the LTP/FTP. For GAST D approaches, the LTP/FTP is to be at the threshold so that these distance-to-go computations reliably reflect the distance to the threshold.

3.6.7.2.4.5 *FPAP location for FAST D.* For an approach that supports GAST D, the FPAP point in the corresponding FAS definition shall be located on the extended runway centre line and the ΔLength offset parameter shall be coded to correctly indicate the stop end of the runway.

3.6.7.2.5 *Predicted ranging source availability data*

Note.— Ranging source availability data are optional for FAST A, B, C or D ground subsystems and may be required for possible future operations.

3.6.7.2.6 *General functional requirements on augmentation*

3.6.7.2.6.1 GBAS ground subsystems classified as FAST C or FAST D shall provide augmentation based on GPS at a minimum.

3.6.7.2.6.2 Ground subsystems classified as FAST C shall be able to process and broadcast corrections for at least 12 satellites of each core constellation for which differential corrections are provided.

3.6.7.2.6.3 Ground subsystems classified as FAST D shall be able to process and broadcast differential corrections for at least 12 satellites of one core constellation.

Note.— Technical validation has only been completed for GAST D when applied to GPS.

3.6.7.2.6.4 Whenever possible, differential corrections for all visible satellites with an elevation greater than 5 degrees above the local horizontal plane tangent to the ellipsoid at the ground subsystem reference location shall be provided for each core constellation for which augmentation is provided.

Note.— The phrase "whenever possible" in this context means whenever meeting another requirement in these SARPs (e.g. 3.6.7.3.3.1) does not preclude providing a differential correction for a particular satellite.

3.6.7.3 MONITORING

3.6.7.3.1 RF monitoring

3.6.7.3.1.1 *VHF data broadcast monitoring.* The data broadcast transmissions shall be monitored. The transmission of the data shall cease within 0.5 seconds in case of continuous disagreement during any 3-second period between the transmitted application data and the application data derived or stored by the monitoring system prior to transmission. For FAST D ground subsystems, the transmission of the data shall cease within 0.5 seconds in case of continuous disagreement during any 1-second period between the transmitted application data and the application data derived or stored by the monitoring system prior to transmission.

Note.— For ground subsystems that support authentication, ceasing the transmission of data means ceasing the transmission of Type 1 messages and Type 11 messages if applicable or ceasing the transmission of Type 101 messages. In accordance with 6.3.6.7.4.1.3, the ground subsystem must still transmit messages such that the defined percentage or more of every assigned slot is occupied. This can be accomplished by transmitting Type 2, Type 3, Type 4 and/or Type 5 messages.

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3.6.7.3.2 *Data monitoring*

3.6.7.3.2.1 *Broadcast quality monitor*. The ground subsystem monitoring shall comply with the time-to-alert requirements given in 3.6.7.1.2.1. The monitoring action shall be one of the following:

a) to broadcast Type 1 (and Type 11 if broadcast) or Type 101 messages with no measurement blocks; or

b) to broadcast Type 1 (and Type 11 if broadcast) or Type 101 messages with the $\sigma_{pr\_gnd,i}$ (and $\sigma_{pr\_gnd\_D,I}$ if broadcast) field set to indicate the ranging source is invalid for every ranging source included in the previously transmitted frame; or

c) to terminate the data broadcast.

Note.— Monitoring actions a) and b) are preferred to c) if the particular failure mode permits such a response, because actions a) and b) typically have a reduced signal-in-space time-to-alert.

3.6.7.3.3 *Integrity monitoring for GNSS ranging sources*

3.6.7.3.3.1 The ground subsystem shall monitor the satellite signals to detect conditions that will result in improper operation of differential processing for airborne receivers complying with the tracking constraints in Attachment 6D, 8.11. The monitor time-to-alert shall comply with 3.6.7.1.2. The monitor action shall be to set σ_{pr_gnd} to the bit pattern "1111 1111" for the satellite or to exclude the satellite from the Type 1, Type 11 or Type 101 message.

3.6.7.3.3.1.1 The ground subsystem shall use the strongest correlation peak in all receivers used to generate the pseudo-range corrections. The ground subsystem shall also detect conditions that cause more than one zero crossing for airborne receivers that use the early-late discriminator function as described in Attachment 6D, 8.11.

3.6.7.3.3.2 For FAST D ground subsystems, the probability that the error at the landing threshold point (LTP) of any runway for which the ground subsystem supports GAST D, $|Er|$, on the 30-second smoothed corrected pseudo-range (see 3.6.5.2) caused by a ranging source fault, is not detected and reflected in the broadcast Type 11 message within 1.5 s shall fall within the region specified in Table B-76A.

Ranging source faults for which this requirement applies are:

a) signal deformation (Note 1.);

b) code/carrier divergence;

c) excessive pseudo-range acceleration, such as a step or other rapid change; and

d) erroneous broadcast of ephemeris data from the satellite.

Note 1.— Refer to Attachment 6D, 8.11 for further information on GAEC-D avionics relating to signal deformation fault.

Note 2.— Upon detection, a ranging source fault may be reflected in the Type 11 message by either:

a) removing the correction for the associated satellite from the Type 11 message; or

b) marking the satellite as invalid using the coding of $\sigma_{pr\_gnd\_D}$ (see 3.6.4.11.4).

Note 3.— The acceptable probability of a missed detection region is defined with respect to differentially corrected pseudo-range error. The differentially corrected pseudo-range error, $|Er|$, includes the error resulting from a single ranging source fault, given the correct application of GBAS ground subsystem message Type 11 broadcast corrections (i.e. pseudorange correction and range rate corrections defined in section 3.6.4.11) by the aircraft avionics as specified within section 3.6.8.3. Evaluation of P_{md} performance includes GBAS ground subsystem fault-free noise. The growth of $|Er|$ with time shall consider the data latency of the ground subsystem, but not the airborne latency, as described in Attachment 6D, 7.5.14.

Note 4.— Additional information regarding the ranging source fault conditions and monitoring requirements for FAST D ground subsystems may be found in Attachment 6D, 7.5.14. Missed messages do not need to be considered as part of compliance with this requirement.

Table B-76 A. P_{md_limit} Parameters

Probability of Missed Detection	Pseudo-range Error (metres)
$P_{md\_limit} \leq 1$	$0 \leq |E_r| < 0.75$
$P_{md\_limit} \leq 10^{(-2.56x|Er|+1.92)}$	$0.75 \leq |E_r| < 2.7$
$P_{md\_limit} \leq 10^{-5}$	$2.7 \leq |E_r| < \infty$

3.6.7.3.3.3 For FAST D ground subsystems, the probability that an error at the landing threshold point (LTP) of any runway for which the ground subsystem supports GAST D, $|Er|$, greater than 1.6 metres on the 30-second smoothed corrected pseudo-range (see 3.6.5.2), caused by a ranging source fault, is not detected and reflected in the broadcast Type 11 message within 1.5 seconds shall be less than 1×10^{-9} in any one landing when multiplied by the prior probability ($P_{apriori}$). Ranging source faults for which this requirement applies are:

a) signal deformation (Note 1);

b) code/carrier divergence;

c) excessive pseudo-range acceleration, such as a step or other rapid change; and

d) erroneous broadcast of ephemeris data from the satellite.

Note 1.— Refer to Attachment 6D, 8.11 for further information on GAEC-D avionics relating to signal deformation fault.

Note 2.— It is intended that the prior probability of each ranging source fault ($P_{apriori}$) be the same value that is used in the analysis to show compliance with error bounding requirements for FAST C and D (see Appendix 6B, 3.6.5.5.1.1.1).

Note 3.— Upon detection, a ranging source fault may be reflected in the Type 11 message by either:

a) removing the faulty satellite correction from the Type 11 message; or

b) marking the satellite as invalid using the coding of $\sigma_{pr\_gnd\_D}$ (see 3.6.4.11.4).

Note 4.— Additional information regarding the ranging source fault conditions and monitoring requirements for FAST D ground subsystems may be found in Attachment 6D, 7.5.14. Missed messages do not need to be considered as part of compliance with this requirement.

3.6.7.3.4 *Ionospheric gradient mitigation*

For FAST D ground subsystems, the probability of an error (|Er|) in the 30-second smoothed corrected pseudo-range at the landing threshold point (LTP) for every GAST D supported runway that: a) is caused by a spatial ionospheric delay gradient,b) is greater than the E_{IG} value computed from a broadcast Type 2 message, and c) is not detected and reflected in the broadcast Type 11 message within 1.5 seconds shall be less than 1×10^{-9} in any one landing. The FAST D ground subsystem shall limit the Type 2 broadcast parameters to ensure that the maximum E_{IG} at every LTP supporting GAST D operations shall not exceed 2.75 metres.

Note 1.— The total probability of an undetected delay gradient includes the prior probability of the gradient and the monitor(s) probability of missed detection.

Note 2.— Validation guidance for this requirement can be found in 7.5.6.1.8

3.6.7.4 *FUNCTIONAL REQUIREMENTS FOR AUTHENTICATION PROTOCOLS*

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3.6.7.4.1.2 The ground subsystem shall broadcast every Type 2 message only in one of a set of slots defined as the MT 2 sanctioned slots. The first slot in the group of MT 2 sanctioned slots corresponds to the SSID coding for the ground subsystem. Slot A is represented by SSID = 0, B by 1, C by 2, and H by 7. The group of MT 2 sanctioned slots then also includes the next slot after the slot corresponding to the station SSID if it exists in the frame. If there is not an additional slot before the end of the frame, only the SSID is included in the set.

Note.— For example, the MT 2 sanctioned slot group for SSID = 0 would include slots {A, B} while the MT 2 sanctioned slot group for SSID = 6 would include slots {G, H}. The MT 2 sanctioned slot group for SSID = 7 includes slot {H} only.

3.6.7.4.1.2.1 The set of slots assigned to a ground station shall include at a minimum all the slots in the MT 2 sanctioned slots as described in section 3.6.7.4.1.2.

3.6.7.4.1.3 *Assigned slot occupancy.* The ground subsystem shall transmit messages such that 89 per cent or more of every assigned slot is occupied. If necessary, Type 3 messages may be used to fill unused space in any assigned time slot.

Note 1.— More information on the calculation of the slot occupancy is provided in Attachment 6D, 7.21.

Note 2.— The requirement applies to the aggregate transmissions from all transmitters of a GBAS ground subsystem. Due to signal blockage, not all of those transmissions may be received in the service volume.

3.6.7.4.1.4 *Reference path identifier coding.* Every reference path identifier included in every final approach segment data block broadcast by the ground subsystem via the Type 4 messages shall have the first letter selected to indicate the SSID of the ground subsystem in accordance with the following coding.

Coding:

A = SSID of 0
X = SSID of 1
Z = SSID of 2
J = SSID of 3
C = SSID of 4
V = SSID of 5
P = SSID of 6
T = SSID of 7

3.6.7.4.2 *Functional requirements for ground subsystems that do not support authentication*

3.6.7.4.2.1 *Reference path identifier coding.* Characters in this set: {A X Z J C V P T} shall not be used as the first character of the reference path identifier included in any FAS block broadcast by the ground subsystem via the Type 4 messages.

3.6.8 AIRCRAFT ELEMENTS

3.6.8.1 *GNSS receiver.* The GBAS-capable GNSS receiver shall process signals of GBAS in accordance with the requirements specified in this section as well as with requirements in 3.1.3.1 and/or 3.2.3.1 and/or 3.5.8.1.

Note.— In order to ensure the required performance and functional objectives for GAST D are achieved, it is necessary for the airborne equipment to meet defined performance and functional standards. The relevant minimum operational performance standards are detailed in RTCA DO-253D.

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3.6.8.2.2.3 *VHF data broadcast message failure rate.* The VHF data broadcast receiver shall achieve a message failure rate less than or equal to one failed message per 1 000 full-length (222 bytes) application data messages, within the range of the RF field strength defined in 3.7.3.5.4.4 as received by the airborne antenna, provided that the variation in the average received signal power between successive bursts in a given time slot does not exceed 40 dB. Failed messages include those lost by the VHF data broadcast receiver system or which do not pass the CRC after application of the FEC.

Note 1.— An aircraft VHF data broadcast receiving antenna can be horizontally or vertically polarized. Due to the difference in the signal strength of horizontally and vertically polarized components of the broadcast signal, the maximum total aircraft implementation loss for horizontally polarized receiving antennas is 4 dB higher than the maximum loss for vertically polarized receiving antennas. For guidance in determining aircraft implementation loss see Attachment 6D, 7.2.

Note 2.— It is acceptable to exceed the signal power variation requirement in limited parts of the service volume when operational requirements permit. Refer to Attachment 6D, 7.12.4.1 for guidance.

3.6.8.2.2.4 *VHF data broadcast time slot decoding.* The VHF data broadcast receiver shall meet the requirements of 3.6.8.2.2.3 for all message types required (see 3.6.8.3.1.2.1) from the selected GBAS ground subsystem. These requirements shall be met in the presence of other GBAS transmissions in any and all time slots respecting the levels as indicated in 3.6.8.2.2.5.1 b).

Note.— Other GBAS transmissions may include: a) other message types with the same SSID, and b) messages with different SSIDs.

3.6.8.2.2.5 *Co-channel rejection*

3.6.8.2.2.5.1 *VHF data broadcast as the undesired signal source.* The VHF data broadcast receiver shall meet the requirements specified in 3.6.8.2.2.3 in the presence of an undesired co-channel VHF data broadcast signal that is either:

a) assigned to the same time slot(s) and 26 dB below the desired VHF data broadcast signal power at the receiver input or lower; or

b) assigned different time slot(s) and no more than 72 dB above the minimum desired VHF data broadcast signal field strength defined in 3.7.3.5.4.4.

3.6.8.2.2.5.2 *VOR as the undesired signal.* The VHF data broadcast receiver shall meet the requirements specified in 3.6.8.2.2.3 in the presence of an undesired co-channel VOR signal that is 26 dB below the desired VHF data broadcast signal power at the receiver input.

3.6.8.2.2.6 *Adjacent channel rejection*

3.6.8.2.2.6.1 *First adjacent 25 kHz channels (±25 kHz).* The VHF data broadcast receiver shall meet the requirements specified in 3.6.8.2.2.3 in the presence of a transmitted undesired signal offset by 25 kHz on either side of the desired channel that is either:

a) 18 dB above the desired signal power at the receiver input when the undesired signal is another VHF data broadcast signal assigned to the same time slot(s); or

b) equal in power at the receiver input when the undesired signal is VOR.

3.6.8.2.2.6.2 *Second adjacent 25 kHz channels (±50 kHz).* The VHF data broadcast receiver shall meet the requirements specified in 3.6.8.2.2.3 in the presence of a transmitted undesired signal offset by 50 kHz on either side of the desired channel that is either:

a) 43 dB above the desired signal power at the receiver input when the undesired signal is another VHF data broadcast source assigned to the same time slot(s); or

b) 34 dB above the desired signal power at the receiver input when the undesired signal is VOR.

3.6.8.2.2.6.3 *Third and beyond adjacent 25 kHz channels (±75 kHz or more).* The VHF data broadcast receiver shall meet the requirements specified in 3.6.8.2.2.3 in the presence of a transmitted undesired signal offset by 75 kHz or more on either side of the desired channel that is either:

a) 46 dB above the desired signal power at the receiver input when the undesired signal is another VHF data broadcast signal assigned to the same time slot(s); or

b) 46 dB above the desired signal power at the receiver input when the undesired signal is VOR.

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3.6.8.2.2.8.2 *Desensitization.* The VHF data broadcast receiver shall meet the requirements specified in 3.6.8.2.2.3 in the presence of VHF FM broadcast signals with signal levels shown in Tables B-80 and B-81.

Table B-79. Maximum levels of undesired signals

Frequency	Maximum level of undesired signals at the receiver input (db above S_{max})
50 kHz up to 88 MHz	-12
88 MHz-107.900 MHz	(see 3.6.8.2.2.8.2 and 3.6.8.2.2.8.3)
108.000 MHz-117.975 MHz	Excluded
118.000 MHz	-43
118.025 MHZ	-40
118.050 MHz up to 1 660.5 MHz	-12
Frequency	Maximum level of undesired signals at the receiver input (dB above S_{max})
50 kHz up to 88 MHz	-12
88 MHz-107.900 MHz	(see 3.6.8.2.2.8.2)
108.000Mhz-117.975 MHz	Excluded
108.000 MHz	-43
118.025 MHz	-40
118.050 MHz up to 1 660.5 MHz	-12

Notes.—

1. The relationship is linear between single adjacent points designated by the above frequencies.

2. These interference immunity requirements may not be adequate to ensure compatibility between VHF data broadcast receivers and VHF communication systems, particularly for aircraft that use the vertically polarized component of the VHF data broadcast. Without coordination between COM and NAV frequencies assignments or respect of a guard band at the top end of the 112 – 117.975 MHz band, the maximum levels quoted at the lowest COM VHF channels (118.000, 118.00833, 118.01666, 118.025, 118.03333, 118.04166, 118.05) may be exceeded at the input of the VDB receivers. In that case, some means to attenuate the COM signals at the input of the VDB receivers (e.g. antenna separation) will have to be implemented. The final compatibility will have to be assured when equipment is installed on the aircraft.

3. S_{max} is the maximum desired VHF data broadcast signal power at the receiver input.

Table B-80. Desensitization frequency and power requirements that apply for VDB frequencies from 108.025 to 111.975 MHz

Frequency	Maximum level of undesired signals at the receiver input (dB above S_{max})
88 MHz $\leq$ f $\leq$ 102 MHz	16
104 MHz	11
106 MHz	6
107.9 MHz	-9

Notes.—

1. The relationship is linear between single adjacent points designated by the above frequencies.

2. This desensitization requirement is not applied for FM carriers above 107.7 MHz and VDB channels at108.025 or 108.050 MHz. See Attachment 6D, 7.2.1.2.2.

3. S_{max} is the maximum desired VHF data broadcast signal power at the receiver input.

Table B-81. Desensitization frequency and power requirements that apply for VDB frequencies from 112.000 to 117.975 MHz

Frequency	Maximum level of undesired signals at the receiver input (dB above S_{max})
88 MHz $\leq$ f $\leq$ 104 MHz	16
106 MHz	11
107 MHz	6
107.9 MHz	1

Notes.—

1. The relationship is linear between single adjacent points designated by the above frequencies.

2. S_{max} is the maximum desired VHF data broadcast signal power at the receiver input.

3.6.8.2.2.8.3 *VHF data broadcast FM intermodulation immunity.* The VHF data broadcast receiver shall meet the requirements specified in 3.6.8.2.2.3 in the presence of interference from two-signal, third-order intermodulation products of two VHF FM broadcast signals having levels in accordance with the following:

$$2N_1 + N_2 + 3\,[23 - S_{max}] \leq 0$$

for VHF FM sound broadcasting signals in the range 107.7 – 108.0 MHz and

$$2N_1 + N_2 + 3\,[23 - S_{max} - 20\,\mathrm{Log}\,(\Delta f\,/\,0.4)] \leq 0$$

for VHF FM sound broadcasting signals below 107.7 MHz

where the frequencies of the two VHF FM sound broadcasting signals produce, within the receiver, a two signal, third-order intermodulation product on the desired VDB frequency.

N_1 and N_2 are the levels (dBm) of the two VHF FM sound broadcasting signals at the VHF data broadcast receiver input. Neither level shall exceed the desensitization criteria set forth in 3.6.8.2.2.8.2.

$\Delta f = 108.1 - f_1$, where f_1 is the frequency of N_1, the VHF FM sound broadcasting signal closer to 108.1 MHz.

S_{max} is the maximum desired VHF data broadcast signal power at the receiver input.

Note.— The FM intermodulation immunity requirements are not applied to a VHF data broadcast channel operating below 108.1 MHz, hence frequencies below 108.1 MHz are not intended for general assignments. Additional information is provided in Attachment 6D, 7.2.1.2.

3.6.8.3 *AIRCRAFT FUNCTIONAL REQUIREMENTS*

Note.— Unless otherwise specified, the following requirements apply to all GBAS airborne equipment classifications as described in Attachment 6D, 7.1.4.3.

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3.6.8.3.1.2.1 *GBAS message processing capability.* The GBAS receiver shall at a minimum process GBAS message types in accordance with Table B-82.

Table B-82. Airborne equipment message type processing

GBAS airborne equipment classification (GAEC)	Minimum message types processed
GAEC A	MT 1 or 101, MT 2 (including ADB 1 and 2 if provided)
GAEC B	MT 1, MT 2 (including ADB 1 and 2 if provided), MT4
GAEC C	MT 1, MT 2 (including ADB 1 if provided), MT 4
GAEC D	MT 1, MT2 (including ADB 1,2,3 and 4), MT 4 and MT 11

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3.6.8.3.1.5 The receiver shall only apply pseudo-range corrections from the most recently received set of corrections for a given measurement type. If the number of measurement fields in the most recently received message types (as required in Appendix 6B, section 3.6.7.2.1.1.1 for the active service type) indicates that there are no measurement blocks, then the receiver shall not apply GBAS corrections for that measurement type.

3.6.8.3.1.6 *Validity of pseudo-range corrections*

3.6.8.3.1.6.1 When the active service type is A, B or C, the receiver shall exclude from the differential navigation solution any ranging sources for which σ_{pr_gnd} in the Type 1 or Type 101 messages is set to the bit pattern "1111 1111".

3.6.8.3.1.6.2 If the active service type is D, the receiver shall exclude from the differential navigation solution any ranging source for which $\sigma_{pr\_gnd\_D}$ in the Type 11 message or σ_{pr_gnd} in the Type 1 message is set to the bit pattern "1111 1111".

3.6.8.3.1.7 The receiver shall only use a ranging source in the differential navigation solution if the time of applicability indicated by the modified Z-count in the Type 1, Type 11 or Type 101 message containing the ephemeris decorrelation parameter for that ranging source is less than 120 seconds old.

3.6.8.3.1.8 *Conditions for use of data to support approach services*

3.6.8.3.1.8.1 During the final stages of an approach, the receiver shall use only measurement blocks from Type 1, Type 11 or Type 101 messages that were received within the last 3.5 seconds.

Note.— Guidance concerning time-to-alert is given in Attachment 6D, 7.5.14

3.6.8.3.1.8.2 *GCID indications*

3.6.8.3.1.8.2.1 When the active service type is A, B or C, the receiver shall use message data from a GBAS ground subsystem for guidance only if the GCID indicates 1, 2, 3 or 4 prior to initiating the final stages of an approach.

3.6.8.3.1.8.2.2 When the active service type is D, the receiver shall use message data from a GBAS ground subsystem for guidance only if the GCID indicates 2, 3 or 4 prior to initiating the final stages of an approach.

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3.6.8.3.1.8.9.2 The receiver shall use the Type 4 messages to determine the FAS for approaches which are supported by GBAS approach service type (GAST) A or B associated with a channel number between 20 001 and 39 999.

3.6.8.3.1.8.9.3 The receiver shall use the FAS held within the on-board database for approaches which are supported by GBAS approach service type (GAST) A associated with a channel number between 40 000 and 99 999.

...

3.6.8.3.2.2 *Use of GBAS integrity parameters.* The aircraft element shall compute and apply the vertical, lateral and horizontal protection levels described in 3.6.5.5. If a $B_{i,j}$ parameter is set to the bit pattern "1000 0000" indicating that the measurement is not available, the aircraft element shall assume that $B_{i,j}$ has a value of zero. For any active service type, the aircraft element shall verify that the computed vertical and lateral protection levels are no larger than the corresponding vertical and lateral alert limits defined in 3.6.5.6.

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3.6.8.3.3.2 *CRC check.* The receiver shall compute the ephemeris CRC for each core satellite constellation's ranging source used in the position solution. The computed CRC shall be validated against the ephemeris CRC broadcast in the Type 1 or Type 101 messages prior to use in the position solution and within one second of receiving a new broadcast CRC. The receiver shall immediately cease using any satellite for which the computed and broadcast CRC values fail to match.

3.6.8.3.3.3 *Ephemeris error position bounds*

3.6.8.3.3.3.1 *Ephemeris error position bounds for GBAS approach services.* If the ground subsystem provides additional data block 1 in the Type 2 messages, the aircraft element shall compute the ephemeris error position bounds defined in 3.6.5.8.1 for each core satellite constellation's ranging source used in the approach position solution within 1s of receiving the necessary broadcast parameters. The aircraft element shall verify that the computed vertical and lateral ephemeris error position bounds (VEB_j and LEB_j) are no larger than the corresponding vertical and lateral alert limits defined in 3.6.5.6.

3.6.8.3.3.3.2 *Ephemeris error position bound for the GBAS positioning service.* The aircraft element shall compute and apply the horizontal ephemeris error position bound (HEB_j) defined in 3.6.5.8.2 for each core satellite constellation's ranging source used in the positioning service position solution.

3.6.8.3.4 *Message loss*

3.6.8.3.4.1 For airborne equipment operating with GAST C as the active service type, the receiver shall provide an appropriate alert if no Type 1 message was received during the last 3.5 seconds.

3.6.8.3.4.2 For airborne equipment operating with GAST A or B as the active service type, the receiver shall provide an appropriate alert if no Type 1 and no Type 101 message was received during the last 3.5 seconds.

3.6.8.3.4.3 For the airborne equipment operating with GAST D as the active service type, the receiver shall provide an appropriate alert or modify the active service type if any of the following conditions are met:

a) The computed position solution is less than 200 ft above the LTP/FTP for the selected approach and no Type 1 message was received during the last 1.5 seconds.

b) The computed position solution is less than 200 ft above the LTP/FTP for the selected approach and no Type 11 message was received during the last 1.5 seconds.

c) The computed position solution is 200 ft or more above the LTP/FTP of the selected approach and no Type 1 message was received during the last 3.5 seconds.

d) The computed position solution is 200 ft or more above the LTP/FTP of the selected approach and no Type 11 message was received during the last 3.5 seconds.

3.6.8.3.4.4 For the GBAS positioning service using Type 1 messages, the receiver shall provide an appropriate alert if no Type 1 message was received during the last 7.5 seconds.

3.6.8.3.4.5 For the GBAS positioning service using Type 101 messages, the receiver shall provide an appropriate alert if no Type 101 message was received during the last 5 seconds.

3.6.8.3.5 *Airborne pseudo-range measurements*

3.6.8.3.5.1 *Carrier smoothing for airborne equipment.* Airborne equipment shall utilize the standard 100-second carrier smoothing of code phase measurements defined in 3.6.5.1. During the first 100 seconds after filter start-up, the value of α shall be either:

a) a constant equal to the sample interval divided by 100 seconds; or

b) a variable quantity defined by the sample interval divided by the time in seconds since filter start-up.

3.6.8.3.5.2 *Carrier smoothing of airborne equipment operating with GAST D as the active service type.* Airborne equipment operating with GAST D as the active service type shall utilize 30-second carrier smoothing of code phase measurements as defined in 3.6.5.1.

Note.— For equipment that supports GAST D, two sets of smoothed pseudo-ranges are used. The form of the smoothing filter given in section 3.6.5.1 is the same for both sets, and only the time constant differs (i.e. 100 seconds and 30 seconds). Guidance concerning carrier-smoothing for GAST D is given in Attachment 6D, 7.19.3.

3.6.8.3.6 *Service type specific differential position solution requirements.* The airborne equipment shall compute all position solutions in a manner that is consistent with the protocols for application of the data (see 3.6.5.5.1.1.2).

Note.— The general form for the weighting used in the differential position solution is given in 3.6.5.5.1.1.2. Exactly which information from the ground subsystem is used in the differential position solution depends on the type of service (i.e. positioning service vs. approach service) and the active approach service type. The specific requirements for each service type are defined in RTCA DO 253D. Additional information concerning the normal processing of position information is given in Attachment 6D, 7.19.

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ATTACHMENT 6B. STRATEGY FOR INTRODUCTION AND APPLICATION OF NON-VISUAL AIDS TO APPROACH AND LANDING

(see 6.2, 6.2.1)

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2. Objectives of strategy

The strategy must:

a) maintain at least the current safety level of all weather operations;

b) retain at least the existing level or planned improved level of service;

c) support lateral and vertical path guidance as outlined in Resolution A37-11;

d) maintain global interoperability;

e) provide regional flexibility based on coordinated regional planning;

f) support infrastructure investment planning cycles;

g) be maintained by periodic review; and

h) take account of economic, operational and technical issues.

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3. Considerations

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3.2 ILS-related considerations

a) There is a limited risk that ILS Category II or III operations cannot be safely sustained at specific locations;

b) ILS receivers have implemented interference immunity performance Standards contained in CAR-ANS 6.3, 6.3.1.4;

c) in some regions, expansion of ILS is limited by channel availability (40 paired ILS/DME channels);

d) in most areas of the world, ILS can be maintained in the foreseeable future;

e) due to cost and efficiency considerations, some States are rationalizing some of their ILS infrastructure at Category I airports with limited operational usage; and

f) based on user-equipage considerations, GNSS-based approaches providing lateral and vertical path guidance may offer a cost-effective option when considering introduction of Category I approach service or when replacing or removing an existing ILS.

3.3 MLS-related considerations

a) MLS Category III is operational;

b) MLS has been implemented at specific locations to improve runway utilization in low visibility conditions; and

c) further MLS deployment is unlikely.

3.4 GNSS-related considerations

a) Standards and Recommended Practices (SARPs) are in place for GNSS with augmentation to support APV and Category I precision approach;

b) GNSS with satellite-based augmentation system (SBAS) for APV and Category I precision approach operations is operational;

c) GNSS with ground-based augmentation system (GBAS) for Category I precision approach operations is operational;

d) it is expected that an internationally accepted GBAS will be available for Category II and III operations in the 2018-2020 timeframe;

e) ongoing dual-frequency, multi-constellation (DFMC) GNSS developments will enhance performance of GNSS augmentations as well as enable new operational capabilities in the 2025 timeframe

f) technical and operational issues associated with GNSS approach, landing and departure operations, such as vulnerabilities due to ionospheric propagation and radio frequency interference, must be addressed in a timely manner; and

g) issues associated with DFMC GNSS must be addressed in a timely manner.

...

3.6 Other considerations

a) There is an increasing demand for Category II and/or III operations in some areas;

b) GNSS can potentially offer unique operational benefits for low-visibility operations, including new procedures, flexible siting requirements and provision of airport surface guidance;

c) only the three standard systems (ILS, MLS and GNSS with augmentation as required) are considered to play a role in supporting all weather operations. The use of head-up displays in conjunction with enhanced and synthetic vision systems may provide operational benefits;

d) a consequence of the global strategy is that there will not be a rapid or complete transition from ILS to GNSS or MLS. It is therefore essential for the implementation of the strategy that the radio frequency spectrum used by all of these systems be adequately protected;

e) the potential operational benefits resulting from the introduction of new landing systems may be limited by the constraints of mixed-system aircraft equipage;

f) APV operations may be conducted using GNSS with augmentation as required or barometric vertical guidance, and GNSS with ABAS lateral guidance;

g) APV operations provide enhanced safety and generally lower operational minima as compared to non-precision approaches;

h) adequate redundancy shall be provided when terrestrial navigation aids are withdrawn; and

i) rationalization shall be part of a national or regional strategy on terrestrial navigation aids; guidance is provided in Attachment 6H.

4. Strategy

Based on the considerations above, the need to consult aircraft operators, airport operators and international organizations, and to ensure safety, efficiency and cost-effectiveness of the proposed solutions, the global strategy is to:

a) continue ILS operations to the highest level of service as long as operationally acceptable and economically beneficial;

b) continue MLS operations where operationally required and economically beneficial;

c) implement GNSS with augmentation (i.e. ABAS, SBAS, GBAS) as required for APV and precision approach operations where operationally required and economically beneficial;

d) promote the continuing development and use of a multi-modal airborne approach and landing capability;

e) promote the use of APV operations, particularly those using GNSS vertical guidance, to enhance safety and accessibility; and

f) enable each region to develop an implementation strategy for these systems in line with this global strategy.

ATTACHMENT 6C. INFORMATION AND MATERIAL FOR GUIDANCE IN THE APPLICATION OF THE STANDARDS AND RECOMMENDED PRACTICES FOR ILS, VOR, PAR, 75 MHz MARKER BEACONS (EN-ROUTE), NDB AND DME

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2. Material concerning ILS installations

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2.1.9 *ILS multipath interference*

Note 1.— This guidance material reflects how new larger aeroplanes (NLA) may impact the size of the ILS critical and sensitive areas. It also documents established engineering practices for determining critical and sensitive area dimensions, outlines the associated operational trade-offs, and presents indicative examples of the resulting sizes of the areas. In practice, however, the size of critical and sensitive areas at an aerodrome may need to be determined by specific assessments at that aerodrome.

Note 2.— This guidance material is not intended to create a need to review established critical and sensitive area dimensions which have been demonstrated to be satisfactory at a particular aerodrome, unless the operational environment has evolved significantly (such as through the introduction of NLA operations at the aerodrome or the construction of new buildings) or the ILS installation has been changed in a way that may affect the dimensions of the areas.

2.1.9.1 *ILS environmental effects.* Large reflecting objects within the ILS coverage volume, whether fixed objects or vehicles, including aircraft, can potentially cause degradation of the signal-in-space, through signal blockage and/or multipath interference, with the consequence that the signal-in-space tolerances defined in CAR-ANS 6.3, 6.3.1 may be exceeded. The amount of degradation is a function of the location, size and orientation of the reflecting surfaces, and of the ILS antenna characteristics. The objective of identifying critical and sensitive areas (see 2.1.9.2) and associated management procedures is to prevent such degradation and ensure that aircraft using the ILS can rely on the signal-in-space meeting the requirements of CAR-ANS 6.3, 6.3.1.

2.1.9.2 *ILS critical and sensitive areas.* States differ in the way they choose to identify ILS protection areas. Practices also differ in how vehicle movement restrictions are managed. One method is to identify critical areas and sensitive areas as follows:

a) the ILS critical area is an area of defined dimensions about the localizer and glide path antennas where vehicles, including aircraft, are excluded during all ILS operations. The critical area is protected because the presence of vehicles and/or aircraft inside its boundaries will cause unacceptable disturbance to the ILS signal-in-space;

b) the ILS sensitive area is an area where the parking and/or movement of vehicles, including aircraft, is controlled to prevent the possibility of unacceptable interference to the ILS signal during ILS operations. The sensitive area is protected against interference caused by large moving objects outside the critical area but still normally within the airfield boundary.

Note 1.— In some States, the term "critical area" is used to describe an area that combines the critical and sensitive areas identified in this guidance material. In cases where the critical area overlaps operational areas, specific operational management procedures are required to ensure protection of aircraft using the ILS for intercept and final approach guidance.

Note 2.— It is expected that at sites, where ILS and MLS are to be collocated, the MLS might be located within ILS critical areas in accordance with guidance material in Attachment 6G, 4.1.

2.1.9.3 *Technical and operational logic associated with critical and sensitive areas.* Ideally, the critical area is enforced during all ILS operations with protection afforded down to at least the Category I decision height. A critical area disturbance would normally impact all aircraft using the ILS signal at a given time (entire approach). The critical area is typically safeguarded through marked boundaries, limiting access to the area or through procedural means if there are overlaps into operational areas. From an operational perspective, the sensitive area would ideally protect aircraft operations at least from the Category I decision height down to the runway, and be activated during low visibility conditions only (e.g. Category II and III). A sensitive area disturbance would normally be of a transient nature, and produce a local disturbance affecting a single aircraft only. However, at many locations, it may not be possible to achieve this ideal situation, and corresponding technical and operational mitigations will be required.

Note.— Guidance on operational procedures for the protection of critical and sensitive areas is provided in ICAO EUR DOC 013, "European Guidance Material on All Weather Operations at Aerodromes".

2.1.9.4 *Technical determination of critical and sensitive area dimensions.* Critical and sensitive areas are normally calculated in the planning stage, prior to ILS installation, using computer simulation. A similar process is used when there are changes to the installation or to the environment. When using computer simulations, it is necessary to allocate the protection of individual parts of the approach to either the critical or sensitive area. It is desirable to ensure that the combined critical and sensitive areas protect the entire approach. However, this may not be possible in all cases. Furthermore, if the logic described in 2.1.9.3 is used, this may lead to restrictively large critical areas. Some States have found that a reasonable compromise can be achieved using a different logic, whereby the critical area protects the segment from the edge of coverage down to 2 NM from the runway threshold, while the sensitive area protects the approach from 2 NM down to the runway. In this case, a Category I sensitive area will exist and may require operational mitigation. Depending on the operational environment (such as timing between leading aircraft on runway roll-out and trailing aircraft on final approach), no particular measures may be needed. There may not necessarily be a direct link between the approach allocation used in simulations to determine critical and sensitive areas, and their operational management. It is a State's responsibility to define the relevant areas. If different disturbance acceptance criteria or different flight segment protections are to be applied, they must be validated through a safety analysis. The safety analysis must take all relevant factors into account, including the aerodrome configuration, traffic density and any operational issues or capacity restrictions.

2.1.9.5 *Factors impacting the sizes of critical and sensitive areas.* Localizer and glide path antennas with optimized radiation patterns, especially when combined with two-frequency transmitters, can be very effective in reducing the potential for signal disturbance and hence the sizes of the critical and sensitive areas. Other factors affecting the sizes of the areas include the category of approach and landing operation to be supported, the amount of static disturbance, locations, sizes and orientations of aircraft and other vehicles (particularly of their vertical surfaces), runway and taxiway layout, and antenna locations. In particular, the maximum heights of vertical aircraft tail surfaces likely to be encountered must be established, together with all possible orientations at a given location, which may include non-parallel or non-perpendicular orientations with respect to the runway. While critical and sensitive areas are evaluated in a two-dimensional (horizontal) context, protection shall actually be extended to volumes, as departing aircraft and/or manoeuvring helicopters/aircraft can also cause disturbances to the ILS signals. The vertical profiles of the protection volumes depend on the vertical patterns of the transmitting arrays.

2.1.9.6 *Allocation of multipath error budget.* It is convenient to consider disturbances caused by mobile objects such as aircraft and other vehicles separately from the static disturbances caused by fixed objects such as buildings and terrain. Once the static multipath is known, the remainder can be allocated to dynamic disturbances. If measurements indicate that the real static multipath is significantly different from that assumed in the simulations, the allocation may need to be revised. In most cases, the root sum square combination of the disturbances due to fixed and mobile objects gives a more statistically valid representation of the total disturbance than an algebraic sum. For example, a limit of plus or minus 5μA for localizer course structure would be respected with plus or minus 3μA of disturbance due to static objects and an allowance of plus or minus 4μA for dynamic objects:

$$\sqrt{(3\mu A)^2 + (4\mu A)^2} = 5\mu\mathrm{A}$$

2.1.9.7 *Site study and computer simulations.* Normally, a site specific study is conducted for a particular airport installation. The study will take into account different assumptions for the static multipath environment, airport topography, types and effective heights of ILS arrays, and orientations of maneuvering aircraft, such as runway crossings, 180° turns at threshold or holding orientations other than parallel or perpendicular. Simulation models can be employed to calculate the probable location, magnitude and duration of ILS disturbances caused by objects, whether by structures or by aircraft of various sizes and orientation at different locations. Air navigation service providers (ANSPs) will need to ensure that simulation models used have been validated by direct comparison with ground and flight measurements for a variety of specific situations and environments, and that the subsequent application of such models is conducted by personnel with appropriate engineering knowledge and judgement to take into account the assumptions and limitations of applying such models to specific multipath environments.

2.1.9.8 *Changes in airport environment.* Shall major changes in the airport environment cause an increase in the static disturbances of the localizer and/or glide path, the sizes of the critical and sensitive areas may need to be redefined, with potential impact on airport efficiency or capacity. This is particularly significant when considering the location, size and orientation of proposed new buildings within or outside the airport boundary. It is recommended that suitable safeguarding criteria be employed to protect the ILS operations.

Note.— Example guidance can be found in ICAO EUR DOC 015 "European Guidance Material on Managing Building Restricted Areas"

2.1.9.9 *Typical examples of critical and sensitive areas.* Figures C-3 and C-4 (including associated Tables C-1, C2-A and C2-B)) show examples of critical and sensitive areas for different classes of vehicle/aircraft heights and several localizer and glide path antenna types. The calculation of these examples has been done with a simulation model using an exact method of resolution of ILS propagation equations applied to a 3D model of corresponding aircraft. The dimensions are based on assumptions of flat terrain, 3.0° glide path, allocations of 60 per cent of applicable tolerances for static multipath and 80 per cent for dynamic multipath, an approaching aircraft at 105 knots, i.e. with a 2.1 rad/s low-pass filter and an omnidirectional receiving antenna pattern. The examples consider typical orientations of reflecting surfaces of taxiing, holding and maneuvering aircraft/large ground vehicles. The tail heights for the ground vehicles/small aircraft, medium, large and very large aircraft categories correspond to CAAP MOS Aerodromes reference code letters A, B/C, D/E and F, respectively, as detailed within FAA Advisory Circular 150/5300-13. In case of uncertainty about which category an aircraft belongs to for the purposes of critical and sensitive areas assessment, the tail height is the determining feature.

2.1.9.9.1 *Purpose and correct application of typical examples.* Since it will be rare that an actual installation fits exactly the assumptions used in these examples, adaptation to local conditions will be required. The examples serve to provide a rough order of magnitude indication of critical and sensitive area sizes, depending on how much local conditions differ from assumptions used in these examples. The example tables may also be used to assess the tools used in simulations, using the listed assumptions. In many installations, airports have established critical and sensitive areas which are different from those listed in these examples, through a combination of further technical optimizations, operational mitigations, experience, and safety assessments applicable to the particular operational environment. In the case of new airport construction projects, potential conflicts of the example areas provided here with planned operational uses shall lead to further evaluations, and may lead to implementing more advanced ILS antenna systems, for example wider aperture localizer antennas, including advanced designs such as very large aperture arrays. The typical examples provided here do not take such specific optimized systems into account. The tables differ slightly between the localizer and the glide path in terms of how different aircraft orientations are considered. These details are explained in the notes to Tables C-1 (note 9), C-2A and C-2B (note 8). In accordance with these notes, in some glide path cases the half-wingspan of aircraft needs to be added to ensure that no portion of the aircraft enters the critical or sensitive areas.

2.1.9.9.2 *Limits of multipath assumptions used in example simulations.* The allocation of 60 per cent for static and 80 per cent for dynamic multipath used in 2.1.9.6 represents a conservative approach which is suitable in locations where both types of multipath coincide. A different allocation may be appropriate for the glide path, especially in the case of flat terrain, as in that case the static multipath will be very small. In locations where static and dynamic multi-path do not coincide, due to the specific layout of the airport, the full tolerance can be consumed by the dynamic multipath. A simulation tool able to model the complete environment (static and dynamic reflection sources) and to compute the combined effect may avoid having to apply the root sum square approximation. This may lead to an optimization of the critical and/or sensitive area dimensions

2.1.9.9.3 *Flight segment protection allocations used in example simulations.* The examples given in Figure C-3 for the localizer use a 2 NM transition point as described in 2.1.9.4. The examples given in Figure C-4 for the glide path use a 0.6 NM transition point (corresponding to the Category I decision height). Depending on local operations, other transition points may be more suitable.

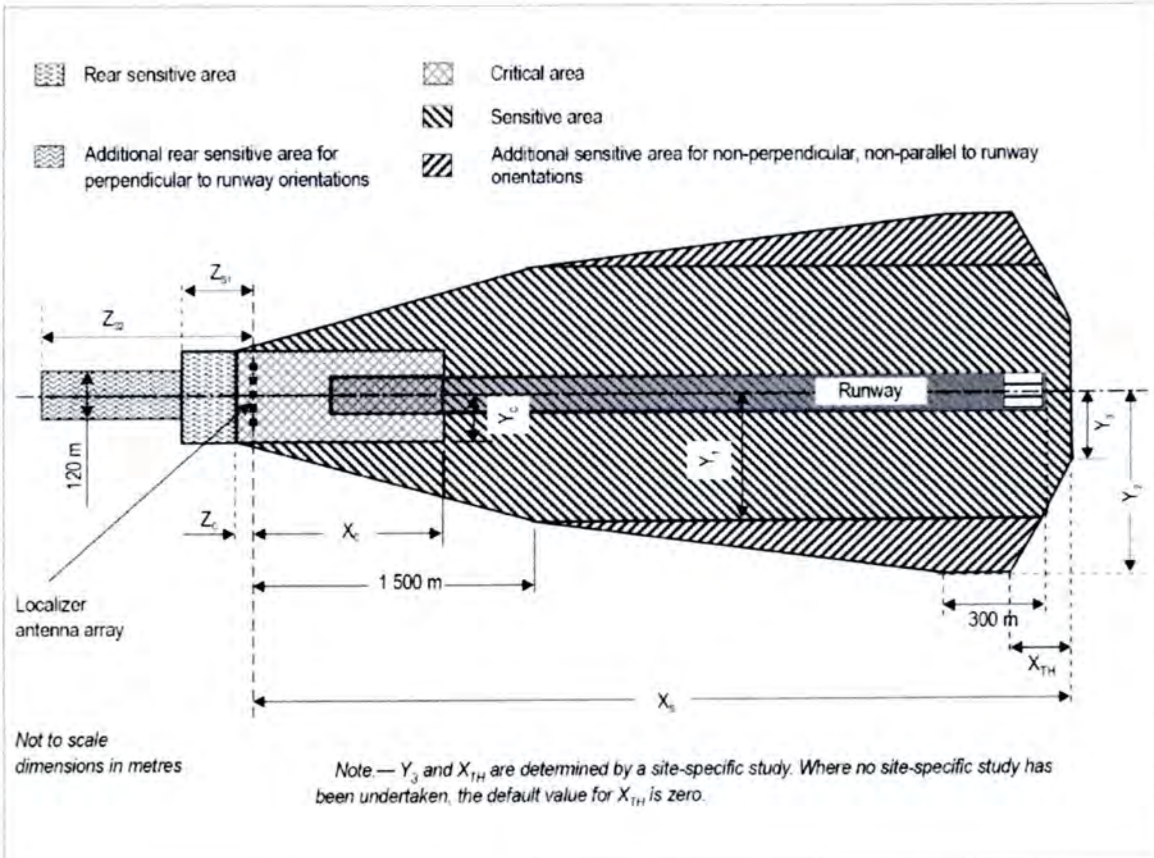

Figure C-3. Example of localizer critical and sensitive area dimensions (values in associated Table C-1 below)

Table C-1. Typical localizer critical and sensitive area sizes

Aircraft/vehicle height	H≤ 6 m (see Note 1) Ground vehicle			6m < H≤ 14 m Medium aircraft			14 m < H ≤ 20 m Large aircraft		20 m < H ≤ 25 m Very large aircraft	
Antenna aperture (see Note 3)	Small	Medium	Large	Small	Mediu m	Large	Medium	Large	Medium	Large
Critical area CAT I Xc	180 m	65 m	45 m	360 m	200 m	150 m	500 m	410 m	660 m	580 m
Z_c	10 m	10 m	10 m	35 m	35 m	35 m	50 m	50 m	60 m	60 m
(see Note 10) Yc	50 m	15 m	20 m	110 m	25 m	25 m	50 m	30 m	55 m	40 m
Sensitive area CAT I X_s	200 m	No sensitive area		500 m	No sensitive area		No sensitive area		1 300 m	1 100m
Y_1	40 m			90 m					90 m	50 m
Y_2	40 m			90 m					90 m	50 m
Z_{S1}	15 m			35 m					60 m	60 m
(see Note 7) Z_{S2}	15 m			35 m					60 m	60 m

Aircraft/vehicle height	H ≤ 6 m (see Note 1) Ground vehicle		6 m < H ≤ 14 m Medium aircraft		14 m < H ≤ 20 m Large aircraft		20 m < H ≤ 25 m Very large aircraft	
Antenna aperture (see Note 3)	**Medium**	**Large**	**Medium**	**Large**	**Medium**	**Large**	**Medium**	**Large**
Critical area CAT II Xc	**75 m**	**55 m**	**200 m**	**200 m**	**500 m**	**475 m**	**750 m**	**675 m**
Zc	10 m	10 m	35 m	35 m	50 m	50 m	60 m	60 m
(see Note 10) Yc	**15 m**	**20 m**	**25 m**	**25 m**	**50 m**	**30 m**	**70 m**	**50 m**
Sensitive area CAT II X_S	**75 m**	No sensitive area	500 m	No sensitive area	**2 100 m**	**1 400 m**	Localizer to threshold distance	Localizer to threshold distance
Y_1	**15 m**		50 m		125 m × K	60 m × K	180 m × K	100 m × K
Y2	15 m		50 m		125 m × K	60 m × K	180 m × K	125 m × K
Z_{S1}	15 m	15 m	35 m	35 m	60 m	60 m	70 m	70 m
(see Note 7) Z_{S2}	15 m	15 m	45 m	45 m	160 m	160 m	250 m	250 m

Aircraft/vehicle height	H ≤ 6 m (see Note 1) Ground vehicle		6m < H ≤ 14 m Medium aircraft		14 m < H ≤ 20 m Large aircraft		20m< H ≤ 25 m Very Large aircraft	
Antenna aperture (see Note 3)	Medium	Large	Medium	Large	Medium	Large	Medium	Large
Critical area CAT III Xc	75 m	55 m	200 m	200 m	500 m	475 m	750 m	675 m
Zc	10 m	10 m	35 m	35 m	50 m	50 m	60 m	60 m
(see Note 10) Yc	15 m	20 m	25 m	25 m	50 m	30 m	70 m	50 m
Sensitive area CAT III Xs	100 m	No sensitive area	900 m	No sensitive area	3 100 m	3 100 m	Localizer to Threshold distance	Localizer to Threshold distance
Y1	15 m		50 m		140 m xK	120 m x K	180 m x K	150 m x K
Y2	15 m		50 m		160 m x K	120 m x K	260 m x K	180 m x K
Zs1	15 m	15 m	35 m	35 m	60 m	60 m	70 m	70 m
(see Note 7) Zs2	15 m	15 m	45 m	45 m	160 m	160 m	250 m	250 m

Notes:

1. For vehicles smaller than 2.5 m in height, $Z_C = 3$ m, assuming a 23 dB front/back ratio for the transmitting antenna for both course and clearance signals.

2. For systems with near-field monitor antennas, vehicles must not enter between the monitor antennas and the transmitting antenna.

3. Small aperture: 11 elements or less. Medium aperture: 12 to 15 elements. Large aperture: 16 elements or more. Simulations have been conducted using a commonly installed 12 element system for the medium and a commonly installed 20 element system for the large aperture cases. It is assumed that Category II/III operations are not conducted on runways equipped with small aperture localizers, and that aircraft as large as a 747 are not operating on such runways.

4. For localizer arrays with very low height, additional critical area will be needed due to the greater attenuation of the direct signal at low vertical angles.

5. A specific study for a particular airport, considering realistic orientations, static multipath environment, and airport topography and type of ILS antennas, may define different critical areas.

6.
$$K = \sqrt{\frac{\textbf{localizer to threshold distance}}{\textbf{3 300 m}}}$$

7. The rear dimensions for sensitive areas may be changed based on specific study results considering fielded antenna pattern characteristics. A directional array with a 23 dB front/back ratio is assumed for course and clearance signals.

8. Single aircraft taxiing or holding parallel to the runway does not generate out-of-tolerance signals.

9. Boundaries for critical areas or rear sensitive areas apply to the entire longitudinal axis (both tail and fuselage) of the interfering aircraft. Boundaries for sensitive areas apply only to the tail of the interfering aircraft.

10. The critical area semi-width, Yc, shall exceed the actual physical dimension of the localizer antenna array by at least 10 m laterally (on both sides) in its portion between the localizer antenna array and the stop end of the runway.

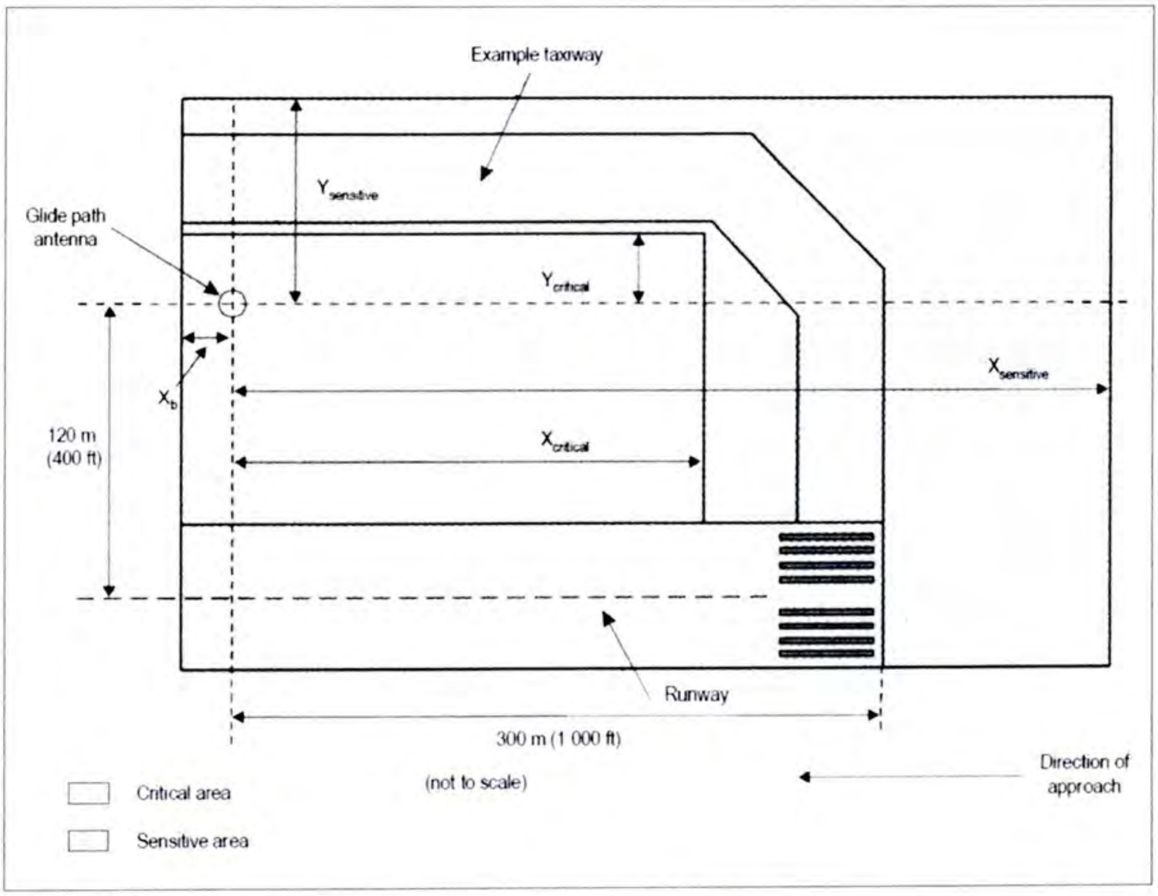

Figure C-4. Example of the glide path critical and sensitive area dimensions (values in associated Tables C-2A below)

Table C-2A. Example of glide path critical and sensitive area dimensions for parallel and perpendicular orientations

Aircraft/vehicle height	Ground vehicle		Medium aircraft		Large aircraft		Very large aircraft	
	H ≤ 6 m		6 m < H ≤ 14 m		14 m < H ≤ 20 m		20 m < H ≤ 25 m	
Glide path type	M-array	Null-ref	M-array	Null-ref	M-array	Null-ref	M-array	Null-ref
CAT I critical area								
X	299 m	191 m	329 m	829 m	467 m	1 117 m	610 m	1 360 m
Y	29 m	29 m	20 m	20 m	22 m	22 m	15 m	15 m
CAT I sensitive area								
X	299 m	399 m	279 m	529 m	417 m	717 m	510 m	760 m
Y	29 m	15 m	20 m	20 m	22 m	16 m	15 m	15 m
CAT II/III critical area								
X	299 m	449 m	329 m	829 m	567 m	1 267 m	660 m	1 410 m
Y	29 m	29 m	20 m	20 m	22 m	22 m	15 m	15 m
CAT II/III sensitive area								
X	299 m	449 m	429 m	629 m	517 m	767 m	560 m	1 010 m
Y	29 m	29 m	20 m	20 m	22 m	22 m	15 m	15 m

Table C-2B. Example of glide path critical and sensitive area dimensions for other orientations

Aircraft/vehicle height	Ground vehicle $H \leq 6$ m		Medium aircraft 6 m $< H \leq 14$ m		Large aircraft 14 m $< H \leq 20$ m		Very large aircraft 20 m $< H \leq 25$ m	
Glide path type	M-array	Null-ref	M-array	Null-ref	M-array	Null-ref	M-array	Null-ref
CAT I critical area								
X	298 m	191 m	297 m	829 m	444 m	**1 167 m**	591 m	1 360 m
Y	24 m	15 m	**39 m**	**39 m**	**35 m**	**55 m**	**34 m**	**55 m**
CAT I sensitive area								
X	298 m	394 m	**297 m**	**537 m**	**444 m**	717 m	**541 m**	710 m
Y	24 m	**24 m**	**39 m**	**39 m**	**25 m**	**18 m**	**24 m**	**24 m**
CAT II/III critical area								
X	298 m	443 m	**347 m**	829 m	544 m	1 267 m	**672 m**	1 410 m
Y	24 m	25 m	**39 m**	**39 m**	**35 m**	**55 m**	**34 m**	**55 m**
CAT II/III sensitive area								
X	298 m	445 m	297 m	**829 m**	**528 m**	**817 m**	**610 m**	1 010 m
Y	24 m	24 m	**39 m**	**39 m**	**25 m**	**25 m**	**24 m**	**24 m**

Notes:

1. X_b = 50 m and applies to both critical and sensitive areas for the large and very large aircraft category only. Otherwise, X_b = 0 m.

2. The ground vehicle category also applies to small aircraft. Simulations have approximated these aircraft or large ground vehicles using a rectangular box (4 m high 12 m long 3 m wide). Depending on local conditions, it may be possible to reduce especially Category I critical area dimensions such that taxiing or driving on the taxiway directly in front of the glide path antenna may be allowed.

3. Separate tables (C-2A and C-2B) are given for parallel/perpendicular and for other orientations in order to not penalize parallel taxiway operations. To derive worst-case keep-out areas, the largest number among the two tables must be used. Values in Table C-2B ("other orientations") that are larger than the corresponding ones in Table C-2A ("parallel and perpendicular orientations") are highlighted in bold. Perpendicular orientations covered in Table C-2A include only the orientation where the nose of the aircraft is pointing towards the runway. Perpendicular orientations with the tail of the aircraft pointing towards the runway are covered in Table C-2B. Table C-2B also considers aircraft turning towards the runway for line-up at angles of 15, 30, 45, 60 and 75 degrees. Orientations causing the largest keep-out areas (i.e. worst aircraft orientation among all orientations causing out-of-tolerance signals) have been derived based on an A380 using an M-array antenna. Since the number of simulations required to cover all possible orientations for all categories of vehicles over a large area would be excessive, the impact of worst-case orientations on the critical and sensitive areas may need to be verified taking into account the particular taxiway layout.

4. Simulations are referenced to the glide path antenna mast using a typical perpendicular distance to the runway centre line of 120 m and a nominal parallel distance from the runway *threshold of 300 m. For different antenna-to-runway offsets, the critical and sensitive areas have to be shifted accordingly.*

5. The edge of the runway closer to the glide path antenna defines the inner limit of the critical area. The farther edge of the runway defines the inner limit of the sensitive area. This sensitive area limit needs to be extended by another 50 m on the opposite side of the runway (starting from the runway centre line) for the large and very large aircraft categories when using a Null-Ref antenna.

6. Depending on simulation choices (transition point), the critical area may be larger than the sensitive area and impact associated management procedures.

7. In line with the operational logic described in 2.1.9.4 (no protection of the Category I glide path is required below decision height) as well as the observation that in Tables C-1, C-2A and C-2B, the Category I critical area is typically equal or larger than the sensitive area, protecting the Category I sensitive area may not be necessary.

8. Boundaries for critical and sensitive areas apply to the entire aircraft (entire fuselage and wings).

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Table C- 3 Required distance separation

	Frequency separation	Minimum separation between second facility and the protection point of the first facility km (NM)		
		List A	List B	List C
Localizer	Co-channel	148 (80)	148 (80)	148 (80)
	50 kHz	---	37 (20)	9 (5)
	100kHz	65 (35)	9 (5)	0
	150 kHz	---	0	0
	200 kHz	11 (6)	0	0
Glide path	Co-channel	93 (50)	93 (50)	93 (50)
	150 kHz	---	20 (11)	2 (1)
	300 kHz	46 (25)	2 (1)	0
	450 kHz	---	0	0
	600 kHz	9 (5)	0	0

List A refers to the use of localizer receivers designed for 200 kHz channel spacing coupled with glide path receivers designed for 600 kHz channel spacing and applicable only in regions where the density of facilities is low.

List B refers to the use of localizer receivers designed for 100 kHz channel spacing coupled with glide path receivers designed for 300 kHz channel spacing

List C refers to the use of localizer receivers designed for 50 kHz channel spacing coupled with glide path receivers designed for 150 kHz channel spacing.

Note 1.- The above figures are based on the assumption of protection points for the localizer at 46 km (25 Nm) distance and 1 900 m (6 250 ft) height and for the ILS glide path at 18.5 km (10 NM) distance and 760 m (2 500 ft) height.

Note 2. – States, in applying the separations shown in the table, have to recognize the necessity to site the ILS and VOR facilities in a manner which will preclude the possibility of airborne receiver error due to overloading by high unwanted signal levels when the aircraft is in the initial and final approach phases.

Note 3. – States, in applying the separations shown in the table, have to recognize the necessity to site the ILS glide path facilities in a manner which will preclude the possibility of erroneous glide indications due to reception of adjacent channel signals when the desired signal ceases to radiate for any reason while the aircraft is in the final approach phase.

Table C-4. Integrity and continuity of service objectives

Level	Localizer or glide path		
	Integrity	Continuity of service	MTBO (hours)
1.		Not demonstrated, or less than required for Level 2	
2.	$1 - 10^{-7}$ in any one landing	$1\text{-}4 \times 10^{-6}$ in any period of 15 seconds	1000
3.	$1\text{-}0.5 \times 10^{-9}$ in any one landing	$1\text{-}2 \times 10^{-6}$ in any period of 15 seconds	2000
4.	$1\text{-}0.5 \times 10^{-9}$ in any one landing	$1\text{-}2 \times 10^{-6}$ in any period of 30 seconds (localizer) 15 seconds (glide path)	4000 (localizer) 2000(glide path)

Note. – For currently installed systems, in the event that the level 2 integrity value is not available or cannot be readily calculated , it is necessary to at least perform a detailed analysis of the integrity to assure proper monitor fail-safe operation.

Table C-5. Values of geographical separation distances for co-channel operation

		VOR facilities of equal effective radiated power		VOR facilities which differ in effective radiated power by 6 dB				VOR facilities which differ in effective radiated power by 12 dB			
		Minimum geographical separation between facilities is $2D_1 + \frac{20}{S}$ if $D_1 > D_2$ or $2D_2 + \frac{20}{S}$ if $D_2 > D_1$		Minimum geographical separation between facilities is $2D_1 + \frac{20-K}{S}$ if $D_1 > D_2 + \frac{K}{S}$ or $2D_2 + \frac{20+K}{S}$ if $D_1 < D_2 + \frac{K}{S}$				Minimum geographical separation between facilities is $2D_1 + \frac{20-K}{S}$ if $D_1 > D_2 + \frac{K}{S}$ or $2D_2 + \frac{20+K}{S}$ if $D_1 < D_2 + \frac{K}{S}$			
Altitude m (ft)	S dB/km (NM)	K dB	$\frac{20}{S}$ km (NM)	K dB	$\frac{K}{S}$ km (NM)	$\frac{20-K}{S}$ km (NM)	$\frac{20+K}{S}$ km (NM)	K dB	$\frac{K}{S}$ km (NM)	$\frac{20-K}{S}$ km (NM)	$\frac{20+K}{S}$ km (NM)
1	2	3	4	5	6	7	8	9	10	11	12
1 200 (4 000)	0.32 (0.60)	0	61 (33)	6	19 (10)	43 (23)	80 (43)	12	37 (20)	24 (13)	98 (53)
3 000 (10 000)	0.23 (0.43)	0	87 (47)	6	26 (14)	61 (33)	113 (61)	12	52 (28)	35 (19)	137 (74)
4 500 (15 000)	0.18 (0.34)	0	109 (59)	6	33 (18)	76 (41)	143 (77)	12	67 (36)	44 (24)	174 (94)
6 000 (20 000)	0.15 (0.29)	0	128 (69)	6	39 (21)	89 (48)	167 (90)	12	78 (42)	52 (28)	206 (110)
7 500 (25 000)	0.13 (0.25)	0	148 (80)	6	44 (24)	104 (56)	193 (104)	12	89 (48)	59 (32)	237 (128)
9 000 (30 000)	0.12 (0.23)	0	161 (87)	6	48 (26)	113 (61)	209 (113)	12	96 (52)	65 (35)	258 (139)
12 000 (40 000)	0.10 (0.19)	0	195 (105)	6	59 (32)	135 (73)	254 (137)	12	119 (64)	78 (42)	311 (168)
18 000 (60 000)	0.09 (0.17)	0	219 (118)	6	65 (35)	154 (83)	284 (153)	12	130 (70)	87 (47)	348 (188)

Note.— S, K and the sign of K are defined in 3.4.5.

Table C- 6. Protection ratio D/U (dB)

Type of assignment	A	B
Co-frequency :		
Same pulse code	8	8
Different pulse code	8	-42
First adjacent frequency:		
Same pulse code	$-(P_u - 1)$	-42
Different pulse code	$-(P_u+7)$	-75
Second adjacent frequency		
Same pulse code	$-(P_u+19)$	-75
Different pulse code	$-(P_u+27)$	-75

Note 1.- The D/U ratios column A protect those DME/N interrogators Operating on x or y channels. Column A applies to decoder rejection of 6 microseconds

Note 2.- The D/u ratios in column B protect those in DME/N or DME/P interrogators utilizing discrimination in conformance with 6.3.5.5.3.4.2 and 6.3.5.5.3.4.3 of CAR-ANS 6.3 and providing a decoder rejection conforming 6.3.5.5.3.5 of CAR-ANS 6.3.

Note 3.- P_u is the peak effective radiated power of the undesired signal in dBw.

Note- 4. The frequency protection requirement is dependent upon the antenna patterns of the desired and undesired facility and the ERP of the undesired ERP of the underside facility

Note.- 5 In assessing adjacent channel protection, the magnitude of D/U ratio in Column A should not exceed the magnitude of the value in column B.

Table C-7.

Function	Typical distance from the threshold	PFE (95% probability)	CMN (95% probability)
Approach (7.3.2.1.3)			
— extended runway centre line	37 km (20 NM)	±250 m (±820 ft)	±68 m (±223 ft)
— at 40° azimuth	37 km (20 NM)	±375 m (±1 230 ft)	±68 m (±223 ft)
Approach (7.3.2.1.4)			
— extended runway centre line	9 km (5 NM)	±85 m (±279 ft)	±34 m (±111 ft)
— at 40° azimuth	9 km (5 NM)	±127 m (±417 ft)	±34 m (±111 ft)
Marker replacement			
— outer marker	9 km (5 NM)	±800 m (±2 625 ft)	not applicable
— middle marker	1 060 m (0.57 NM)	±400 m (±1 312 ft)	not applicable
30 m decision height determination (100 ft) (7.3.2.1.5)	556 m (0.3 NM)	±30 m (±100 ft)	not applicable
— 3° glide path (CTOL)	556 m (0.3 NM)	±15 m (±50 ft)	not applicable
— 6° glide path (STOL)			
Flare initiation over uneven terrain (7.3.2.1.6)			
— 3° glide path (CTOL)	0	±30 m (±100 ft)	±18 m (±60 ft)
— 6° glide path (STOL)	0	±12 m (±40 ft)	±12 m (±40 ft)
Sensitivity modifications (7.3.2.1.7) (autopilot gain scheduling)	37 km (20 NM) to 0	±250 m (±820 ft)	not applicable
Flare manoeuvre with MLS flare elevation (7.3.2.1.8)			
— CTOL	0	±30 m (±100 ft)	±12 m (±40 ft)
— STOL	0	±12 m (±40 ft)	±12 m (±40 ft)
Long flare alert (7.3.2.1.9)	Runway region	±30 m (±100 ft)	not applicable
CTOL high speed roll-out/turnoffs (7.3.2.1.10)	Runway region	±12 m (±40 ft)	±30 m (±100 ft)
Departure climb and missed approach	0 to 9 km (5 NM)	±100 m (±328 ft)	±68 m (±223 ft)
VTOL approaches (7.3.2.1.11)	925 m (0.5 NM) to 0	±12 m (±40 ft)	±12 m (±40 ft)
Coordinate translations (7.3.2.1.12)	—	±12 m to ±30 m (±40 ft to ±100 ft)	±12 m (±40 ft)

Table C-8. Example of DME/P error budget

Error source	Error component	FA mode Standard 1 PFE m (ft)	FA mode Standard 1 CMN m (ft)	FA mode Standard 2 PFE m (ft)	FA mode Standard 2 CMN m (ft)	IA mode PFE m (ft)	IA mode CMN m (ft)
Instrumentation	Transponder	± 10 (±33)	±8 (±26)	±5(±16)	± 5(±16)	±15(±50)	±10(±33)
	Interrogator	± 15 (±50)	±10 (±33)	±7(±23)	± 7(±23)	±30(±100)	±15(±50)
Site related	Down-link specular multipath	±10 (±33)	±8(±26)	±3(±10)	±3(±10)	±37(±121)	±20(±66)
	Up-link specular multipath	±10 (±33)	±8(±26)	±3(±10)	±3(±10)	±37(±121)	±20(±66)
	Non-specular(Diffuse) multipath	±3 (±10)	±3(±10)	±3(±10)	±3(±10)	±3(±10)	±3(±10)
	Garble	±6 (±20)	±6(±20)	±6(±20)	±6(±20)	±6(±20)	±6(±20)

Note 1.- The figures for "non-specular multipath" and for "garble" are the totals of the up-link and down-link components.

Note 2.- PFE contains both bias and time varying components. In the above table the time varying components and most site related errors are assumed to be essentially statistically independent. The bias components may not conform to any particular statistical distribution.

In considering these error budgets, caution is to be exercised when combining the individual components in any particular mathematical manner.

Note 3. The transmitter wave form is assumed to have a 1 200 nanosecond rise time.

Table C-9. CTOL ground-to-air power budget

Power budget items	41 km (22 NM)	13 km (7 NM)	Ref. datum	Roll-out
Peak effective radiated power, dBm	55	55	55	55
Ground multipath loss, dB	–5	–3	–4	–17
Antenna pattern loss, dB	–4	–2	–5	–5
Path loss, dB	–125	–115	–107	–103
Monitor loss, dB	–1	–1	–1	–1
Polarization and rain loss, dB	–1	–1	0	0
Received signal at aircraft, dBm	–81	–67	–62	–71
Power density at aircraft, dBW/m^2	–89	–75	–70	–79
Aircraft antenna gain, dB	0	0	0	0
Aircraft cable loss, dB	–4	–4	–4	–4
Received signal at interrogator, dBm	–85	–71	–66	–75
Receiver noise video, dBm				
(Noise factor (NF) = 9 dB)				
IF BW: 3.5 MHz		–103	–103	–103
IF BW: 0.8 MHz	–109			
Signal-to-noise ratio (video), dB	24	32	37	28

Table C-10. CTOL air-to-ground power budget

Power budget items	41 km (22 NM)	13 km (7 NM)	Ref. datum	Roll-out
Interrogator transmitter power, dBm	57	57	57	57
Aircraft antenna gain, dB	0	0	0	0
Aircraft cable loss, dB	–4	–4	–4	–4
Peak effective radiated power, dBm	53	53	53	53
Ground multipath loss, dB	–5	–3	–4	–17
Path loss, dB	–125	–115	–107	–103
Polarization and rain loss, dB	–1	–1	0	0
Received signal at transponder antenna, dBm	–78	–66	–58	–67
Ground antenna gain, dB	8	8	8	8
Pattern loss, dB	–4	–2	–5	–5
Cable loss, dB	–3	–3	–3	–3
Received signal at transponder, dBm	–77	–63	–58	–67
Receiver noise video, dBm (Noise factor (NF) = 9 dB)				
IF BW: 3.5 MHz		–106	–106	–106
IF BW: 0.8 MHz	–112			
Signal-to-noise ratio (video), dB	35	43	48	39

Table C-11. Power supply switch-over times for ground-based radio aids used at aerodromes

Type of runway	Aids requiring power	Maximum switch-over times (seconds)
Instrument approach	SRE	15
	VOR	15
	NDB	15
	D/F facility	15
Precision approach, Category I	ILS localizer	10
	ILS glide path	10
	ILS middle marker	10
	ILS outer marker	10
	PAR	10
Precision approach, Category II	ILS localizer	0
	ILS glide path	0
	ILS inner marker	1
	ILS middle marker	1
	ILS outer marker	10
Precision approach, Category III	(same as Category II)	

7.2 Guidance material concerning DME/N only

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7.2.3 *DME-DME RNAV*

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7.2.3.3 Errors in published DME facility locations will result in RNAV position errors. It is therefore important that DME positions are correctly surveyed and that adequate procedures are in place to ensure that the location data are correctly published. For DME facilities collocated with VOR, the DME position shall be separately surveyed and published if the separation distance exceeds 30 m (100 ft).

Note.— Specifications concerning data quality and publication of DME location information are contained in PANS-AIM(Doc 10066), Appendix 1.

ATTACHMENT 6D. INFORMATION AND MATERIAL FOR GUIDANCE IN THE APPLICATION OF THE GNSS STANDARDS AND RECOMMENDED PRACTICES

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3. NAVIGATION SYSTEM PERFORMANCE REQUIREMENTS

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3.2 Accuracy

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3.2.7.1 Requirements for position domain accuracy to support precision approach operations below Category I are not defined in the SARPs. GBAS service types intended to support operations with lower than Category I minima are required to meet the SIS accuracy requirements for Category I at a minimum. In addition, specific pseudo-range accuracy requirements apply to support the assessment of adequate performance during aircraft certification. The additional requirements on pseudo-range accuracy may be combined with geometry screening to ensure the resulting position domain accuracy is adequate for a given aeroplane design to achieve suitable landing performance. See 7.5. 13.

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3.2.9 SBAS and GBAS receivers will be more accurate, and their accuracy will be characterized in real time by the receiver using standard error models, as described in CAR-ANS 6.3, 6.3.5, for SBAS and 6.3, 6.3.6, for GBAS.

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Note 2.— The term "GBAS receiver" designates the GNSS avionics that at least meet the requirements for a GBAS receiver as outlined in Annex 10, Volume I and the specifications of the RTCA documents covering the applicable performance types, amended by United States FAA TSO (or equivalent).

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3.3 Integrity

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3.3.10 For GBAS, a technical provision has been made to broadcast the alert limit to aircraft. For SBAS, technical provisions have been made to specify the alert limit through an updatable database (see Attachment 6C).

3.3.10.1 For GBAS approach service type D (see 7.1.2.1) additional lower level performance and functional requirements are introduced in order to achieve a total system capable of supporting aircraft landing operations. This service type also supports guided take-off operations.

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3.3.15 Another environmental effect that shall be accounted for in the ground system design is the errors due to multipath at the ground reference receivers, which depend on the physical environment of monitoring station antennas as well as on satellite elevations and times in track.

3.3.16 SBAS needs to assure the integrity of its broadcast corrections as required in 3.7.2.4 throughout its coverage area. This requirement also applies outside the intended service area, where user receivers could navigate using either an SBAS navigation solution, if available, or a fault detection and exclusion (FDE) navigation solution. The SBAS contributions to a FDE navigation solution are limited to assuring the integrity of the transmitted corrections. SBAS systems have to comply with all the integrity requirements for all typical operations from En-route to Category I, defined in Table 6.3.7.2.4-1, in the coverage area when, for a given operation, the horizontal and vertical protection levels are lower than the corresponding alert limits. This is of particular importance for vertically guided operations using SBAS that are not controlled by FAS data block.

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6.2 SBAS coverage area and service areas

6.2.1 It is important to distinguish between the coverage area and service areas for an SBAS. A coverage area typically corresponds to the GEOs footprint areas and comprises one or more service areas. Service areas are declared by SBAS service providers or by the State or group of States managing the SBAS, for the typical operations defined in Table 6.3.7.2.4-1 (e.g. En-route, APV-I, Category I) where the corresponding accuracy, integrity and continuity requirements are met with a certain availability (e.g. 99 per cent). Some SBAS service providers publish service areas of their systems (e.g. WAAS Performance standard, EGNOS Service Definition Document and AIPs). The service area for En-route may be wider than the service area for APV-I. For the GNSS receiver, the SIS is usable whenever the protection levels are lower than the alert limits for the intended operation (VPL<VAL and HPL<HAL), irrespective of whether or not the GNSS receiver is inside the corresponding service area defined by the SBAS service provider.

6.2.1.1 SBAS systems support operations based on some or all of the SBAS functions defined in CAR-ANS 6.3, 6.3.7.3.4.2. These functions can be related to the operations that are supported as follows:

a) *Ranging*: SBAS provides a ranging source for use with other augmentation(s) (ABAS, GBAS or other SBAS);

b) *Satellite status and basic differential corrections*: SBAS provides en-route, terminal, and non-precision approach service. Different operations (e.g. performance-based navigation operations) may be supported in different service areas;

c) *Precise differential corrections*: SBAS provides APV and precision approach service (i.e. APV-I, APV-II and precision approach may be supported in different service areas).

6.2.2 Satellite-based augmentation services are provided by the Wide Area Augmentation System (WAAS) (North America), the European Geostationary Navigation Overlay Service (EGNOS) (Europe and Africa), the Multifunction Transport Satellite (MTSAT) Satellite-based Augmentation System (MSAS) (Japan) and the GPS-aided Geo-augmented Navigation (GAGAN) (India). The System of Differential Correction and Monitoring (SDCM) (Russia) and other SBAS systems are also under development to provide these services.

6.2.3 An SBAS may provide accurate and reliable service outside the defined service area(s). The ranging, satellite status and basic differential corrections functions are usable throughout the entire coverage area. The performance of these functions may be technically adequate to support en-route, terminal and non-precision approach operations by providing monitoring and integrity data for core satellite constellations and/or SBAS satellites. SBAS mitigates errors which cannot be monitored by its ground network through message Types 27 or 28.

6.2.4 Each State is responsible for approving SBAS-based operations within its airspace. In some cases, States will field SBAS ground infrastructure linked to an SBAS. In other cases, States may simply approve service areas and SBAS based operations using available SBAS signals. In either case, each State is responsible for ensuring that SBAS meets the requirements of CAR-ANS 6.3, 6.3.7.2.4, within its airspace, and that appropriate operational status reporting and NOTAMs are provided for its airspace.

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6.4 RF characteristics

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6.4.6 *SBAS pseudo-random noise (PRN) codes.* Receivers compliant with RTCA DO-229D with Change 1 and earlier versions only search for PRN codes in the range 120 to 138 only (out of the full 120 to 158 range in Table B-23), and therefore will not acquire and track SBAS signals identified by a PRN code in the range 139 to 158. Receivers compliant with DO-229E and subsequent versions can acquire and track SBAS signals identified by all PRN codes in Table B-23.

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7.GROUND-BASED AUGMENTATION SYSTEM (GBAS) AND GROUND-BASED REGIONAL AUGMENTATION SYSTEM (GRAS)

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7.1 System description

7.1.1 GBAS consists of ground and aircraft elements. A GBAS ground subsystem typically includes a single active VDB transmitter and broadcast antenna, referred to as a broadcast station, and multiple reference receivers. A GBAS ground subsystem may include multiple VDB transmitters and antennas that share a single common GBAS identification (GBAS ID) and frequency as well as broadcast identical data. The GBAS ground subsystem can support all the aircraft subsystems within its service volume providing the aircraft with approach data, corrections and integrity information for GNSS satellites in view. GBAS ground and aircraft elements are classified according to the types of service they support (as defined in section 7.1.2).

7.1.2 GBAS systems may provide two types of services: approach services and the GBAS positioning service. The approach service provides deviation guidance for FASs within the approach service volume. The GBAS positioning service provides horizontal position information to support RNAV operations within the positioning service volume. The two types of services are also distinguished by different performance requirements associated with the particular operations supported (see Table 6.3.7.2.4-1) including different integrity requirements as discussed in 7.5.1.

7.1.2.1 GBAS approach services are further differentiated into multiple types referred to as GBAS approach service types (GAST). A GAST is defined as the matched set of airborne and ground performance and functional requirements that are intended to be used in concert in order to provide approach guidance with quantifiable performance. Four types of approach service, GAST A, GAST B, GAST C and GAST D are currently defined. GAST A, B and C are intended to support typical APV I, APV II and Category I operations, respectively. GAST D has been introduced to support landing and guided take-off operations in lower visibility conditions including Category III operations. Note that provisions for a separate service type to support Category II operations, but not Category I nor Category III, have not been made. Since equipment supporting GAST D will function the same when supporting Category II minima as when supporting Category III minima, GAST D provides one means of supporting Category II operations. Category II operations may potentially be supported using GAST C in conjunction with an appropriate aeroplane level integration. A relevant analogy is the authorization in at least one State of lower than Category I minima based on guidance from a facility performance Category I ILS used in conjunction with a head-up display (HUD). Requirements for the approval of Category II operations using GBAS will be defined by the airworthiness and operational approval authorities within States

7.1.2.1.1 A GBAS ground subsystem may support multiple service types simultaneously. There are two types of ground subsystems, those that support multiple types of approach service and those that do not. Equipment designed in compliance with earlier versions of these SARPs may only support a single type of approach service, GAST C. Equipment designed in compliance with these SARPs may or may not support multiple types of service on one or more runway ends. The type of services supported for each approach are indicated in the approach performance designation field in a FAS data block within the Type 4 message. The GBAS continuity/integrity designator (GCID) parameter in the Type 2 message indicates whether a GBAS ground subsystem is currently supporting multiple types of approach service. Airborne equipment that can support multiple service types will first check the GCID to determine if the ground segment supports multiple types of service. If it does, the equipment will then check the approach performance designator (APD) field of the selected FAS data block within the Type 4 message to determine which types of service are supported by the ground segment for the approach selected (using the channel selection scheme described in section 7.7 below). The airborne equipment will then determine which approach service to select based on APD, the current status of GCID and the airborne equipment type. Operators shall understand that the available operations may be restricted by many factors including pilot qualifications or temporary ANSP limitations which are not reflected in the APD value. Therefore, APD shall not be interpreted as an indication of the availability of any operational use, only as an indication of the service types that are supported for the given runway.

7.1.2.1.2 GBAS airborne equipment may attempt to automatically select the highest type of service supported by both the airborne equipment and the ground segment for the selected approach (as indicated in APD). If the desired type of service is not available, the airborne equipment may select the next lower available type of service and annunciate this appropriately. Therefore, during a GBAS operation, there is the selected service type (SST) and the active service type (AST). The SST is the service type that the airborne equipment would use if it were available, and can be no higher than the highest type of service offered by the ground segment for the selected approach. The AST is the service type that the airborne equipment is actually using at a particular time. The AST may differ from the SST if the SST is unavailable for some reason. The airborne equipment annunciates both the SST and AST so that proper action (e.g. annunciations) may be taken in the context of the airborne integration and operational procedures.

7.1.2.1.3 Service providers shall give consideration to what service type or types are actually required for each runway given the planned operations and encode the availability of the appropriate service types in the APD field of the associated FAS block.

7.1.2.1.4 When the ground subsystem is no longer capable of meeting FAST D requirements there are several options, depending upon which requirements are not met. If the ground subsystem cannot meet all of the FAST D integrity requirements (Appendix 6B, 3.6.7.1.2.1.1.2, 3.6.7.1.2.1.1.3, and 3.6.7.1.2.2.1.1, 3.6.7.3.2) FAST D needs to be removed within the time-to-alert defined in Appendix 6B, 3.6.7.1.2.1.1.3. If it is still capable of meeting FAST C integrity requirements, the ground subsystem shall only remove FAST D and continue to broadcast in FAST C mode. The procedure for removing FAST D includes two options for reflecting this in the corrections (Appendix 6B, 3.6.7.3.2.1).

7.1.2.1.4.1 When downgrading from FAST D to C, the GCID in the Type 2 message (Appendix 6B, 3.6.7.2.3.2) also needs to change. A FAST D ground subsystem normally broadcasts a GCID of 2, indicating it supports FAST C and FAST D. When the ground subsystem can no longer support FAST D, but can still support FAST C, the GCID shall change to 1. Note that it is assumed here that a FAST D ground subsystem would downgrade to FAST C only, and not to FAST A or B.

7.1.2.1.4.2 Another condition that could result in the ground subsystem no longer being capable of supporting FAST D would be a failure such that FAST D continuity (Appendix 6B, 3.6.7.1.3.1 and 3.6.7.1.3.2) cannot be met (e.g. failure of redundant components). If FAST D integrity requirements are still met, the ground subsystem is not required to remove the corrections in the Type 11 messages. However, the GCID needs to change to 1. Communicating the change in GCID nominally would take 10 seconds, as the minimum update rate for Type 2 messages is 10 seconds. It may take as long as one minute. A change in FAST shall be reflected in the next scheduled broadcast of the Type 2 message. In addition, changes to GCID are ignored by the airborne equipment when the aircraft is in the final stages of the approach. Therefore, GCID changes only affect the FAST for aircraft outside of the final stages of the approach.

7.1.3 A significant distinguishing feature for GBAS ground subsystem configurations is whether additional ephemeris error position bound parameters are broadcast. This feature is required for the positioning service, but is optional for some approach services. If the additional ephemeris error position bound parameters are not broadcast, the ground subsystem is responsible for assuring the integrity of ranging source ephemeris data without reliance on the aircraft calculating and applying the ephemeris bound as discussed in 7.5.9.

7.1.4 *GBAS configurations.* There are multiple configurations possible of GBAS ground subsystems conforming to the GNSS Standards, examples of such configurations are:

a) a configuration that supports GAST C only;

b) a configuration that supports GAST A, GAST B, GAST C, and also broadcasts the additional ephemeris error position bound parameters;

c) a configuration that supports only GAST C and GAST D, and the GBAS positioning service, while also broadcasting the ephemeris error position bound parameters referred to in b); and

d) a configuration that supports only GAST A and the GBAS positioning service, and is used within a GRAS.

7.1.4.1 *GBAS facility classification (GFC).* A GBAS ground subsystem is classified according to key configuration options. A GFC is composed of the following elements:

a) facility approach service type (FAST);

b) ranging source types;

c) facility coverage; and

d) polarization.

7.1.4.1.1 *Facility approach service type (FAST).* The FAST is a collection of letters from A to D indicating the service types that are supported by the ground subsystem. For example, FAST C denotes a ground subsystem that meets all the performance and functional requirements necessary to support GAST C. As another example, a FAST ACD designates a ground subsystem that meets the performance and functional requirements necessary to support service types A, C and D.

Note.— The facility classification scheme for GBAS includes an indication of which Service Types the ground subsystem can support. This means the ground subsystem meets all the performance requirements and functional requirements such that a compatible airborne user can apply the information from the ground subsystem and have quantifiable performance at the output of the processing. It does not necessarily mean that the ground subsystem supports all service types on every runway end. Which GBAS approach service types are supported on a given runway end is indicated in the Type 4 message and is included as part of the approach facility designation defined in section 7.1.4.2.

7.1.4.1.2 *Ranging source types*: The ranging source type designation indicates what ranging sources are augmented by the ground subsystem. The coding for this parameter is as follows:

G1 - GPS
G2 - SBAS
G3 - GLONASS
G4 - Reserved for Galileo
G5+ - Reserved for future ranging sources

7.1.4.1.3 *Facility coverage*: The facility coverage designation indicates positioning service capability and maximum use distance. The facility coverage is coded as 0 for ground facilities that do not provide the positioning service. For other cases, the facility coverage indicates the radius of D_{max} expressed in nautical miles.

Note.— The service volume for specific approaches is defined as part of the approach facility designations defined in section 7.1.4.2.

7.1.4.1.4 *Polarization*: The polarization designation indicates the polarization of the VHF data broadcast (VDB) signal. E indicates elliptical polarization and H indicates horizontal polarization.

7.1.4.1.5 *GBAS facility classification examples.* The facility classification for a specific facility is specified by a concatenated series of codes for the elements described in sections 7.1.4.1 through 7.1.4.1.4. The general form of the facility classification is:

GFC = Facility Approach Service Type/Ranging Source Type /Facility Coverage/Polarization.

For example, a facility with the designation of GFC – C/G1/50/H, denotes a ground subsystem that meets all the performance and functional requirements necessary to support service type C on at least one approach, using GPS ranges only, with the GBAS positioning service available to a radius of 50 NM from the GBAS reference position and a VDB that broadcasts in Horizontal polarization only. Similarly, GFC-CD/G1G2G3G4/0/E denotes a ground subsystem that supports at least one approach with a service type of C and D, provides corrections for GPS, SBAS, GLONASS and Galileo satellites, does not support the positioning service and broadcasts on elliptical polarization.

7.1.4.2 *Approach facility designations.* A GBAS ground subsystem may support many approaches to different runway ends at the same airport or even runways at adjacent airports. It is even possible that a GBAS will support multiple approaches to the same runway end with different types of service (intended, for example, to support different operational minima). Each approach provided by the ground system may have unique characteristics and in some sense may appear to the user to be a separate facility. Therefore, in addition to the GBAS facility classification, a system for classifying or designating the unique characteristics of each individual approach path is needed. For this purpose, a system of approach facility designations is defined. Figure D-10 illustrates the relationship between GBAS facility classifications and approach facility designations. The classification is intended to be used for pre-flight planning and published in the AIP.

7.1.4.2.1 *Approach facility designation elements.* Each approach supported by a GBAS can be characterized by an approach facility designation (AFD). The AFD is composed of the following elements:

GBAS identification: Indicates the GBAS facility identifier that supports the approach (4-character GBAS ID).

Approach identifier: This is the approach identifier associated with the approach in the message Type 4 data block. It is 4 characters and must be unique for each approach within radio range of the GBAS facility.

Channel number: This is the channel number associated with the approach selection. It is a 5 digit channel number between 20001 and 39999.

Approach service volume: Associated with each published approach, indicates the service volume either by a numerical value in feet corresponding to the minimum decision height (DH) or by the GBAS points as defined below (i.e. GBAS Points A, B, C, T, D, E, or S).

Supported service types: Designates the GBAS service types (A-D) that are supported for the approach by the ground subsystem. This field can never be given a value greater than the facility approach service type for the GBAS ground subsystem that supports the approach.

The GBAS points A, B, C, T, D and E define the same locations relative to the runway as the ILS Points in Attachment 6C, Figure C-1 used to define the ILS localizer course and glide path bend amplitude limits. Point S is a new point defining the stop end of the runway. For

GBAS, the points are used to indicate the location along the nominal approach and/or along the runway for which GBAS performance for the supported service type(s) has been verified. When a decision height is used instead to define the approach service volume, the service volume is provided to a height of half the DH as defined in CAR-ANS 6.3, 6.3.7.3.5.3.1. The choice of coding using a DH or GBAS points depends upon the intended operational use of the runway. For example, if the approach identifier corresponds to a Category I instrument approach procedure from which automatic landings are authorized, the approach service volume element is intended to indicate at what point along the runway the performance has been verified. The point definitions are given below:

GBAS Point "A". A point on a GBAS final approach segment measured along the extended runway centre line in the approach direction a distance of 7.5 km (4 NM) from the threshold.

GBAS Point "B". A point on the GBAS final approach segment measured along the extended runway centre line in the approach direction a distance of 1 050 m (3 500 ft) from the threshold.

GBAS Point "C". A point through which the downward extended straight portion of the nominal GBAS final approach segment passes at a height of 30 m (100 ft) above the horizontal plane containing the threshold.

GBAS Point "D". A point 3.7 m (12 ft) above the runway centre line and 900 m (3 000 ft) from the threshold in the direction of the GNSS azimuth reference point (GARP).

GBAS Point "E". A point 3.7 m (12 ft) above the runway centre line and 600 m (2 000 ft) from the stop end of the runway in the direction of the threshold.

GBAS Point "S". A point 3.7 m (12 ft) above the runway centre line at the stop end of the runway.

GBAS reference datum (Point "T"). A point at a height specified by TCH located above the intersection of the runway centre line and the threshold.

7.1.4.2.2 Approach facility designation examples

The approach facility designation consists of the concatenation of the parameters defined in section 7.1.4.2.1 as: GBAS ID/approach ID/ranging sources/approach service volume/required service type. An example application of this concept to a particular approach at the US Washington, DC Ronald Reagan International Airport is:

"KDCA/XDCA/21279/150/CD"

where:

KDCA – indicates the approach is supported by the GBAS installation at DCA
XDCA – indicates the approach ident (echoed to the pilot on approach selection) for this specific approach is "XDCA"

21279 – is the 5-digit channel number used to select the approach
150 – indicates the GBAS coverage has been verified to be sufficient to support a DH as low as 150 ft.
CD – indicates that GBAS approach service types C and D are supported by the ground subsystem for the approach

Another example application of this concept to a particular approach at Boeing Field is:

"KBFI/GBFI/35789/S/C"

where:

KBFI – indicates the approach is supported by the GBAS installation at BFI (with GBAS Station identifier KBFI)
GBFI – indicates the approach ident (echoed to the pilot on approach selection) for this specific approach is "GBFI"
35789 – is the 5-digit channel number used to select the approach.
S – indicates the GBAS service volume extends along the approach and the length of the runway surface (i.e. 12 ft above the runway to the stop end).
C – indicates that GBAS approach service type C is supported by the ground subsystem for this FAS.

7.1.4.3 *GBAS airborne equipment classification (GAEC)*

7.1.4.3.1 GBAS airborne equipment may or may not support multiple types of approach service that could be offered by a specific ground subsystem. The GBAS airborne equipment classifications (GAEC) specifies which subsets of potentially available services types the airborne equipment can support. The GAEC includes the following elements:

Airborne approach service type (AAST): The AAST designation is a series of letters in the range from A to D indicating which GASTs are supported by the airborne equipment. For example, AAST C denotes airborne equipment that supports only GAST C. Similarly, AAST ABCD indicates the airborne equipment can support GASTs A, B, C & D.

Note.— For airborne equipment, designating only the highest GBAS approach service type supported is insufficient as not all airborne equipment is required to support all service types. For example, a particular type of airborne equipment may be classified as AAST CD, meaning the airborne equipment supports GAST C and D (but not A or B).

Ranging source types: This field indicates which ranging sources can be used by the airborne equipment. The coding is the same as for the ground facility classification (see section 7.1.4.1.2)

7.1.4.3.2 *Multiple service type capable equipment.* Ground and airborne equipment designed and developed in accordance with previous versions of these SARPs (Amendment 80) and RTCA DO-253A will only support GAST C. The current version of the Standards has been designed such that legacy GBAS airborne equipment will still operate correctly when a ground subsystem supports multiple types of service. Also, airborne equipment which can support multiple types of service will operate correctly when operating with a ground subsystem that supports only GAST C.

7.1.4.3.3 *GBAS airborne equipment classification examples.* GBAS airborne equipment classifications consist of a concatenated series of codes for the parameters defined in 7.1.4.3. The general form of the GAEC is:

GAEC = (airborne approach service type)/(ranging source type)

For example:

GAEC of C/G1 - denotes airborne equipment that supports only GAST C and uses only GPS ranges.

Similarly:

GAEC of ABC/G1G4 - denotes airborne equipment that supports all GASTs except GAST D and can use both GPS and Galileo ranging sources.

GAEC of ABC/G1G3 - denotes airborne equipment that supports all GASTs except GAST D and can use both GPS and GLONASS ranging sources.

Finally:

GAEC – CD/G1G2G3G4 - denotes airborne equipment that supports GASTs C and D and uses GPS, SBAS, GLONASS and Galileo ranging sources.

7.1.5 *GRAS configurations.* From a user perspective, a GRAS ground subsystem consists of one or more GBAS ground subsystems (as described in 7.1.1 through 7.1.4), each with a unique GBAS identification, providing the positioning service and one or more approach service types where required. By using multiple GBAS broadcast stations, and by broadcasting the Type 101 message, GRAS is able to support en-route operations via the GBAS positioning service, while also supporting terminal, departure, and operations supported by GAST A or B over a larger coverage region than that typically supported by GBAS. In some GRAS applications, the corrections broadcast in the Type 101 message may be computed using data obtained from a network of reference receivers distributed in the coverage region.

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7.1.7 Interoperability of the GBAS ground and aircraft elements compatible with RTCA/DO-253() is addressed in Appendix 6B, 3.6.8.1. GBAS receivers compliant with RTCA/DO-253A will not be compatible with GRAS ground subsystems broadcasting Type 101 messages. However, GRAS and GBAS receivers compliant with RTCA/DO-310 GRAS MOPS, will be compatible with GBAS ground subsystems. SARPs-compliant GBAS receivers may not be able to decode the FAS data correctly for GAST A transmitted from

GBAS ground subsystems (i.e. a FAS data block with APD coded as "0"). These receivers will apply the FASLAL and FASVAL as if the active service type is GAST C. ANSPs shall be cognizant of this fact and relevant operational restrictions may have to be applied to ensure the safety of the operation. For GBAS ground subsystems providing GAST D, APD in the FAS data blocks may be coded as values of 1 or 2 (Appendix 6B, 3.6.4.5.1). SARPs compliant GBAS receivers developed in accordance with SARPs prior to Amendment 91 may not be able to use FAS data blocks with APD equal to 2 or above.

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7.1.11 *Availability considerations for GBAS.* A single GBAS ground subsystem may provide multiple types of service to multiple users and service for multiple runway ends simultaneously. These different types of service may have different availability and consequently one type of service may be available when another is not. Furthermore, as some elements of GBAS are optional (e.g. augmentation of multiple constellations or use of SBAS ranging sources), the capabilities of different users will vary. For this reason, it is not practical for the service provider to predict if a given user will find a specific service type to be available at any given time. All that can be known by the service provider is the status of the ground subsystem and satellite constellation. An assessment can be made as to whether the ground subsystem is meeting the allocated requirements for some target service type and further, the availability of service can be predicted based on an assumed level of performance and a nominal user. The definition of the nominal user includes which elements of GNSS are used (core satellite systems, SBAS ranges etc.) and within that, which subset of satellites are used in the position solution. For GBAS supporting GAST D this is further complicated by the fact that certain parameters (e.g. geometry screening thresholds) may be adjusted by the airframe designer to ensure adequate landing performance given the characteristics of the specific aircraft type. ANSPs and air space designers shall be cognizant of the fact that availability of service for GNSS augmentation systems in general is less predictable than conventional navigation aids. Variations in user capabilities will result in times where service may be available to some users and unavailable to others.

7.2 RF characteristics

7.2.1 *Frequency coordination*

7.2.1.1 *Performance factors*

7.2.1.1.1 The geographical separation between a candidate GBAS station, a candidate VOR station and existing VOR or GBAS installations must consider the following factors:

a) the service volume, minimum field strength and effective isotropically radiated power (EIRP) of the candidate GBAS including the GBAS positioning service, if provided. The minimum requirements for service volume and field strength are found in CAR-ANS 6.3, 6.3.7.3.5.3 and 6.3.7.3.5.4.4, respectively. The EIRP is determined from these requirements;

b) the coverage and service volume, minimum field strength and EIRP of the surrounding VOR and GBAS stations including the GBAS positioning service, if provided. Specifications for coverage and field strength for VOR are found in CAR-ANS 6.3, 6.3.3, and respective guidance material is provided in Attachment 6C;

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h) the four-character GBAS ID to differentiate between GBAS ground subsystems. The GBAS ID is normally identical to the location indicator at the nearest aerodrome. The requirement is found in Appendix 6B, 3.6.3.4.1; and

i) *Slot assignment*. The relative assignment of slots to a GBAS ground subsystem can impact performance in instances where messages in multiple slots need to be received by the airborne subsystem prior to processing. This will occur when using linked messages and/or for a GAST D ground subsystem where correction data is contained in both the Type 1 and Type 11 messages. In these cases slot assignments for all MT 1 and 11 should be adjacent to avoid unnecessary latency and complexity of design. Non-adjacent assignments may, depending on the design of the ground subsystem, result in a lack of time for the ground subsystem to process fault detections, render some slot combinations unusable and thus result in lower efficiency of spectrum use.

7.2.1.1.2 Nominal link budgets for VDB are shown in Table D-3. The first example in Table D-3 assumes a user receiver height of 3 000 m (10 000 ft) MSL and a transmit antenna designed to suppress ground illumination in order to limit the fading losses to a maximum of 10 dB at VDB coverage edge. In the case of GBAS/E equipment, the 10 dB also includes any effects of signal loss due to interference between the horizontal and vertical components. The second example in Table D-3 provides a link budget for longer range positioning service. It is for a user receiver height sufficient to maintain radio line-of-sight with a multi-path limiting transmitting antenna. No margin is given in Table D-3 for fading as it is assumed that the receiver is at low elevation angles of radiation and generally free from significant null for the distances shown in the table (greater than 50 NM). In practice, installations will experience a fade margin that will be dependent on many parameters including aircraft altitude, distance from transmit antenna, antenna type/design and ground reflectors.

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7.2.1.4 *Example of GBAS/GBAS geographical separation criteria*

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7.2.1.4.2 The geographic separation for co-channel, co-slot GBAS VDB assignments is obtained by determining the distance at which the transmission loss equals 145 dB for receiver altitude of 3 000 m (10 000 ft) above that of the GBAS VDB transmitter antenna. This distance is 318 km (172 NM) using the free-space attenuation approximation and assuming a negligible transmitter antenna height. The minimum required geographical separation can then be determined by adding this distance to the nominal distance between the edge of VDB coverage and the GBAS transmitter 43 km (23 NM). This results in a co-channel, co-slot reuse distance of 361 km (195 NM).

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7.2.1.6 *Guidelines on GBAS/VOR geographical separation criteria*. The GBAS/VOR minimum geographical separation criteria are summarized in Table D-5 based upon the same methodology and the nominal VOR coverage volumes in Attachment 6C.

Table D-3 Nominal VDB link budget

VDB link elements				
For approach service		Vertical component at coverage edge		Horizontal component at coverage edge
Required receiver sensitivity (dBm)		-87		-87
Maximum aircraft implementationloss (dB)		11		15
Power level after aircraft antenna (dbm)		-76		-72
Operating margin (dB)		3		3
Fade margin (dB)		10		10
Free space path loss (dB)at 43 km (23 NM)		106		106
Nominal effective isotropically radiated power (EIRP) (dBm)		43		47

For longer range and low radiation angle associated with positioning service		Vertical component		Horizontal component	
Required receiver sensitivity (dBm)		–87		–87	
Maximum aircraft implementation loss (dB)		11		15	
Power level after aircraft antenna (dBm)		–76		–72	
Operating margin (dB)		3		3	
Fade margin (dB)		0		0	
Nominal EIRP (dBm)					
Range (km (NM))	Free space loss (dB)	EIRP (dBm)	EIRP (W)	EIRP (dBm)	EIRP (W)
93 (50)	113	39.9	10	43.9	25
185 (100)	119	45.9	39	49.9	98
278 (150)	122	49.4	87	53.4	219
390 (200)	125	51.9	155	55.9	389

Notes.—

1 It is possible, with an appropriately sited multipath limiting VDB transmitting antenna with an effective radiated power sufficient to meet the field strength requirements for approach service and considering local topographical limitations, to also satisfy the field strength requirements such that positioning service can be supported at the ranges in this table.

2. Actual aircraft implementation loss (including antenna gain, mismatch loss, cable loss, etc.) and actual receiver sensitivity may be balanced to achieve the expected link budget. For example, if the aircraft implementation loss for the horizontal component is 19 dB, the receiver sensitivity must exceed the minimum requirement and achieve -91 dBm to satisfy the nominal link budget.

3. The long-range performance estimates may generally be optimistic with the assumption of no fade margin, i.e., link budget performance will generally not be as good as these estimates indicate.

Note 1.— When determining the geographical separation between VOR and GBAS, VOR as the desired signal is generally the constraining case due to the greater protected altitude of the VOR coverage region.

Note 2.— Reduced geographical separation requirements can be obtained using standard propagation models defined in ITU-R Recommendation P.528-2.

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7.2.2 The geographical separation criteria for GBAS/ILS and GBAS/VHF communications are under development.

7.2.3 *Compatibility with ILS.* Considerations for assignment of VDB channels include the frequency separation between the ILS and the VDB, the distance separation between the ILS coverage area and the VDB, the VDB and ILS field strengths, and the VDB and ILS localizer receiver sensitivity. Until compatibility criteria are developed for GBAS VDB and ILS, VDB can generally not be assigned to channels below 112.025 MHz (i.e. a minimum frequency separation of 75 kHz from the highest assignable ILS localizer frequency).

7.2.3.1 *Inter-airport compatibility.* The minimum geographical separation based on a minimum frequency separation of 75 kHz between ILS localizer and GBAS ground station deployed at different airports is 3 NM between the undesired transmitter antenna location and the edges of the coverage of the desired service that are assumed to be at minimum signal power. Smaller necessary separation distance values may be obtained by taking into account additional information such as the actual desired service field strength and actual undesired service transmit antenna radiation patterns.

Note.— The coverage of the ILS localizer is standardized in CAR-ANS 6.3, section 6.3.1.3.3 and the GBAS service volume is standardized in CAR-ANS 6.3, section 6.3.7.3.5.3, respectively.

7.2.3.2 *Same-airport compatibility.* To analyse the constraints for the deployment of a GBAS ground station at the same airport as ILS, it is necessary to consider ILS and VDB compatibility in detail taking into account information such as the actual desired service field strength and actual undesired service transmit antenna radiation patterns. For GBAS equipment with transmitter power such that the maximum field strength of 0.879 volts per metre (-27 dBW/m^2) for the horizontally polarized signal component is not exceeded in the ILS coverage volume, the 16th channel (and beyond) will be below -100.5 dBm in a 25 kHz bandwidth at a distance of 80 m from the VDB transmitter, including allowance for a +5 dB increase due to constructive multipath. This -100.5 dBm in a 25 kHz bandwidth translates to a signal-to-noise ratio of 21.5 dB (above the assumed minimum signal-to-noise ratio of 20 dB) for a -79 dBm localizer signal which corresponds to an ILS localizer field strength of 90 microvolts per metre (minus 107 dBW/m^2).

Note.— When deploying GBAS and ILS at the same airport, it is recommended to also analyse the impact of the GBAS VDB transmission on the ILS localizer monitor. Interference may be avoided by installing an appropriate filter.

7.2.4 *Compatibility with VHF communications.* For GBAS VDB assignments above 116.400 MHz, it is necessary to consider VHF communications and GBAS VDB compatibility. Considerations for assignment of these VDB channels include the frequency separation between the VHF communication and the VDB, the distance separation between the transmitters and coverage areas, the field strengths, the polarization of the VDB signal, and the VDB and VHF communication receiver sensitivity. Both aircraft and ground VHF communication equipment are to be considered. For GBAS/E equipment with a transmitter maximum power of up to 150 W (100 W for horizontal 64th channel (and beyond) will be below −112 dBm in a 25 kHz bandwidth at a distance of 80 m from the VDB transmitter including an allowance of +5 dB increase due to constructive multipath. For GBAS/H equipment with a transmitter maximum power of 100 W, the 32nd channel (and beyond) will be below −112 dBm in a 25 kHz bandwidth at a distance of 80 m from the VDB transmitter including an allowance of +5 dB increase due to constructive multipath, and a 10 dB polarization isolation. It must be noted that due to differences in the GBAS VDB and VDL transmitter masks, separate analysis must be performed to ensure VDL does not interfere with the GBAS VDB.

Table D-4. Typical GBAS/GBAS frequency assignment criteria

Channel of undesired VDB in the same time slots	Path loss (dB)	Minimum required geographical separation for Tx_U = 47 dBm and $P_{D,min}$ = −72 dBm in km (NM)
Cochannel	145	361 (195)
1st adjacent channel (±25 kHz)	101	67 (36)
2nd adjacent channel (±50 kHz)	76	44 (24)
3rd adjacent channel (±75 kHz)	73	No restriction
4th adjacent channel (±100 kHz)	73	No restriction

Note 1.— No geographic transmitter restrictions are expected between co-frequency, adjacent time slots provided the undesired VDB transmitting antenna is located at least 80 m from areas where the desired signal is at minimum field strength.

Note 2.— The PD,min of -72 dBm is the output from an ideal isotropic antenna.

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7.2.5 For a GBAS ground subsystem that only transmits a horizontally-polarized signal, the requirement to achieve the power associated with the minimum sensitivity is directly satisfied through the field strength requirement. For a GBAS ground subsystem that transmits an elliptically-polarized component, the ideal phase offset between HPOL and VPOL components is 90 degrees. In order to ensure that an appropriate received power is maintained throughout the GBAS service volume during normal aircraft maneuvers, transmitting equipment should be designed to radiate HPOL and VPOL signal components with an RF phase offset of 90 degrees. This phase offset shall be consistent over time and environmental conditions. Deviations from the nominal 90 degrees must be accounted for in the system design and link budget, so that any fading due to polarization loss does not jeopardize the minimum receiver sensitivity. System qualification and flight inspection procedures will take into account an allowable variation in phase offset consistent with maintaining the appropriate signal level throughout the GBAS service volume. One method of ensuring both horizontal and vertical field strength is to use a single VDB antenna that transmits an elliptically-polarized signal, and flight inspect the effective field strength of the vertical and horizontal signals in the service volume.

7.3 Service volume

7.3.1 The minimum GBAS service volume to support approach services is depicted in Figure D-4. Where practical, it is operationally advantageous to provide valid guidance along the visual segment of an approach. The lateral approach service volume may be different (larger) than the vertical approach service volume. When the additional ephemeris error position bound parameters are broadcast, differential corrections may only be used within the Maximum Use Distance (D_{max}) defined in the Type 2 message. It is also allowable for D_{max} to extend beyond an approach service volume. Reasons why this may be desirable include providing pilots with situational awareness and GBAS status information prior to intercepting the approach procedure, and improving GBAS course capture at the limits of the service volume. In such cases, the potential for reduced protection level, ephemeris bound, and VDB continuity outside the approach service volume shall be considered especially when broadcasting large or unlimited values of D_{max}.

7.3.1.1 If a GBAS installation supports multiple approach service volumes, use of a single omnidirectional data broadcast covering all intended service volumes should be considered to limit complexity, if geographically feasible.

7.3.1.2 In addition, autoland or guided take-off may be used at facilities or runways not intended to support or not currently supporting Category II or III operations using GBAS. Even in Category I or better visual conditions, use of an approved autoland system with GAST C can aid pilots in achieving stabilized approaches and reliable touchdown performance, for Category II or III training, to exercise the airborne system to ensure suitable performance, and for maintenance checks. Use of this capability may also provide pilot workload relief. Similarly, use of an approved guided take-off system will also provide operational benefits. Autoland and guided take-off service volume requirements are contained in CAR-ANS 6.3, 6.3.7.3.5.3.2. VDB reception on the runway surface is significantly affected by the transmit antenna design and its installed height as well as the geography of the airport. Service along all runways at an airport using a single VDB antenna/transmitter location may be difficult. However, where practical, service to support autoland and guided take-off operations shall be provided at suitable runways supporting any precision approach. The approach service volume element of the approach facility designation allows this information to be contained in the AIP (refer to 7.1.4.2.1). A useful autoland capability may be achievable for some aircraft even when the requirements of CAR-ANS 6.3, 6.3.7.3.5.3.2 are not entirely met. Similarly, some aircraft may not be able to conduct automatic landings with only the minimum service volume provided. For approaches with a FAS data path not aligned with the runway centre line, autoland service volume is not required.

7.3.2 An increased signal power (-62.5 dBm) from 36 ft and above, compared to the minimum requirement set for the GBAS service volume at 12 ft above the ground (-72 dBm), is required above the runway surface to accommodate various implementations of airborne VDB antenna. Indeed, VDB antenna height and aircraft implementation loss might not be suitable to meet adequate continuity for autoland under Category III conditions and guided take-off if:

a) aircraft VDB antenna height located above 12 ft may induce more than the expected 15 dB aircraft implementation loss; and

b) aircraft VDB antenna height located below 12 ft may receive a signal power that is below the minimum required value of -72 dBm.

7.3.2.1 To mitigate a lack of adequate VDB link budget, actual aircraft implementation loss (including type of antenna and location of antenna on the fuselage, antenna gain, mismatch loss, cable loss, etc.) and actual receiver sensitivity may be balanced to achieve the expected link budget. The need for additional operational mitigations might be identified and implemented during the aircraft approval process in case of potential loss of VDB along the flight path. It is common practice that a verification flight test is performed by a candidate operator to perform autoland under Category III conditions on a given runway.

7.3.2.2 It is not practical to measure the signal strength at 36 ft. Therefore, two example means of verification are identified below:

- Simplified analysis method: Measure the signal at 12 ft and estimate the signal strength at 36 ft using mathematical tools;

- Complex analysis method: Model the airport configuration and simulate, using a mathematical tool, the signal strength at 12 ft and 36 ft.

Note 1.— There exists an upper limit in the autoland service volume above the runway surface set at 100 ft.

Note 2.— Verification of minimum signal strength at 36 ft is sufficient to ensure compliance above 36 ft.

7.3.2.3 Simplified analysis method.

In order to apply this method, it is assumed the following:

o VDB transmitters are installed above a planar ground with line-of-sight to runways in the desired GBAS service volume as mentioned in Attachment 6D 7.12.3.

•The analysis methodology consists of:

o Ground subsystem manufacturers and/or service providers perform a generic (non-airport specific) analysis to show that signal strength requirements at both 12 ft and 36 ft can be met based on distance from and height of the VDB antenna at their specific location. Studies have shown that signal strength will increase from the signal strength measured at 12 ft in various airport configurations. When verifying compliance for a specific installation, an acceptable means of compliance is to measure the signal strength at 12 ft and estimate the signal strength by using the following formula:

To estimate the power $P\ h$dBm (in dBm) at a height h (in metres) from the power $P\ h_0$dBm at a height h_0 (in metres), one can use the following expression:

$$P_{h\mathrm{dBm}} = P_{h_0\mathrm{dBm}} + 20\log\left(\sin\left(\frac{2\pi h h_a}{\lambda d}\right)\right) - 20\log\left(\sin\left(\frac{2\pi h_0 h_a}{\lambda d}\right)\right)$$

where

- d is the distance to the transmitter antenna in metres
- h_a is the height of the transmitter antenna phase centre in metres
- $\lambda = c / f$ is the wavelength in metres
- f is the frequency in Hertz
- c is the speed of light

For $h < \frac{\lambda d}{8h_a}$, the previous formulation can be approximated with an error smaller than 1dB as follows:

$$P_{h\mathrm{dBm}} = P_{h_0\mathrm{dBm}} + 20\log\left(\frac{h}{h_0}\right)$$

Alternatively, converting heights in feet and considering, $h_0^{\mathrm{ft}} = 12\ \mathrm{ft}$, the previous expressions become:

$$P_{h\mathrm{dBm}} = P_{h_0\mathrm{dBm}} + 20\log\left(\sin\left(\frac{0.584 h^{\mathrm{ft}} h_a^{\mathrm{ft}}}{\lambda d}\right)\right) - 20\log\left(\sin\left(\frac{7h_a^{\mathrm{ft}}}{\lambda d}\right)\right)$$

and

$$P_{h\mathrm{dBm}} = P_{h_0\mathrm{dBm}} + 20\log(h^{\mathrm{ft}}) - 21.58\mathrm{dB}$$

The applicability of the above-mentioned formula at different heights above the runway surface may vary with the distance between the VDB transmitter and the intended path on the runway surface and the VDB transmitter antenna height. Some siting constraints may be needed to verify the minimum signal strength is met in the service volume above the runway surface.

7.3.2.4 Complex analysis method

This method assumes that:

• Airport configuration is so complex that "noise like multipath" (multipath reflections from buildings or aircraft standing or moving) cannot be easily accounted for and must be addressed in the analysis;

and/or

- Line-of-sight between the VDB antenna and runway cannot be maintained.

The analysis methodology consists of:

- The airport configuration includes relevant surfaces such as buildings and metallic fences, and topology of the ground surface is modeled with their electromagnetic characteristics. Radiation pattern of the VDB transmitter antenna is also modeled.

- Signal powers at 12 ft and 36 ft are estimated by simulating radio propagation. One of the acceptable means of the simulation is the ray-tracing method based on geometric optics. Such simulation is available with commercially available software with an intuitive human-machine interface to the airport modeling.

- Effects of small-scale (less than 5-10 wavelengths) structures limit the accuracy of simulation by the ray-tracing method. Therefore, an additional margin to represent such effects may need to be added to the simulation results.

- The signal power at 12 ft is measured and compared with the simulated one. If the measured and simulated signal powers at 12 ft match well, the simulation can be regarded as being able to model the signal powers at different heights over the runway

- The simulated signal power and the minimum requirement at 36 ft are compared to verify the compliance of the VDB coverage over the runway.

7.3.3 The service volume required to support the GBAS positioning service is dependent upon the specific operations intended. The optimal service volume for this service is intended to be omnidirectional in order to support operations using the GBAS positioning service that are performed outside of the approach service volume. Each State is responsible for defining a service volume for the GBAS positioning service and ensuring that the requirements of CAR-ANS 6.3, 6.3.7.2.4 are satisfied. When making this determination, the characteristics of the fault-free GNSS receiver shall be considered, including the reversion to ABAS-based integrity in the event of loss of GBAS positioning service.

7.3.4 The limit on the use of the GBAS positioning service information is given by the Maximum Use Distance (D_{max}). D_{max} however does not delineate the coverage area where field strength requirements specified in CAR-ANS 6.3, 6.3.7.3.5.4.4 are necessarily met nor matches this area. Accordingly, operations based on the GBAS positioning service can be predicated only in the service volume(s) (where performance requirements are met) within the D_{max} range.

7.3.5 As the desired service volume of a GBAS positioning service may be greater than that which can be provided by a single GBAS broadcast station, a network of GBAS broadcast stations can be used to provide the service. These stations can broadcast on a single frequency and use different time slots (8 available) in neighbouring stations to avoid interference or they can broadcast on different frequencies. Figure D-4A details how the use of different time slots will allow a single frequency to be used without interference subject to guard time considerations noted under Table B-59. For a network based on different VHF frequencies, guidance material in 7.17 should be considered.

7.4 Data structure

A bit scrambler/descrambler is shown in Figure D-5

Note.— Additional information on the data structure of the VHF data broadcast is given in RTCA/DO-246E, GNSS Based Precision Approach Local Area Augmentation System (LAAS) — Signal-in-Space Interface Control Document (ICD).

7.5 Integrity

7.5.1 Different levels of integrity are specified for precision approach operations and operations based on the GBAS positioning service. The signal-in-space integrity risk for approach services is 2×10^{-7} per approach. GBAS ground subsystems that are also intended to support other operations through the use of the GBAS positioning service have to also meet the signal-in-space integrity risk requirement specified for terminal area operations, which is 1×10^{-7}/hour (CAR-ANS 6.3, Table 6.3.7.2.4-1). Therefore, additional measures are necessary to support these more stringent requirements for positioning service. The signal-in-space integrity risk is allocated between the ground subsystem integrity risk and the protection level integrity risk. The ground subsystem integrity risk allocation covers failures in the ground subsystem as well as core constellation and SBAS failures such as signal quality failures and ephemeris failures. For GAST A, B, and C the protection level integrity risk allocation covers rare fault-free position domain performance risks and the case of failures in one of the reference receiver measurements. In both cases the protection level equations ensure that the effects of the satellite geometry used by an aircraft fault-free receiver are taken into account. This is described in more detail in the following paragraphs. For GAST D, the position domain integrity is delegated to the aircraft and a FAST D ground subsystem provides additional data and ranging source monitoring for aircraft using this service type.

7.5.1.1 Additional integrity requirements apply for GAST D, which is intended to support precision approach and automatic landing in low visibility conditions with minima less than Category I. The same requirements for bounding the position solution within a protection level that is compared to an alert limit apply, for all error sources except single ground reference receiver faults and errors induced by ionospheric anomalies. Single ground reference receiver faults are mitigated as described in 7.5.11. The responsibility for some errors induced by anomalous ionospheric conditions has been allocated to the airborne equipment. Mitigation of errors due to ionospheric anomalies is described in 7.5.6.1.6. Additional monitoring requirements and design assurance requirements are needed to allow a FAST D GBAS ground subsystem to provide a service that can provide equivalent safety to Category III ILS operations. Some additional monitoring requirements are allocated to the ground subsystem (see 7.5.6.1 to 7.5.6.1.7) and some are allocated to the airborne equipment. The additional monitoring performance requirements for the ground subsystem can be found in Appendix 6B, 3.6.7.3.3.

7.5.1.2 The ground subsystem integrity risk requirement for GAST D (Appendix 6B, section 3.6.7.1.2.1.1.3) limits the probability of a ground subsystem failure resulting in the transmission of erroneous data during a minimum exposure time of "any one landing." Typically the critical period of exposure to failures for vertical guidance in Category III operations is taken to be the period between the Category I Decision Height (200 ft) and the threshold (50 ft height). This is nominally 15 seconds, depending upon the aircraft approach speed. The critical period of exposure to failures for lateral guidance in Category III operations is taken to be the period between the Category I Decision Height and completion of the roll-out, which occurs when the aircraft decelerates to a safe taxi speed (typically less than 30 knots). This is nominally 30 seconds, again depending upon the aircraft approach speed and rate of deceleration. The term "any one landing" is used to emphasize that the time period where faults could occur extends prior to the critical period of exposure. The reason for this is that the fault may develop slowly over time; it could occur earlier in the landing phase and become a hazard during the critical period of exposure.

7.5.1.3 The critical period of exposure to failure for lateral guidance during a guided take-off in low visibility conditions is nominally 60 seconds. Erroneous or loss of guidance during a guided take-off being less critical than for Category III landings, it does not introduce any changes to the ground subsystem integrity requirements.

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7.5.3 The individual error uncertainties described above are used by the receiver to compute an error model of the navigation solution. This is done by projecting the pseudo-range error models to the position domain. General methods for determining that the model variance is adequate to guarantee the protection level integrity risk are described in section 14. The lateral protection level (LPL) provides a bound on the lateral position error with a probability derived from the integrity requirement. Similarly, the vertical protection level (VPL) provides a bound on the vertical position. For approach services, if the computed LPL exceeds the lateral alert limit (LAL) or the VPL exceeds the vertical alert limit (VAL), integrity is not adequate to support the selected service type. For the positioning service the alert limits are not defined in the standards, with only the horizontal protection level and ephemeris error position bounds required to be computed and applied. The alert limits will be determined based on the operation being conducted. The aircraft will apply the computed protection level and ephemeris bounds by verifying they are smaller than the alert limits. Two protection levels are defined, one to address the condition when all reference receivers are fault-free (H_0 – Normal Measurement Conditions), and one to address the condition when one of the reference receivers contains failed measurements (H_1 – Faulted Measurement Conditions).

Additionally, an ephemeris error position bound provides a bound on the position error due to failures in ranging source ephemeris. For approach services, a lateral ephemeris error bound (LEB) and a vertical ephemeris error bound (VEB) are defined. For the positioning service a horizontal ephemeris error bound (HEB) is defined.

7.5.3.1 The GBAS signal-in-space integrity risk (Appendix 6B, 3.6.7.1.2.1.1) is defined as the probability that the ground subsystem provides information which when processed by a fault-free receiver, using any combination of GBAS data allowed by the protocols for data application (Appendix 6B, 3.6.5), results in an out-of-tolerance lateral or vertical relative position error without annunciation for a period longer than the maximum time-to-alert. An out-of-tolerance lateral or vertical relative position error is defined as an error that exceeds the GBAS approach services protection level and, if additional data block 1 is broadcast, the ephemeris error position bound. Hence it is the responsibility of the ground subsystem to provide a consistent set of data including the differential corrections, and all parameters that are used by the protocols for data application (e.g, σ_{pr_gnd} and the B values as defined in the Type 1 message), so that the protection levels bound the position error with the required integrity risk. This error bounding process must be valid for any set of satellites that the user might be using. To ensure the computed protection levels actually bound the error with the required probability, it may in some cases be necessary to inflate or otherwise manipulate one or more of the parameters that are used by the protocols for data application. For example, to address the impact of anomalous ionospheric effects one strategy that has been used is to inflate σ_{pr_gnd} and $\sigma_{vert\_iono\_gradient}$ to ensure that airborne equipment that complies with the protocols for data application will be adequately protected.

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7.5.6 *Residual ionospheric errors.* An ionospheric parameter is broadcast in Type 2 messages to model the effects of the ionosphere between the GBAS reference point and the aircraft. This error can be well-characterized by a zero-mean, normal distribution during nominal conditions.

7.5.6.1 *Ionospheric anomalies.* Small scale structures in the ionosphere can result in non-differentially corrected errors in the GBAS position. Such phenomena are typically associated with solar storm activity and may be characterized by steep gradients in the ionospheric delay over a relatively short distance (e.g. a few tens of kilometres). The errors that may be induced by these phenomena result when the airborne receiver and ground subsystem are receiving satellite signals that have different propagation delays. Also, since GBAS uses code-carrier smoothing with a relatively long time constant, biases build up in these filters that are a function of the rate of change of ionospheric delay. If the ground subsystem and airborne receivers experience significantly different delays and rates of change of the ionospheric delays, the biases that build up in these filters will not match and will not be cancelled by the differential processing.

7.5.6.1.1 *Ionospheric anomaly mitigation.* Ionospheric anomalies can produce position errors which are significant (i.e. tens of metres) in the context of approach operations. To mitigate these errors, different strategies are used depending on the GBAS approach service type.

7.5.6.1.2 *Ionospheric anomaly mitigation for GAST A, B and C.* For GAST A, B or C, the ground subsystem is responsible for mitigating the potential impact of ionospheric anomalies. This may be handled through various monitoring schemes (e.g. far-field monitors or integration with a wide area ground network supporting SBAS) which detect the presence of ionosphere anomalies and deny service if the resulting user position errors would be unacceptable. One means to deny service is to inflate some combination of the broadcast integrity parameters: σ_{pr_gnd}, $\sigma_{vert\_iono\_gradient}$, the ephemeris decorrelation parameter (P), the ephemeris missed detection parameters $K_{md\_e,GPS}$ and $K_{md\_e\_,GLONASS}$ such that any geometry that could be used by an airborne user will not be subjected to intolerably large errors (given the intended operational use). This inflation scheme could also be used without the complexity of monitoring the ionosphere during operations by assuming ionosphere anomalies are present. In this case, a model of the possible ionosphere conditions that could occur is used to determine the proper values of the broadcast integrity parameters. Since the extremes of ionosphere conditions vary significantly through the world, the model is location dependent. Such an inflation scheme results in a reduction in availability because it inflates the values even when anomalies are not present.

7.5.6.1.3 *Ionospheric anomaly mitigation for GAST D.* Requirements for monitoring and geometry screening in the airborne equipment have been introduced for GAST D to mitigate the potential impact of ionospheric anomalies. The airborne monitoring consists of monitoring the code-carrier divergence continuously in order to detect large gradients in the ionosphere. In addition, the airborne equipment will screen geometries to ensure that an unacceptably large amplification of residual pseudo-range errors (i.e. errors that may exist after airborne monitoring has been applied) will not occur. Another factor which is useful for the mitigation of errors induced by ionospheric anomalies is the use of the 30-second carrier smoothed pseudo-ranges in a position solution. (The shorter time constant smoothing is inherently less susceptible to filter bias mismatch errors.) Finally, GAST D includes parameters: $K_{md\_e\_D,GLONASS}$, $K_{md\_e\_D,GPS}$, P_D and $\sigma_{vert\_iono\_gradient\_D}$, which are intended to be used in place of the parameters $K_{md\_e,GLONASS}$, $K_{md\_e,GPS}$, P, and $\sigma_{vert\_iono\_gradient}$, respectively, when the active service type is GAST D. This is done so that if the ground subsystem employs inflation of the parameters $K_{md\_e\_,GLONASS}$, $K_{md\_e,GPS}$, P and $\sigma_{vert\_iono\_gradient}$ to mitigate the effects of ionospheric anomalies for GAST A, B or C, the GAST D user can be provided with non-inflated parameters for use in GAST D where airborne monitoring is employed to address the ionospheric anomaly errors. This enables GAST D service to have improved availability.

7.5.6.1.4 *Bounding of ionospheric anomaly errors.* As stated above, ionospheric anomalies may be addressed by inflating one or more of the parameters: σ_{pr_gnd}, $\sigma_{vert\_iono\_gradient}$, the ephemeris decorrelation parameter (P), the ephemeris missed detection parameters $K_{md\_e,GPS}$ and $K_{md\_e,GLONASS}$. The ground subsystem is responsible for providing values in these parameters such that the error is appropriately bounded by the VPL and HPL computations at the output of a fault free receiver. In GAST D, responsibility for mitigation of errors due to anomalous ionospheric conditions has been divided between the airborne subsystem and the ground subsystem. Although GAST D still requires the protection levels to bound the errors (as described in 7.5.3.1), they are not required to bound the errors that result from an anomalous ionospheric event as is the case for GAST C. Hence, the protection levels as computed with P_D, $K_{md\_e\_D,GLONASS}$, $K_{md\_e\_D,GPS}$, and $\sigma_{vert\_iono\_gradient\_D}$ must bound the error for all error sources as discussed in 3.6.7.1.2.1.1.2 except for the errors due to anomalous ionospheric conditions. The protections level computations must bound the nominal ionospheric errors.

7.5.6.1.5 *Dual solution ionospheric gradient monitoring.* Another component of the airborne mitigation of errors induced by ionospheric anomalies is by the use of dual position solutions computed simultaneously with two different carrier smoothing time constants (see 7.19.3). This dual solution computation has two purposes. Firstly, taking the difference of two corrected pseudo-range measurements as detection statistics allows the filter build-up errors on each satellite, due to large differences in ionospheric gradients between the ground measurements and airborne measurements, to be directly observable. Hence a threshold can be applied to these detection statistics in order to detect a large portion of the ionospheric anomalies. The second application of the dual solutions is to compute a bound for the 30-second smoothed position (excluding the impact of ionospheric anomalies). The data provided by the ground segment allows a protection level bound to be computed for the 100-second solution. By adding the direct observation of the magnitude of the difference between the 30-second smoothed position and the 100-second smoothed position, to the protection level computation, a protection level is obtained, which is guaranteed to bound the 30-second position solution with the required $1x10^{-7}$/approach. This allows airborne equipment, with an active service type of D to provide equivalent bounding performance, as required for approaches to Category I minima even though the 30-second solution is used to develop the guidance.

7.5.6.1.6 *Requirements for FAST D ground subsystems to support mitigation of errors caused by ionospheric anomalies.* Although much of the responsibility for mitigation of ionospheric errors is allocated to the airborne segment, there is a requirement for FAST D ground subsystems that is necessary to support mitigation of such effects. Appendix 6B, 3.6.7.3.4 specifies that the ground subsystem is responsible for ensuring mitigation of ionospheric spatial delay gradients. The ground subsystem ensures that the value of the maximum corrected pseudo-range error (E_{IG}) computed from the Type 2 data does not exceed 2.75 metres at all LTPs associated with runways that support GAST D procedures. One option available to the manufacturer is to restrict the distance between the GBAS reference point and the LTP.

7.5.6.1.7 *Ionospheric anomaly threat models used for GAST D validation.* As discussed above, the mitigation of errors that could be induced by ionospheric anomalies is accomplished through a combination of airborne and ground system monitoring. The effectiveness of the required monitoring has been demonstrated through simulation and analysis and the maximum errors at the output of the monitoring have been shown to be consistent with airworthiness certification criteria for a range of anomalies described below. This range of anomalies is described in terms of a "standard threat space" consisting of an ionospheric anomaly model which defines physical attributes of the ionospheric anomaly. The model described in 7.5.6.1.7.1 is a conservative rendition of the model developed for the continental United States. This model has been shown to bound the ionospheric threat evaluated in several other mid-latitude regions, relative to the magnetic equator. Recent data collected in some low-latitude regions, relative to the magnetic equator, has shown ionospheric conditions associated with local ionospheric density depletion ("plasma bubbles") that exceed this threat model. Research has resulted, for example, in a reference low-latitude threat model for the Asia-Pacific Region by a dedicated Ionospheric Studies Task Force (APAC ISTF). The threat models define an ionospheric environment for which the standardized monitoring is known to produce acceptable performance on a per-pseudo-range basis. Each service provider shall evaluate whether the standard threat space model described below is appropriate for the ionospheric characteristics in the region where GBAS is intended to support GAST D service. This evaluation shall always be performed, regardless of the latitudes involved. If a service provider determines that the ionospheric behaviour is not adequately characterized by this threat model (e.g. for a region of uniquely severe ionospheric behaviour), that service provider must take appropriate action to ensure the users will not be subjected to ionospheric anomalies with characteristics outside the range of the standard threat space. The service provider may elect to:

1. alter the characteristics of its ground subsystem; and/or

2. introduce additional monitoring (internal or external to the GBAS); and/or

3. introduce other operational mitigations that limit users' exposure to the extreme ionospheric conditions.

Potential ground subsystem changes which could achieve this risk reduction include tighter siting constraints (see 7.5.6.1.6) and improved ground subsystem monitoring performance (Appendix 6B, 3.6.7.3.4). Another mitigation strategy is monitoring of space weather (external to the GBAS system) in conjunction with operational limitations on the use of the system during predicted periods of severely anomalous ionospheric activity. Combinations of these strategies may be used to ensure that the GAST D user is not subjected to ionospheric anomalies outside the standard threat space.

7.5.6.1.7.1 *Ionosphere anomaly model: moving wedge.* This model a severe ionospheric spatial gradient as a moving wedge of constant, linear change in slant ionosphere delay, as shown in Figure D-11 The key parameters of this model are the gradient slope (g) in mm/km, the width (w) of the wedge in km, the amplitude of the change in delay (D) in m, and the speed (v) at which the wedge moves relative to a fixed point on the ground. These values are assumed to remain (approximately) constant over the period in which this wedge affects the satellites tracked by a single aircraft completing a GAST D approach. While the width of the wedge is small, the "length" of the wedge in the East-North coordinate frame (i.e. how far the "ionospheric front" containing the wedge extends) is not constrained.

In this model, the upper bound on g is dependent on wedge speed as specified in Table D-5A. This value is not dependent on satellite elevation angle. Because g is expressed in terms of slant delay, no "obliquity" correction from zenith delay is needed. The width w can vary from 25 to 200 km. The maximum value of D is 50 m. Note that, to make the model consistent, D must equal the product of slope g and width w. In cases where slope and width each fall within their allowed ranges, but their product D exceeds the 50-metre bound, that combination of slope and width is not a valid point within the threat model. For example, both g = 400 mm/km and w = 200 km are individually allowed, but their product equals 80 metres. Since this violates the constraint on D, a wedge with g = 400 mm/km and w = 200 km is not included in this threat model.

Note.— In the GAST D validation, it was assumed that each simulated wedge model is applied to the two ranging sources that produced the worst-case position errors. However, the numbers of wedges and impacted ranging sources depend on the ionospheric characteristics in the region where GBAS is intended to support GAST D service.

Table D-5A Upper bound on gradient slope

Propagation speed (v)	Upper bound on gradient slope (g)
$v < 750$ m/s	500 mm/km
$750 \le v < 1500$ m/s	100 mm/km

7.5.6.1.8 *Ionosphere gradient mitigation validation*

7.5.6.1.8.1 Because the mitigation responsibility for spatial ionosphere gradients is shared between the airborne and ground subsystems, this section includes guidance for modeling the critical airborne components (e.g. aircraft motion and monitoring) which will enable a ground manufacturer to validate the mitigation of spatial ionosphere gradients from a total system perspective. The validation can take into account the combination of ground and airborne monitors for the detection of gradients. When accounting for the combination of monitors, the correlation or independence between the monitors needs to be considered. Monitor performance shall also consider the effective time between independent samples of each monitor's test statistic. Modeling of the ionosphere monitoring shall include re admittance criteria for an excluded satellite, as appropriate per the ground subsystem design and DO-253D.

7.5.6.1.8.2 This section also includes test scenario guidance to help ensure all possible airborne position, ground reference point, approach direction, and gradient direction orientations are considered during validation.

7.5.6.1.8.3 Airborne monitor implementation

Validation may account for the following airborne monitors:

a) airborne code carrier divergence filtering as described in 2.3.6.11 of DO-253D;

b) differential RAIM used for satellite addition as described in 2.3.9.6.1 of DO-253D; and

c) dual solution pseudo-range ionospheric gradient monitoring as described in 2.3.9.7 of DO-253D.

7.5.6.1.8.3.1 In assessing the probability of missed detection, the contribution of all noise sources to the test statistic used for the airborne code carrier divergence monitor, excluding the effects of the ionosphere, can be assumed to have a normal distribution with a zero mean and a standard deviation of 0.002412 m/s.

7.5.6.1.8.3.2 In assessing the probability of missed detection, the contribution of all noise sources to the test statistic used for the dual solution pseudo-range ionospheric gradient monitor can be assumed to have a normal distribution with a zero mean and a standard deviation of 0.1741 m.

7.5.6.1.8.3.3 Note that the prior probability of the gradient that can be utilized during validation of 3.6.7.3.4 applies for these airborne monitors as well.

7.5.6.1.8.4 *Modeling airborne positioning and speed*

The airborne speed and position can be modeled working backward from the threshold crossing time using the following four values:

a) speed at landing;

b) amount of time at landing speed;

c) deceleration rate; and

d) speed at start of deceleration.

7.5.6.1.8.4.1 Figure D-12 illustrates how these four values are used to define a speed profile and Table D-5B shows the values that define the family of curves to be used in determination of GAST D broadcast parameters for a specific IGM design.

Table D-5B. Airborne speed profile from initial position to LTP

Landing ground speed (knots)	Time at landing speed (seconds)	Deceleration rate (knots/s)	Ground speed at start of deceleration (knots)
161	50	1.1	290
148	50	1.1	277
135	50	1.1	264

Note.— Modeling aircraft altitude is not necessary.

7.5.6.1.8.4.2 Figure D-13 shows the approach speed profiles based on the values in Table D-5B in terms of ground speed versus time until the aircraft reaches the landing threshold point.

7.5.6.1.8.5 *Gradient, airborne position, ground reference point, and approach direction considerations*

7.5.6.1.8.5.1 Figure D-14 illustrates the basic anomalous ionospheric scenarios (A-D) that constitute a threat. For a given ground station installation, the ground manufacturer shall demonstrate valid mitigation for any ionosphere gradient/airborne/approach orientations corresponding to that particular installation.

7.5.6.1.8.5.2 Validation test scenarios shall also address the timing component for each orientation. For example, for a given scenario, an approach shall be executed at least at one minute intervals.

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7.5.9 *Ephemeris error uncertainty.* Pseudo-range errors resulting from ephemeris errors (defined as a discrepancy between the true satellite position and the satellite position determined from the broadcast data) are spatially decorrelated and will therefore be different for receivers in different locations. When users are relatively close to the GBAS reference point, the residual differential error due to ephemeris errors will be small and both the corrections and uncertainty parameters σ_{pr_gnd} sent by the ground subsystem will be valid to correct the raw measurements and compute the protection levels. For users further away from the GBAS reference point, protection against ephemeris failures can be ensured in two different ways:

a) the ground subsystem does not transmit the additional ephemeris error position bound parameters. In this case, the ground subsystem is responsible for assuring integrity in case of satellite ephemeris failures without reliance on the aircraft calculating and applying the ephemeris bound. This may impose a restriction on the distance between the GBAS reference point and the decision altitude/height depending upon the ground subsystem means of detecting ranging source ephemeris failures. One means of detection is to use satellite integrity information broadcast by SBAS; or

b) the ground subsystem transmits the additional ephemeris error position bound parameters which enable the airborne receiver to compute an ephemeris error bound. These parameters are: coefficients used in the ephemeris error position bound equations ($K_{md\_e\_()}$, where the subscript () means either "GPS", "GLONASS", "POS, GPS" or "POS, GLONASS"), and the ephemeris decorrelation parameters (P). The ephemeris decorrelation parameter (P) in the Type 1 or Type 101 message characterizes the residual error as a function of distance between the GBAS reference point and the aircraft. The value of P is expressed in m/m. The values of P are determined by the ground subsystem for each satellite. One of the main factors influencing the values of P is the ground subsystem monitor design. The quality of the ground monitor will be characterized by the smallest ephemeris error that it can detect. The relationship between the P parameter and the smallest detectable error ε_{ephdet} for a particular satellite, i, can be approximated by $P_i = \varepsilon_{ephdet} / R_i$ where R_i is the smallest of the predicted ranges from the ground subsystem reference receiver antenna(s) for the period of validity of P_i. Since R_i varies with time, the P parameters values are time dependent as well. However, it is not a requirement for the ground subsystem to dynamically vary P. Static P parameters can be sent if they properly ensure integrity. In this latter case, the availability would be slightly degraded. Generally, as ε_{ephdet} becomes smaller, overall GBAS availability improves.

7.5.10 *Ephemeris error/failure monitoring.* There are several types of monitoring approaches for detecting ephemeris errors/failures. They include:

a) *Long baseline.* This requires the ground subsystem to use receivers separated by large distances to detect ephemeris errors that are not observable by a single receiver. Longer baselines translate to better performance in smallest detectable error;

b) *SBAS.* Since SBAS augmentation provides monitoring of satellite performance, including ephemeris data, integrity information broadcast by SBAS can be used as an indication of ephemeris validity. SBAS uses ground subsystem receivers installed over very long baselines, therefore this provides optimum performance for ephemeris monitoring and thus makes small errors detectable;

c) *Ephemeris data monitoring.* This approach involves comparing the broadcast ephemeris over consecutive satellite orbits. This monitoring assumes that the only threat of failure is due to a failure in the ephemeris upload from the constellation ground control network so that the ephemeris is inconsistent with previously broadcast ephemeris; and

d) *Delta-V (change in velocity) monitoring.* This monitoring covers the cases of uncommanded satellite manoeuvres out of view with unchanged ephemeris.

7.5.10.1 The monitor design (for example, its smallest detectable error) is to be based upon the integrity risk requirements and the failure model the monitor is intended to protect against. A bound on the GPS ephemeris failure rate can be determined from the reliability requirements defined in CAR-ANS 6.3, 6.3.7.3.1.3, since such an ephemeris error would constitute a major service failure.

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7.5.11 *Ground reference receiver faults.* A typical GBAS ground subsystem processes measurements from 2 to 4 reference receivers installed in the immediate vicinity of the reference point. For GAST A, B, C and D, the aircraft receiver is protected against a large error or fault condition in a single reference receiver by computing a protection level based on the B parameters from the Type 1 or Type 101 message and comparing that protection level to the alert limit. Ground subsystem compliance with the GAST A, B, C and D integrity risk (Appendix 6B, 3.6.7.1.2.2.1) is demonstrated taking into account the protocols required of the airborne subsystem (Appendix 6B, 3.6.5.5.1.2) and explicit monitoring required in the airborne subsystem. Alternative system architectures with sufficiently high redundancy in reference receiver measurements may employ processing algorithms capable of identifying a large error or fault in one of the receivers. This may apply for a GRAS network with receivers distributed over a wide area and with sufficient density of ionospheric pierce points to separate receiver errors from ionospheric effects. The integrity can then be achieved using only the protection levels for normal measurement conditions (VPL_{H0} and LPL_{H0}), with appropriate values for K_{ffmd} and σ_{pr_gnd}. This can be achieved using the Type 101 message with the B parameters excluded.

7.5.11.1 *GAST D ground reference receiver faults.* For GAST D, there is an additional standardized monitor implemented in the airborne receiver used to maintain the single reference receiver faulted measurement condition integrity regardless of the satellite geometry used in the aircraft. The aircraft receiver computes a position error estimate based on the B parameters and compares that error estimate directly to a threshold set as low as possible consistent with acceptable continuity risk. Although the monitor is mechanized in the airborne subsystem, the ground subsystem must meet specific requirements for the monitor to provide the required protection. The integrity performance depends on the assumed a priori failure rate (Appendix 6B, 3.6.7.1.2.2.1.2) and the probability of missed detection of the monitor. The a priori rate of a single reference receiver providing faulted measurements is required to be less than 1 x 10^{-5} per 150 seconds. The rate per individual receiver is dependent upon the number of reference receivers in the ground subsystem. For example, with four reference receivers the rate per receiver would be required to be less than 2.5 x 10^{-6} per 150 seconds. This a priori rate is achieved through a combination of receiver design requirements and proper reference receiver siting and operational constraints. Because conditions during system operation vary, ground subsystems may monitor receiver outputs to verify continued compliance with the requirement. The integrity performance also depends on the probability of missed detection (P_{md}) performance of the monitor implemented in the airborne equipment. The P_{md} performance of this monitor in turn depends on the characteristics of the errors that confound the observability of a reference failure. This is also true for the existing protection level integrity risk equations associated with faulted measurement conditions. The ground subsystem is required to broadcast integrity parameters that bound the errors such that a normal distribution can sufficiently characterize the errors and the P_{md} can be estimated (Appendix 6B, 3.6.7.1.2.2.1.1 and 3.6.7.2.2.4.1).

7.5.11.2 *GAST D ground reference receiver fault magnitude bounding.* Because the airborne subsystem implements the monitor as defined in the MOPS, it is possible to compute the size of the largest error that can result from the failure of a single reference receiver with a probability of greater than 1 x 10^{-9}. The calculated maximum size of the error will depend on the assumed a priori failure rate (Appendix 6B, 3.6.7.1.2.2.1.1) and the probability of missed detection of the monitor. The monitor P_{md} is dependent on the monitor threshold which is computed by the airborne equipment as a function of the geometry and the error distribution associated with the H_1 hypothesis.

7.5.12 *Range domain monitoring requirements for GAST D.* To support equivalent safety of Category II/III operations, requirements beyond the basic "signal-in-space" requirements defined for GAST A, B and C are necessary. These requirements include performance requirements for monitors implemented to detect pseudo-range errors. Two requirements apply to the post monitoring error in the corrected pseudo-range due to specific ranging source failures (Appendix 6B, 3.6.7.3.3.2 and 3.6.7.3.3.3). In both cases, the requirement applies to the probability of missed detection as a function of the size of an error due to the failure in the 30-second smoothed pseudo-range after the correction is applied.

1) The first requirement constrains the P_{md} performance of the specified ranging source failures without regard for the a priori probability of the ranging source failure. The bound for a ground subsystem's monitor performance defined in Appendix 6B, 3.6.7.3.3.2 is illustrated in Figure D-15. GAEC-D equipment will use the 30-second differential corrections to form

the position solution used for deviation guidance. The limits of the constraint region define the minimum P_{md} that the ground subsystem must ensure for any single ranging source failure condition.

Note.— The example compliant P_{md} in Figure D-15 is based on a hypothetical monitor with a threshold set to 0.8 m and monitor noise of 0.123 m. The curve is for illustration purposes only and does not represent the performance of any specific monitor design.

2) The second requirement constrains the conditional probability of the P_{md} performance of the specified ranging source given the a-priori failure probability for the specific ranging source failure. The conditional probability bound, $P_{md} \times P_{apriori}$, for a ground subsystem's monitor performance defined in Appendix 6B, 3.6.7.3.3.3 is illustrated in Figure D-16. The prior probability of each ranging source failure ($P_{apriori}$), used to evaluate compliance, shall be the same value that is used in the analysis to show compliance with the bounding requirements for FAST C and D (see 7.5.3.1).

7.5.12.1 *Verification of ground subsystem compliance with range domain monitoring requirements*

Verifying that a ground system design complies with the monitor requirements provided in Appendix 6B, 3.6.7.3.3.2 and 3.6.7.3.3.3 is achieved by a combination of testing and analysis. The requirements take the form of a constraint on the probability of missed detection as a function of the size of an error in the corrected pseudo-range. The general process that may be used to verify that a specific monitor, included as part of a ground subsystem design, meets the specified performance is as follows:

• Identify the threat space for each fault mode to be considered. (The requirements in Appendix 6B, 3.6.7.3.3 apply to four specific fault modes). These fault modes (i.e. the threat space), which may be used for evaluating compliance with a ground subsystem design, are provided in 7.5.12.1.3.1 through 7.5.12.1.3.4. These fault modes and fault combinations constitute the threat space. These threat space definitions represent what at least one State has found acceptable as an assumed threat space for each fault mode.

• Identify the airborne configuration space. The airborne system requirements introduce constraints on the design and performance of airborne equipment. These constraints define the range of critical airborne parameters of the configuration space for each fault mode and/or monitor that must be protected by the ground subsystem. For example, the bandwidth and correlator spacing of a compliant airborne receiver will conform to the requirements in sections 8.11.4 through 8.11.7.1. These are two of the critical parameters of the airborne configuration space for the satellite signal deformation fault mode. A critical airborne parameter directly influences how each point in the threat space translates to an error in the differentially corrected pseudo-range.

• An error analysis is done considering the specific monitor design under consideration given the full range of fault characteristics that comprise the threat space. For each characterized fault, the error that would be induced in the corrected pseudo-range (using the 30-second smoothed pseudo-ranges and pseudo-range corrections) is computed given the full range of critical airborne parameters that comprise the airborne configuration space.

• When assessing the compliance of a ground subsystem design, the performance is characterized by relevant statistical measures. Any monitor is subject to noise and therefore the performance may be characterized by the false detection rate and the missed detection probability. Both of these performance metrics are specified in the ground requirements in Appendix 6B by means of a not-to-exceed constraint. The missed detection probability performance is constrained by the requirements in Appendix 6B, 3.6.7.3.3.2 and 3.6.7.3.3.3. The false detection rate performance is constrained by the continuity requirements given in Appendix 6B, 3.6.7.1.3.2. It shall be understood that the ground subsystem must meet all requirements in the Standards. It is possible that the performance of individual monitors may be further constrained by other requirements, such as the ground subsystem integrity risk requirement in Appendix 6B, 3.6.7.1.2.1.1.1. Ground station accuracy performance may have an impact on airborne and ground monitor performance. In the validation of requirement feasibility a GAD C4 performance was assumed to account for instance for single reference receiver faults. Use of lower performance categories may have an availability or continuity impact and shall be investigated in the design process.

7.5.12.1.1 *Compliance of ground subsystem monitoring with continuity requirements.* The compliance with the false detection rate (continuity) may be established based on collected real data combined with analysis and/or simulation. The required number of truly independent samples shall be sufficient to adequately characterize the cumulative distribution function (CDF) of the monitor discriminator, which is compared to the threshold set for the monitor. The fault free noise CDF must be such that for the threshold set in the monitor the false detection probability is smaller than that required to support continuity. An allocation of the continuity to each monitor must be done with consideration given to the overall specified probability of false detection (Appendix 6B, 3.6.7.1.3.2). The achieved probability of false detection is determined by extrapolation of the observed trends in the measured CDF. Additionally, detection events in the ground system may be logged and if, over time, the false detection rates are not maintained at the required levels, thresholds may be adjusted as the result of a maintenance action to correct the problem.

7.5.12.1.2 *Compliance of ground subsystem monitoring with integrity requirements.* The compliance with the missed detection probability (integrity risk) is typically established based on simulation and analysis. (Given the low allowed probability of observing actual faults, collection of enough real data to establish that the probability is met with any statistical significance is impossible.) The threat space for the fault mode is divided into discrete intervals across the relevant parameters that define the fault behavior. The total space of potential faults is represented by a multidimensional grid of discrete points that span the threat space. The airborne configuration space is also discretized i.e. represented by multidimensional grid of discrete (critical parameter) points. A simulation is used to compute the expected pseudo-range error performance for each point in the threat space, each possible airborne configuration and the ground receiver function with the monitors. The worst-case error in the corrected pseudo-range is computed as a function of the discriminator value for the monitor addressing the threat (assuming no noise at this point). This also makes it possible to determine the discriminator value as a function of the worst-case error in the corrected pseudo-range (the inverse mapping). The missed detection probability is obtained by superimposing noise based on a conservative noise model (using an over bound of the CDF that was generated by the real data), on the discriminator determined from the worst-case differential range. This can be done either analytically or by simulation. The mapping from discriminator to worst-case error in the corrected pseudo-range and the noise levels applied may have further dependencies (for instance satellite elevation), and the established missed detection probability is therefore also a function of a set of parameters that constitute the detection parameter space which is divided into discrete intervals as well, i.e. represented by a multidimensional grid of discrete (detection parameter) points. The final missed detection probability is obtained by searching for the worst case when evaluating all the grid points in the detection parameter space.

7.5.12.1.3 *Threat space and relevant airborne configuration space for each fault mode*

7.5.12.1.3.1 *Code carrier divergence threat*

7.5.12.1.3.1.1 The code carrier divergence threat is a fault condition in a GPS satellite that causes the code and carrier of the broadcast signal to diverge excessively.

7.5.12.1.3.1.2 A code carrier divergence fault may cause a differential ranging error in one or both of the following cases: (1) the aircraft and ground filter designs are not identical, and (2) the aircraft and ground filters start at different times. Both of these cases can result in a difference between the transient responses of the filters in the presence of a CCD event. The critical airborne parameters are:

— The time of initialization of the airborne smoothing filter relative to the fault onset.

— The smoothing filter type (fixed time constant 30 seconds or adjustable time constant equal to time from initialization up to 30 seconds and thereafter fixed).

— The carrier code divergence rate monitoring required in airborne system for GAST D and the associated fault reaction.

— The time period from initialization of the airborne smoothing filter to the incorporation of the measurement in the position solution.

7.5.12.1.3.2 *Excessive acceleration threat*

The excessive acceleration threat is a fault condition in a GPS satellite that causes the carrier (and code in unison) of the broadcast signal to accelerate excessively. The threat space is one-dimensional and corresponds to all possible accelerations including ramps and steps.

7.5.12.1.3.3 *Ephemeris error threat*

The ephemeris error threat is a fault condition that causes the broadcast ephemeris parameters to yield excessive satellite position errors perpendicular to the ground subsystem's line of sight to the satellite. The resultant differential range error is the satellite position error (true compared to broadcast ephemeris) multiplied by the distance between ground subsystem and airborne and scaled by the inverted distance to the satellite. It is bounded by the product of the P parameter (see 7.5.9) and the distance between the user and the ground subsystem. The critical airborne parameter for the ephemeris error threat is therefore the distance between the user and the ground subsystem. Satellite ephemeris faults are categorized into two types, A and B, based upon whether or not the fault is associated with a satellite manoeuvre. There are two subclasses of the type A fault, A1 and A2.

7.5.12.1.3.3.1 *Ephemeris error threat type B*

7.5.12.1.3.3.1.1 The type B threat occurs when the broadcast ephemeris data is anomalous, but no satellite manoeuvre is involved.

7.5.12.1.3.3.1.2 The GBAS ground subsystem can monitor against such faults by comparing current and prior ephemerides. One example of a type B fault: no manoeuvre occurs, an incorrect upload is sent to a satellite, and the satellite subsequently broadcasts an erroneous ephemeris.

7.5.12.1.3.3.2 *Ephemeris error threat type A1*

7.5.12.1.3.3.2.1 The type A1 threat occurs when the broadcast ephemeris data is anomalous following an announced and intentional satellite manoeuvre.

7.5.12.1.3.3.2.2 Prior ephemerides are of limited use in the detection of type A1 failures because of the intervening manoeuvre. The GBAS ground subsystem will need to monitor ranging data directly as part of ephemeris validation. One example of a type A1 fault: a satellite is set unhealthy, a manoeuvre is executed, an incorrect upload is sent to the satellite, the satellite is reset to healthy and subsequently broadcasts an erroneous ephemeris.

7.5.12.1.3.3.3 *Ephemeris error threat type A2*

7.5.12.1.3.3.3.1 The type A2 threat occurs when the broadcast ephemeris data is anomalous following an unannounced or unintentional satellite manoeuvre.

7.5.12.1.3.3.3.2 Prior ephemerides are of limited use in the detection of type A2 failures because of the intervening manoeuvre. The GBAS ground subsystem will need to monitor ranging data directly as part of ephemeris validation. One example of a type A2 fault: a satellite is set healthy, an intentional manoeuvre or unintentional thruster firing occurs, and the satellite continues to broadcast the pre-manoeuvre (now erroneous) ephemeris.

7.5.12.1.3.4 *Signal deformation threat*

7.5.12.1.3.4.1 The signal deformation threat is a fault condition in the GPS satellite that causes the broadcast C/A code to be distorted so that the correlation peaks used for tracking in the airborne system and the ground system are deformed. The extent of the deformation depends on the receiver bandwidth and the resulting tracking error depends on where the correlator points used for code tracking are located (along the correlator peak).

7.5.12.1.3.4.2 The signal deformation monitoring threat space is defined in section 8. There are three fault types A, B, C.

7.5.12.1.3.4.3 Most satellites naturally show some degree of correlator peak deformation and these are referred to as natural (correlator measurement) biases. These natural biases may vary over time.

7.5.12.1.3.4.4 A fault condition (onset) will appear as a step in the raw (unfiltered) code measurement both in the airborne system and in the ground. If both system had exactly the same front end (RF and IF filtering, sampling method), correlator type and correlator spacing the error would be the same in ground and air and no differential error would occur. But typically that is not the case.

7.5.12.1.3.4.5 The step is filtered by the smoothing algorithm in the ground and in the airborne systems and the steady state differential error will gradually manifest itself in a 60 – 90 second time frame when using corrections from message Type 11 (or 200 – 300 seconds for message Type 1).

7.5.12.1.3.4.6 If a fault (A, B or C) occurs in a satellite it will take about 60 – 90 seconds before the steady state for the error and the monitor discriminator is reached. In essence the fault onset starts a race between the increasing differential error and the monitor discriminator as it moves towards the threshold. This is referred to as the transient state. If the range error reaches the limit that must be protected while the discriminator is not yet past the threshold with sufficient margin to guarantee the required detection probability, the requirement is not met. Both the steady state and the transient state performance must be evaluated.

7.5.12.1.3.4.7 The critical airborne parameters for the signal deformation threat are:

• The time period from initialization of the airborne smoothing filter to incorporation of the measurement in the position solution.

• The parameters that have constraints defined in the GAST D standard (Attachment B) including:

o Correlator type Early-Late (EL) or Double Delta (DD)

o Correlator spacing

o GPS signal bandwidth (from reception at antenna through RF, IF, and A/D conversion)

• Group delay (from reception at antenna through RF, IF, and A/D conversion).

7.5.12.1.3.4.8 Apart from the discrete choice of EL versus DD the configuration space is two-dimensional (correlator spacing and bandwidth). The filters implemented in the airborne system may be of different types (Butterworth, Chebychev, Elliptical, etc.). The group-delay constraints will exclude some of these filters. However the possible variation in receiver design introduces additional dimensions that the ground subsystem manufacturer must consider. The filter types are part of the configuration space to be considered.

7.5.13 *Ground subsystem requirements and airworthiness performance assessment.* Airworthiness certification of autoland systems, for use in Category II/III operations, requires an assessment of landing performance under fault-free and faulted conditions. More information, describing how the technical standards can be used to support an assessment, may be found in RTCA document DO-253D, "Minimum Operational Performance Requirements for Airborne Equipment using the Local Area Augmentation System" Appendix J".

7.5.14 *GBAS signal-in-space time-to-alert.* The GBAS signal-in-space time-to-alert (SIS TTA) is defined below within the context of GBAS based upon the TTA definition in CAR-ANS 6.3, section 6.3.7.1. The GBAS SIS TTA is the maximum allowable time elapsed from the onset of an out-of-tolerance condition at the output of the fault-free aircraft GBAS receiver until the aircraft GBAS receiver annunciates the alert. This time is a never-to-be-exceeded limit and is intended to protect the aircraft against prolonged periods of guidance outside the lateral or vertical alert limits.

7.5.14.1 There are two allocations made to support the GBAS SIS TTA in the Standards.

1) The first allocation, the ground subsystem TTA for SIS requirements, limits the time it takes the ground subsystem to provide an indication that it has detected an out-of-tolerance situation considering the output of a fault-free GBAS receiver. The indication to the aircraft element is either: a) to broadcast Type 1 (and Type 11 if broadcast) or Type 101 messages indicating the condition (in accordance with Appendix 6B, 3.6.7.3.2.1), or b) terminate all VDB transmissions. The ground subsystem is allocated 3 seconds to take either action.

For airborne receivers using GAST C, at least one Type 1 message signaling the out-of-tolerance condition must be received by a fault-free airborne receiver within the message time out to meet the SIS TTA. For airborne receivers using GAST D at least one of each (Type 1 and Type 11) message with the same applicable modified z-count (and the same set of satellites) must be received by a fault-free airborne receiver within the message time out to meet the SIS TTA. Because shutting down the VDB may result in an exposure time longer than the SIS TTA for satellite faults, this option is recommended only under conditions where the VDB transmission does not meet its associated performance requirements (reference Appendix 6B, 3.6.7.3.1.1.).

In addition, for ground subsystems that support GAST D monitoring performance requirements, the ground subsystem is allocated only 1.5 seconds to detect a condition producing out-of-tolerance errors in 30-second corrected pseudo-ranges and to either exclude the ranging source measurements from the broadcast or mark them as invalid. This time-to-detect and broadcast is similar in definition, but not equivalent in function to the ground subsystem TTA, as an out-of-tolerance condition in a single ranging source does not necessarily lead to out-of-tolerance guidance information.

2) The second allocation for the GBAS signal-in-space time-to-alert provides for the possible temporary loss of message reception. Airborne equipment operating with GAST C active will generate an alert if a Type 1 message is not received within 3.5 seconds when on the final

stages of approach. When the airborne equipment is below 200 ft height above the runway threshold (HAT), airborne equipment operating with GAST D active will generate an alert or change the active service type if a set of Type 1 and Type 11 messages with the same modified z-count are not received within 1.5 seconds. Note that these time-outs will also dictate the achieved signal-in-space time-to-alert when the ground subsystem ceases VDB transmissions instead of broadcasting messages as an alert to the airborne equipment.

Requirements on how quickly the receiver outputs must be invalidated (so annunciating an alert), as well as additional conditions requiring the outputs to be indicated as invalid, are contained in RTCA DO-253D. For example, there is a requirement for the aircraft GBAS receiver position determination function to use the most recently received message content and reflect the message content in its outputs within 400 ms. The SIS TTA is defined by start and stop events at the same point in the aircraft. Any processing that is common to generating outputs under both normal conditions and alert conditions will not change the achieved SIS TTA. That is, this common period acts like a lag to both the start event and end event and does not affect the total exposure time to the aircraft. Within the GBAS receiver, the outputs under both of these conditions must meet the same latency requirement, so large differences are not expected. SIS TTA will differ from ground subsystem TTA by a value equal to the difference between receiver processing time and receiver time to invalidate outputs.

7.5.14.2 Table D-5C summarizes the time periods that contribute to the GBAS SIS TTA and the range of achieved TTA that can be expected.

7.5.14.3 Figure D-17 illustrates the nominal case with no missed messages and Figure D-18 illustrates the effect of missed messages for GAST D below 200 ft. Above 200 ft, the situation is similar, but the aircraft has a longer missed message allocation, as described above.

7.5.14.3.1 Figure D-18 illustrates the effect on the SIS TTA due to missed messages (upper half) and VDB termination (lower half) using the example of GAST D requirements below 200 ft. The upper time-line shows just two messages being missed, but the third is received, so operations can continue, unless the third message is indicating a fault condition that results in an alert from the receiver. The lower time-line shows the effect of the VDB terminating. The aircraft receiver invalidates its outputs after three messages are missed. The SIS TTA combines the ground TTA and the missed message allocation (See Table D-5B), but it is now displaced by the aircraft receiver processing time. Above 200 ft, the situation is similar, but the aircraft has a longer allocation, as described in RTCA DO-253D.

7.5.14.3.2 For SIS integrity, the diagram indicates that the SIS TTA starting point is where the fault-free airborne receiver outputs out-of-tolerance data. The SIS TTA end event is also at the output of the airborne receiver.

7.5.14.3.3 The start event of the ground subsystem's time-to-alert or time-to-detect and broadcast is the last bit of the first message (Type 1 and Type 11 message pair for GAST D) including the out-of-tolerance data. For ground equipment failures or termination of the VDB signal, this is the first message the ground subsystem broadcasts containing correction, integrity or path information that does not conform to the applicable integrity requirement (e.g. SIS integrity, ground subsystem integrity). For satellite failures, the requirements are out-of-tolerance once differential pseudo-range errors exceed the performance metrics detailed within a certain requirement (e.g. Ranging Source Monitoring). Their end event is the last bit of the first message (message pair for GAST D) removing the out-of-tolerance data or flagging it invalid.

7.5.14.3.4 It shall be noted that, while the Figure D-17 indicates that the SIS and ground subsystem TTAs reference different start and end points in time, an ANSP may assume that they are the same. A ground subsystem shall be evaluated and certified with no credit or penalty for airborne receiver variations due to a specific, approved aircraft implementation. From the ground subsystem perspective, all received messages are assumed to be instantaneously applied or acted upon by the airborne receiver. This effectively results in equivalent SIS and ground subsystem TTA reference points from the ground subsystem's point of view.

7.5.15 *Ground subsystem integrity risk for GAST D.* Appendix 6B, 3.6.7.1.2.1.1.3 specifies a new ground subsystem integrity requirement relating to fail-safe design criteria. This integrity method will ensure that failures within the ground subsystem that might affect the stations functions and result in erroneous information are extremely improbable. The intent of this requirement is to specify the allowable risk that the ground subsystem would internally generate and cause erroneous information to be broadcast. Other requirements specify the required performance of the ground subsystem with respect to detection and mitigation of faults originating outside the ground subsystem (such as ranging source failures). This requirement relates to the probability that the ground subsystem fails to meet the intended function. The intended function for GBAS is defined in CAR-ANS 6.3, 6.3.7.3.5.2. The functions listed in that section and their associated performance requirements characterize the intended function of the system.

Table D-5C. Contributions to signal-in-space time-to-alert

Integrity risk requirements and service types	Ground subsystemTTA *[Note 1]*	Message time-out in aircraft *[Note 5]*	Signal-in-space TTA (nominal) *[Note 6]*	Signal-in-space TTA (maximum) *[Note 7]*
App B, 3.6.7.1.2.1.1.1 and 3.6.7.1.2.2.1 (GAST A,B,C)	3.0 s *[Note 2]*	3.5 s	3.0 s	6.0 s
App B, 3.6.7.1.2.1.1.2 and 3.6.7.1.2.2.1	3.0 s *[Notes 2 and 8]*	3.5 s (above 200 ft HAT) 1.5 s (below 200 ft HAT)	3.0 s 3.0 s	6.0 s 4.0 s
App. B, 3.6.7.1.2.1.1.3 (GAST D)	1.5 s	3.5 s (above 200 ft HAT) 1.5 s (below 200 ft HAT)	1.5 s 1.5 s	4.5 s *[Note 3]* 2.5 s *[Note 3]*
App. B, 3.6.7.3.3 (GAST D)	1.5 s *[Note 9]*	3.5 s (above 200 ft HAT) 1.5 s (below 200 ft HAT)	1.5 s 1.5 s	4.5 s *[Note 4]* 2.5 s *[Note 4]*

Note 1.— These ground subsystem TTA requirements apply to a ground subsystem transmitting Type 1 messages. Ground subsystems transmitting Type 101 messages have a 5.5 s TTA as standardized in Appendix 6B, 3.6.7.1.2.1.2.1.2.

Note 2.— These times apply to excluding all ranging sources, marking all ranging sources as invalid in message Type 1 or the cessation of VDB transmission. When a single ranging source is marked invalid or excluded, it may or may not cause the aircraft receiver to generate an alert, depending on the role of that ranging source in the aircraft's position solution.

Note 3.— This design requirement applies to the integrity of internal ground subsystem functions (excluding single reference receiver failures). This includes the ground subsystem ranging source monitoring capability. The table illustrates the exposure time for ground equipment failures that result in the transmission of non-compliant information and that are enunciated to the aircraft using the VDB transmission.

Note 4.— These requirements apply to the integrity monitoring for GNSS ranging sources. When a single ranging source is marked invalid or excluded, it may or may not cause the aircraft receiver to generate an alert, depending on the role of that ranging source in the aircraft's position solution. The times listed in the table assume the ranging source was critical to determining the position solution.

Note 5.— The missed message time-out allocation starts with the last received message and not with the first missed message, so is 0.5 s longer than time added to the SIS time-to-alert.

Note 6.— If transmissions continue and there are no missed messages, the "nominal" column is relevant. This value includes the maximum ground subsystem contribution.

Note 7.— The maximum SIS TTA includes the maximum ground subsystem contribution and the possible temporary loss of message reception. When VDB transmissions cease, the maximum SIS TTA is relevant. This time is computed by adding the ground subsystem TTA and the airborne message time out minus 0.5 s (see Note 5).

Note 8.— Although these sections are related to FAST D and the maximum TTA values are larger than those historically associated with Category II/III operations, the TTA values in this line are not relevant for integrity to support Category II/III. These TTA values apply to the bounding conditions (see 7.5.3.1) and therefore are related to the total risk of fault-free error sources and faults exceeding the protection levels. For GAST D, the effects of malfunctions are addressed by the additional requirements in Appendix 6B, 3.6.7.1.2.1.1.3, Appendix B, 3.6.7.3.3 and additional airborne requirements as provided in RTCA DO-253D, for example the reference receiver fault monitor. These additional requirements are more constraining and enforce a shorter TTA that is appropriate for Category II/III operations. The existence of the longer TTA values in this line shall not be interpreted to imply that errors near or exceeding the alert limit for up to these longer exposure times can occur with a probability greater than 1×10^{-9} in any landing.

Note 9.— This is "time to detect and broadcast"; the other ground system requirements apply in addition.

7.5.15.1 *Verification of compliance with subsystem integrity risk for GAST D.* Verification that a ground subsystem meets the integrity risk requirements of Appendix 6B, 3.6.7.1.2.1.1.3 would typically be accomplished through a combination of analysis and appropriate safety-related design practices/processes. The overall process must ensure that failures within the ground subsystem that might affect the stations intended functions and result in erroneous information are extremely improbable. All ground subsystem component failure conditions must be shown to be sufficiently mitigated through either direct monitoring or through use of an acceptable design assurance development process (such as RTCA/DO-178 and RTCA/DO-254). The methodology shall provide assurance of mitigation of component (HW, SW) failures. The integrity method of design assurance, applied in conjunction with fail-safe design concepts and other assurance actions (such as those in SAE ARP 4754) to detect and remove systematic errors in the design, provides safety assurance of the GAST D ground system. Some States have used safety assurance guidance from ICAO's *Safety Management Manual (SMM)* (Doc 9859).

7.6 Continuity of service

7.6.1 *GBAS continuity /integrity designator.* The GBAS continuity/integrity designator (GCID) provides an indication of the current capability of GBAS ground subsystems. The ground subsystem meets the performance and functional requirements of GAST A, B or C when GCID is set to 1. The ground subsystem meets the performance and functional requirements of GAST A, B, C and D when GCID is set to 2. GCID of 3 and 4 are intended to support future operations with an associated service type that has requirements that are more stringent than GAST D. The GCID is intended to be an indication of ground subsystem status to be used when an aircraft selects an approach. It is not intended to replace or supplement an instantaneous integrity indication communicated in a Type 1 or Type 101 message. GCID does not provide any indication of the ground subsystem capability to support the GBAS positioning service.

7.6.2 *Ground subsystem continuity of service.* GBAS ground subsystems are required to meet the continuity of service specified in Appendix 6B to CAR-ANS 6.3, 6.3.6.7.1.3 in order to support GAST A, B and C. GBAS ground subsystems that are also intended to support other operations through the use of the GBAS positioning service shall support the minimum continuity required for terminal area operations, which is $1–10^{-4}$/hour (CAR-ANS 6.3, Table 6.3.7.2.4-1). When the GAST A, B or C required continuity ($1–8 \times 10^{-6}$/15 seconds) is converted to a per hour value it does not meet the $1–10^{-4}$/hour minimum continuity requirement. Therefore, additional measures are necessary to meet the continuity required for other operations. One method of showing compliance with this requirement is to assume that airborne implementation uses both GBAS and ABAS to provide redundancy and that ABAS provides sufficient accuracy for the intended operation.

7.6.2.1 *Ground subsystem continuity of service for GAST D.* A ground segment that supports GAST D must meet the SIS continuity requirement ($1-8.0 \times 10^{-6}$/15 seconds) for a GAST A, B and C system but must also meet the continuity requirements specific to GAST D as defined in Appendix 6B, 3.6.7.1.3.2. The ground subsystem continuity is defined by two requirements. One is the continuity of the ground subsystem that includes failures of all components necessary for the VDB broadcast, including the reference receivers. It also includes loss of service due to integrity failures in the ground subsystem that result in alerts and monitor false alerts. The other allocation is the continuity associated with monitor fault-free detections. The reason for defining the ranging source monitor detections as a separate requirement is because the VDB broadcast portion includes all failures that result in the loss of the SIS, whereas the monitor contribution is related only to exclusion of individual satellites from the broadcast corrections. This does not necessarily result in a loss of the SIS by the airborne receiver. The requirement is defined on a per ranging source basis so that the ground design does not need to account for the actual number of satellites in view or the number considered critical to the user for a specific approach. It is the responsibility of the airborne user to demonstrate the overall continuity achieved when considering the contribution of the satellites and the airborne monitors.

7.7 GBAS channel selection

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7.7.2 A channel number in the range from 20 001 to 39 999 is assigned when the FAS data are broadcast in the Type 4 message. A channel number in the range from 40 000 to 99 999 is assigned when the FAS data associated with a GAST A service type are obtained from the on-board database.

7.7.3 Every FAS data block uplinked in a Type 4 message will be associated with a single 5-digit channel number regardless of whether or not the approach is supported by multiple approach service types. For approaches that are supported by multiple approach service types, the approach performance designator field in the Type 4 message is used to indicate the most demanding approach service type supported by the ground subsystem for any specific approach.

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7.10 GBAS identification

The GBAS identification (ID) is used to uniquely identify a GBAS ground subsystem broadcasting on a given frequency within the VDB coverage of the GBAS. The aircraft will navigate using data broadcast from one or more GBAS broadcast stations of a single GBAS ground subsystem (as identified by a common GBAS identification).

7.11 Final approach segment (FAS) path

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7.11.3.1.1 *Lateral deviation reference.* The lateral deviation reference plane is the plane that includes the LTP/FTP, FPAP and a vector normal to the WGS-84 ellipsoid at the LTP/FTP. The rectilinear lateral deviation is the distance of the computed aircraft position from the lateral deviation reference plane. The angular lateral deviation is a corresponding angular displacement referenced to the GNSS azimuth reference point (GARP). The GARP is defined to be beyond the FPAP along the procedure centre line by a fixed offset value of 305 m (1 000 ft).

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7.12 Airport siting considerations

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7.12.3 *Locating the VDB antenna.* The VDB antenna must be located to comply with the minimum and maximum field strength requirements within the service volume(s) as defined in CAR-ANS 6.3, 6.3.7.3.5.4.4. Compliance with the minimum field strength for approach services can generally be met if the VDB antenna is located so that an unobstructed line-of-sight exists from the antenna to any point within the service volume for each supported FAS. Consideration shall also be given to ensuring the minimum transmitter-to-receiver separation so that the maximum field strength is not exceeded. For the nominal link budget, typically, an 80 m separation is required to avoid exceedance of the maximum field strength requirement. Though it is desirable to apply the separation criteria to any location where an aircraft may operate (including taxiways, ramp areas and gates), it is only necessary to meet the maximum field strength in the service volume(s) (see 6.3.7.3.5.3 for service volume definitions). If the minimum separation cannot be met for all operating aircraft (including taxiways, ramp areas and gates) it must be ensured that the airborne receiver is protected from burn-out in accordance with the RTCA/DO-253 D MOPS. This typically requires a minimum separation of 20 m from the VDB antenna to the aircraft antenna. In order to provide the required coverage for multiple FASs at a given airport, and in order to allow flexibility in VDB antenna siting, the actual coverage around the transmitter antenna may need to be considerably larger than that required for a single FAS. The ability to provide this coverage is dependent on the VDB antenna location with respect to the runway and the height of the VDB antenna. Generally speaking, increased antenna height may be needed to provide adequate signal strength to users at low altitudes, but may also result in unacceptable multipath nulls within the desired coverage. A suitable antenna height trade-off must be made based on analysis, to ensure the signal strength requirements are met within the entire coverage. Consideration shall also be given to the effect of terrain features and buildings on the multipath environment.

7.12.3.1 In order to ensure that the maximum field strength requirements defined in CAR-Ans 6.3, 6.3.7.3.5.4.4 are not violated, VDB transmitters shall not be located any closer than 80 m to where aircraft are approved to operate based on published procedures using GBAS or ILS guidance information. This applies to aircraft on final approach, departure, and on runways. The 80-metre separation applies to the slant range distance between VDB transmit antennas and the aircraft antenna position. For aircraft on the runway the maximum deviation from the centre line can be assumed to be 19 m. In regions prior to runway thresholds, the maximum lateral course angular deviation from the extended centre line on final approach is plus and minus one sixth of the full course width, which is nominally 210 m (±105 m (±350 ft)) at threshold. The origin of the lateral course shall be assumed to be the GBAS GARP, or the ILS localizer, as appropriate. The maximum vertical deviation is one half of the full scale deflection from the glide path, where full scale deflection is calculated as ±0.25 times the glide path angle. The origin of the glide path shall be assumed to be the GPIP. See 7.11.3 for further guidance on lateral and vertical course width deviation sensitivity.

7.12.4 *Use of multiple transmit antennas to improve VDB coverage.* For some GBAS installations, constraints on antenna location, local terrain or obstacles may result in ground multipath and/or signal blockage that make it difficult to provide the specified field strength at all points within the service volume. Some GBAS ground facilities may make use of one or more additional antenna systems, sited to provide signal path diversity such that collectively they meet the service volume requirements.

7.12.4.1 Whenever multiple antenna systems are used, the antenna sequence and message scheduling must be arranged to provide broadcasts at all points within the service volume that adhere to the specified minimum and maximum data broadcast rates, considering the receiver's ability to adapt to transmission-to-transmission variations in signal strength in a given slot. Exceedance of the signal power variation requirement in Appendix 6B, 3.6.8.2.2.3 is acceptable for limited areas within the service volume, provided it can be shown based on receiver behaviour as described, for example in RTCA DO- 253D and the assumptions listed below, that the resulting performance is acceptable.

7.12.4.1.2 Message transmission and reception rate requirements, and time-to-alert requirements prevent Type 1 and Type 11 messages from being alternated between antennas in the same slot from frame to frame. Only Type 2 and 4 messages (and Type 3 messages as a filler message) are candidates for being alternated. Continuity is maintained as long as a Type 2 message is received at least once per minute. The receiver does not verify repeated reception of Type 4 messages during the final stages of an approach.

7.12.4.1.3 While the signal power variation requirement in Appendix 6B, 3.6.8.2.2.3 applies on the input port of the receiver, the situation for a specific site has to be assessed in the field strength domain. Therefore, the potential variation in aircraft antenna gain must be taken into account. If the area where the signal power variation requirement may be exceeded is so large that it may take one minute or more for an approaching aircraft to pass through it, it may be necessary to address the potential message loss from a probabilistic point of view. In these cases the multiple VDB antenna set-up shall be limited so that in case alternation of messages in the same slot from frame to frame is applied, the alternating pattern shall only involve two transmitter antennas, with a scheduled burst in every frame, and the transmission shall alternate between the antennas every frame, in order to resemble the situation for which the receiver has been tested. This is necessary in order to be able to make assumptions on receiver message failure rates (MFR).

7.12.4.1.4 When analysing the probability of lost messages, the following basic assumptions apply:

1. If all received signal levels are between the receiver minimum design input power (S_{min}) and maximum design input power (S_{max}), and they are within 40 dB of each other, then the analysis can assume 10^{-3} message failure rate (MFR).

2. If all received signals are below S_{min}, then the analysis must assume a MFR of 100 per cent.

3. If any signal exceeds S_{max} it must be assumed that reception in all slots in that frame and any number of subsequent frames is adversely affected (not only those where S_{max} is exceeded), as no receiver recovery time is specified for these conditions.

Furthermore, in the case of a dual antenna set-up with messages alternating in each frame, the following assumptions can be made:

4. If one signal is below S_{min} ($S_{min} - \Delta$) and the second signal is within 40 dB (i.e., $S_{min} - \Delta +$ 40 dB or less), then the analysis must assume that the MFR for the signal below S_{min} is 100 per cent and the MFR for the stronger signal is 10^{-3}.

5. If both signals are within S_{min} to S_{max}, but the variation between the signals is greater than 40 dB, then the analysis must assume a MFR of 60 per cent.

6. If one signal is below S_{min} ($S_{min} - \Delta$) and the second is above S_{min}, and exceeds 40 dB variation ($S_{min} - \Delta + 40$ dB $+ \varepsilon$ or more), then the analysis must assume that the MFR for the signal below S_{min} is 100 per cent and the MFR for the stronger signal is 60 per cent.

7.12.4.1.5 The resulting probability of no Type 2 messages being received for a duration of one minute shall be assessed against the applicable continuity requirement.

Note.— The analysis may have to consider up to 15 dB variation for the aircraft VDB antenna gain variation depending upon the scenario, such that the 40 dB power variation ≤ SIS power variation + up to 15 dB aircraft antenna gain variation.

To avoid receiver processing issues concerning lost or duplicated messages, all transmissions of the Type 1, Type 11 or Type 101 message, or linked pairs of Type 1, Type 11 or Type 101 messages for a given measurement type within a single frame need to provide identical data content.

7.12.4.2 One example of the use of multiple antennas is a facility with two antennas installed at the same location but at different heights above the ground plane. The heights of the antennas are chosen so that the pattern from one antenna fills the nulls in the pattern of the other antenna that result from reflections from the ground plane. The GBAS ground subsystem alternates broadcasts between the two antennas, using one, two or three assigned slots of each frame for each antenna. Type 1, Type 11 or Type 101 messages as appropriate for the service type supported are broadcast once per frame, per antenna. This allows for reception of one or two Type 1, Type 11 or Type 101 messages per frame, depending on whether the user is located within the null of one of the antenna patterns. Type 2 and 4 messages are broadcast from the first antenna in one frame, then from the second antenna in the next frame. This allows for reception of one each of the Type 2 and 4 messages per one or two frames, depending on the user location.

7.13 Definition of lateral and vertical alert limits

7.13.1 The lateral and vertical alert limits when the active service type is C or D are computed as defined in Appendix 6B, Tables B-68 and B-69. In these computations the parameters D and H have the meaning shown in Figure D-8.

7.13.2 The vertical alert limit when the active service type is C or D is scaled from a height of 60 m (200 ft) above the LTP/FTP. For a procedure designed with a decision height of more than 60 m (200 ft), the VAL at that decision height will be larger than the broadcast FASVAL.

7.13.3 The lateral and vertical alert limits for procedures supported by GAST A service type associated with channel numbers 40 001 to 99 999 are computed in the same manner as SBAS as given in Attachment 6D 6.6.

7.14 Monitoring and maintenance actions

7.14.1 Specific monitoring requirements or built-in tests may be necessary in addition to the monitors defined in Appendix 6B, 3.6.7.3 and shall be determined by individual States. Since the VDB signal is critical to the operation of the GBAS broadcast station, any failure of the VDB to successfully transmit a usable signal within the assigned slots and over the entire service volume is to be corrected as soon as possible. Therefore, it is recommended that the following conditions be used as a guide for implementing a VDB monitor:

a) *Power.* A significant drop in power is to be detected within an appropriate time period.

b) *Loss of message type.* The failure to transmit any scheduled message type(s). This could be based on the failure to transmit a unique message type in succession, or a combination of different message types.

c) *Loss of all message types.* The failure to transmit any message type for an appropriate time period will be detected.

The appropriate time periods for these monitors depend on the FAST and on whether a back-up transmitter is provided. Where a back-up transmitter is provided, the objective is to switch to the back-up transmitter quickly enough to avoid an alert being generated in the airborne equipment. This means that the appropriate time periods are a maximum of 3 seconds for FAST C and a maximum of 1.5 seconds for FAST D ground systems in order to be consistent with the aircraft equipment message loss requirements. If longer periods than this are implemented, the changeover to the back-up transmitter will cause an alert and must therefore be considered to be a continuity failure. If no back-up transmitter is provided, the time periods for these monitors are not critical.

7.14.2 Upon detection of a failure, and in the absence of a back-up transmitter, termination of the VDB service shall be considered if the signal cannot be used reliably within the service volume to the extent that aircraft operations could be significantly impacted. Appropriate actions in operational procedures are to be considered to mitigate the event of the signal being removed from service. These would include dispatching maintenance specialists to service the GBAS VDB or special ATC procedures. Additionally, maintenance actions shall be taken when possible for all built-in test failures to prevent loss of GBAS service.

7.14.3 The use of a back-up transmitter also applies to the VDB monitoring requirements defined in Appendix 6B, 3.6.7.3.1. The time to switch over to the back-up needs to be taken into account while remaining compliant with the time to detect and terminate transmissions defined in Appendix 6B, 3.6.7.3.1.1 and 3.6.7.3.1.2.

7.15 Examples of VDB messages

7.15.1 Examples of the coding of VDB messages are provided in Tables D-7 through D-10A. The examples illustrate the coding of the various application parameters, including the cyclic redundancy check (CRC) and forward error correction (FEC) parameters, and the results of bit scrambling and D8PSK symbol coding. The engineering values for the message parameters in these tables illustrate the message coding process, but are not necessarily representative of realistic values.

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7.15.4.1 Table D-8B provides an example of Type 2 messages with additional data blocks 1, 3 and 4 coded within a single burst with a Type 3 message that is used to fill the rest of the time slot.

7.15.6 Table D-10 provides an example of a Type 5 message. In this example, source availability durations common to all approaches are provided for two ranging sources. Additionally, source availability durations for two individual approaches are provided: the first approach has two impacted ranging sources and the second approach has one impacted ranging source

7.15.7 Table D-10A provides an example of a Type 11 message.

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7.17 Type 2 message additional data blocks

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7.17.4 Type 2 message additional data block 3 contains information necessary to support GAST D. All FAST D ground subsystems are required to transmit a Type 2 message with additional data block 3 properly populated so that the bounding requirements are met.

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Table D-8B. Example of a Type 2 message containing data blocks 1, 3 and 4 and a Type 3 message to fill the remainder of the slot

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
BURST DATA CONTENT					
Power ramp-up and settling	15	—	—	—	000 0000 0000 0000
Synchronization and ambiguity resolution	48	—	—	—	0100 0111 1101 1111 1000 1100 0111 0110 0000 0111 1001 0000
SCRAMBLED DATA					
Station slot identifier	3	—	—	E	100
Transmission length	17	0 to 1824 bits	1 bit	1704	0 0000 0110 1010 1000
Training sequence FEC	5	—	—	—	01000
APPLICATION DATA					
Message Block 1 (Type 2 message)					
Message Block Header					
Message block identifier	8	—	—	Normal	1010 1010
GBAS ID	24	—	—	BELL	000010 000101 001100 001100
Message type identifier	8	1 to 101	1	2	0000 0010
Message length	8	10 to 222 bytes	1 byte	43	0010 1011
Message (Type 2 example)					
GBAS reference receivers	2	2 to 4	1	4	10
Ground accuracy designator letter	2	—	—	C	10
Spare	1	—	—	—	0
GBAS continuity/integrity designator	3	0 to 7	1	2	010
Local magnetic variation	11	±180°	0.25°	E58.0°	000 1110 1000
Reserved	5	—	zero	—	0000 0
$\sigma_{vert\_iono\_gradient}$	8	0 to 25.5 x 10^{-6} m/m	0.1 x 10^{-6}m/m	4 x 10^{-6}	0010 1000
Refractivity index	8	16 to 781	3	379	1111 1001
Scale height	8	0 to 25 500 m	100 m	100 m	0000 0001

Refractivity uncertainty	8	0 to 255	1	20	0001 0100
Latitude	32	±90.0°	0.0005 arcsec	N45° 40' 32" (+164432")	0001 0011 1001 1010 0001 0001 0000 0000
Longtitude	32	±180.0°	0.0005 arcsec	W93° 25' 13" (-336313")	1101 0111 1110 1000 1000 1010 1011 0000
Ellipsoid height	24	±83 886.07 m	0.01 m	892.55 m	0000 0001 0101 1100 1010 0111
Additional Data Block 1					
Reference station data selector	8	0 to 48	1	5	0000 0101
Maximum use distance (Dmax)	8	2 to 510 km	2 km	50 km	0001 1001
$K_{md\_e\_POS,GPS}$	8	0 to 12.75	0.05	6	0111 1000
DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
Kmd_ e,GPS	8	0 to 12.75	0.05	5	0110 0100
Kmd_e_POS,GLONASS	8	0 to 12.75	0.05	0	0000 0000
Kmd_ e,GLONASS	8	0 to 12.75	0.05	0	0000 0000
Additional Data Block 4					
Additional data block length	8	3	1 byte	3	0000 0011
Additional data block number	8	4	1	4	0000 0100
Slot group definition	8	—	—	E+F	0011 0000
Additional Data Block 3					
Additional Data Block Length	8	6	1 byte	6	0000 0110
Additional Data Block Number	8	3	1	3	0000 0011
$K_{md\_e\_D,GPS}$	8	0 to 12.75	0.05	5.55	0110 1111
$K_{md\_e\_D,GLONASS}$	8	0 to 12.75	0.05	0	0000 0000
$\sigma_{vert\_iono\_gradient\_D}$	8	$0 - 25.5 \times 10^{-6}$ m/m	0.1×10^{-6} m/m	4×10^{-6}	0010 1000
Y_{EIG}	5	0 to 3.0 m	0.1	1	0 1010
M_{EIG}	3	0 to 0.7 m/km	0.1	0.3	011
Message Block 1 CRC	32	—	—	—	0011 1100 1110 0001 1000 0100 1011 1011
Message Block 2 (Type 3 message)					

Message Block Header					
Message block identifier	8	—	—	Normal	1010 1010
GBAS ID	24	—	—	BELL	000010 000101 001100 001100
Message type identifier	8	1 to 101	1	3	0000 0011
Message length	8	N/A	1 byte	164	1010 0100
Message (Type 3 example)					
Filler	1232	—	—	—	1010 1010 ...... 1010 1010
Message Block 2 CRC	32	—	—	—	0110 1101 1011 1001 1110 0100 1110 0100
Application FEC	48	—	—	—	1111 0110 0011 0100 1101 1001 1110 0010 1110 0011 1111 1101
Input to the bit scrambling (Note 2)	0 45 58 02 55 30 CA 10 40 D4 52 17 00 14 9F 80 28 00 88 59 C8 0D 51 17 EB E5 3A 80 A0 98 1E 26 00 00 C0 20 0C 60 C0 F6 00 14 56 DD 21 87 3C 55 30 CA 10 C0 25 55 27 27 9D B6 BF C7 47 9B 2C				
Output from the bit scrambling (Note 3)	0 63 6F 8A 1F 2F D2 3B 9F 4E 87 CE 32 C8 D9 50 DE C1 C1 5A D4 09 7E E7 81 5A 5C D4 28 56 00 CE 29 60 A3 5F 77 34 64 38 71 03 15 16 24 9C CF 8F 8A 13 B6 1D AC 78 B6 C7 D0 93 58 5D 46 B5 6F D5 0C AA 77 FE D3 30 A2 27 E1 EC E4 F7 17 2D AD F4 0B 29 82 04 61 96 E4 50 E9 58 FA B8 C0 38 99 C7 BB 6C 3D 09 CA 7B 7E C2 CF 60 8D 18 75 B9 2B C5 FC 94 C8 57 79 52 C5 5F 6A B2 FF DF 33 4D DD 74 B5 28 2A 06 01 91 9B A4 43 E9 63 05 1D 95 B4 54 29 56 05 51 95 5B AA BC 00 3666 2E EE 0F 0E 72 71 21 25 E5 EB 14 FD A8 CB F8 83 38 62 39 1E 3A 4E 3E 8E 30 71 D9 24 BA 17 C1 AC 9B F7 BC D3 C8 A3 78 1D 39 B5 C4 2B 69 FD 04 CA 68 81 07 9A 1E 33 C1 86 6F 86 78 98 87 95				
Fill bits	0 to 2	—	—	2	00
Power ramp-down	9	—	—	—	000 000 000
D8PSK Symbols (Note 4)	00000035 11204546 31650102 46331130 13067746 52652552 60712455 15066026 22433136 20007526 34111714 74536644 75444673 47266102 52635407 12243401 11561037 01237127 60553360 64340421 37024663 76701711 41435042 46314343 14302740 43711436 70511643 01271030 13504154 47365114 45511504 12200201 40164744 00021467 34131754 52554125 73741336 24044706 62272634 50547410 75654505 73645775 05153625 27427624 71315376 42507750 01000470 73036771 61401006 63561510 31143140 01422617 26364743 33357073 46405563 35412370 11472764 14014631 72320522 11576761 26127747 24352562 32277467 01242252 66037246 31604613 72367522 27243731 56617534 16114672 47000774 37674402 66002316 56521466 56347666 6				

Notes.-

1. *The rightmost bit is the LSB of the binary parameter value and is the first bit transmitted or sent to the bit scrambler. All data fields are sent in the order specified in the table.*
2. *This field is coded in hexadecimal with the first bit to be sent to the bit scrambler as its MSB. The first character represents a single bit.*
3. *In this example, fill bits are not scrambled.*
4. *This field represents the phase, in units of $\pi/4$(e.g. a value of five represents a phase of $5\pi/4$ radians), relative to the phase of the first symbol.*

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Table D-10A. Example of a Type 11 VDB message

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
BURST DATA CONTENT					
Power ramp-up and settling	15				000 0000 0000 0000
Synchronization and ambiguity resolution	48				0100 0111 1101 1111 1000 1100 0111 0110 0000 0111 1001 0000
SCRAMBLED DATA					
Station slot identifier (SSID)	3	—	—	E	100
Transmission length (bits)	17	0 to 1 824 bits	1 bit	440	0 0000 0001 1011 1000
Training sequence FEC	5	—	—	—	0 1011
APPLICATION DATA MESSAGE BLOCK					
Message Block 1 (Type 11 message)					
Message Block Header					
Message block identifier	8	—	—	Normal	1010 1010
GBAS ID	24	—	—	BELL	0000 1000 0101 0011 0000 1100
Message type identifier	8	1 to 101	1	11	0000 1011
Message length	8	10 to 222 bytes	1 byte	49	0011 0001
Message (Type 11 example)					
Modified Z-count	14	0 to 1 199.9 s	0.1 s	100 s	00 0011 1110 1000
Additional message flag	2	0 to 3	1	0	00
Number of measurements	5	0 to 18	1	5	0 0101
Measurement type	3	0 to 7	1	C/A L1	000
Ephemeris Decorrelation Parameter (P_D)	8	0 to 1.275 $\times 10^{-3}$m/m	5×10^{-6}m/m	1×10^{-4}	0001 0100
Measurement Block 1					
Ranging source ID	8	1 to 255	1	12	0000 1100
Pseudo-range correction (PRC_{30})	16	±327.67 m	0.01 m	+1.04 m	0000 0000 0110 1000
Range rate correction (RRC_{30})	16	±32.767 m	0.001 m/s	–0.18 m/s	1111 1111 0100 1100
$\sigma pr\_gnd,D$	8	0 to 5.08 m	0.02 m	0.96 m	0011 0000
$\sigma pr\_gnd,30$	8	0 to 5.08 m	0.02 m	1.00 m	0011 0010
Measurement Block 2					
Ranging source ID	8	1 to 255	1	4	0000 0100
Pseudo-range correction (PRC_{30})	16	±327.67 m	0.01 m	–1.08 m	1111 1111 1001 0100
Range rate correction (RRC_{30})	16	±32.767 m	0.001 m/s	+0.18 m/s	0000 0000 1011 0100
$\sigma_{pr\_gnd,D}$	8	0 to 5.08 m	0.02 m	0.24 m	0000 1100
$\sigma_{pr\_gnd,30}$	8	0 to 5.08 m	0.02 m	0.6 m	0001 1110
Measurement Block 3					
DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
Ranging source ID	8	1 to 255	1	2	0000 0010
Pseudo-range correction (PRC_{30})	16	±327.67 m	0.01 m	+1.2 m	0000 0000 0111 1000
Range rate correction	16	±32.767 m	0.001 m/s	0.3 m/s	0000 0001 0010 1100

(RRC$_{30}$)					
$\sigma_{pr\_gnd,D}$	8	0 to 5.08 m	0.02 m	0.64 m	0010 0000
$\sigma_{pr\_gnd,30}$	8	0 to 5.08 m	0.02 m	0.74 m	0010 0101
Measurement Block 4					
Ranging source ID	8	1 to 255	1	23	0001 0111
Pseudo-range correction (PRC$_{30}$)	16	±327.67 m	0.01 m	−2.64 m	1111 1110 1111 1000
Range rate correction (RRC$_{30}$)	16	±32.767 m	0.001 m/s	−0.51 m/s	1111 1110 0000 0010
σpr_gnd,D	8	0 to 5.08 m	0.02 m	0.08 m	0000 0100
σpr_gnd,30	8	0 to 5.08 m	0.02 m	0.14 m	0000 0111
Measurement Block 5					
Ranging source ID	8	1 to 255	1	122	0111 1010
Pseudo-range correction (PRC$_{30}$)	16	±327.67 m	0.01 m	+0.8 m	0000 0000 0101 0000
Range rate correction (RRC$_{30}$)	16	±32.767 m	0.001 m/s	−0.25 m/s	1111 1111 0000 0110
$\sigma_{pr\_gnd,D}$	8	0 to 5.08 m	0.02 m	0.92 m	0010 1110
$\sigma_{pr\_gnd,30}$	8	0 to 5.08 m	0.02 m	1.08 m	0011 0110
Message Block CRC	32	—	—	—	0010 1111 0000 0101 1101 1001 0000 1100
APPLICATION FEC	48	—	—	—	1001 0011 1110 0111 1101 1100 0100 0001 0100 0101 1011 1110
Input to the bit scrambling (Note 2)	0 47 60 1A 55 30 CA 10 D0 8C 17 C0 A0 28 30 16 00 32 FF 0C 4C 20 29 FF 2D 00 30 78 40 1E 00 34 80 04 A4 E8 1F 7F 40 7F 20 E0 5E 0A 00 60 FF 74 6C 30 9B A0 F4 7D A2 82 3B E7 C9				
Output from the bit scrambling (Note 3)	0 61 57 92 1F 2F D2 3B 0F 16 C2 19 92 F4 76 C6 F6 F3 B6 0F 50 24 06 0F 47 BF 56 2C C8 D0 1E DC A9 64 C7 97 64 2B E4 B1 51 F7 1D C1 05 7B 0C AE D6 E9 3D 7D 7D 50 41 10 BE 21 C4				
Fill bits	0 to 2	—	—	0	
Power ramp-down	9	—	—	—	000 000 000
D8PSK Symbols (Note 4)	00000035 11204546 31650101 42701130 13067746 60457114 40234621 31760262 76357705 07725551 13760416 17615700 43341354 25047116 53736646 34577501 64015223 34742121 71757170 16162053 65544366 41033007 777				

Notes.—

1. *The rightmost bit is the LSB of the binary parameter value and is the first bit transmitted or sent to the bit scrambler. All data fields are sent in the order specified in the table.*
2. *This field is coded in hexadecimal with the first bit to be sent to the bit scrambler as its MSB. The first character represents a single bit.*
3. *In this example, fill bits are not scrambled.*
4. *This field represents the phase, in units of $\pi/4$ (e.g. a value of 5 represents a phase of $5\pi/4$ radians), relative to the phase of the first symbol.*

...

7.19 Airborne processing for GBAS approach service types

Note.— In order to ensure the required performance and functional objectives for GAST D are achieved, it is necessary for the airborne equipment to meet defined performance and functional standards. The relevant minimum operational performance standards (MOPS) are detailed in RTCA DO-253D.

...

7.19.1 *Differential position solution for the GBAS positioning service.* The position solution used to provide position, velocity and time outputs is based on 100-second smoothed pseudo-ranges corrected with corrections obtained from message Type 1 or message Type 101.

7.19.2 *Differential position solution for approach service GAST A, B and C.* When the active approach service type is A, B or C, the position solution used to generate deviations is based on 100 second smoothed pseudo-ranges corrected with corrections obtained from message Type 1 or message Type 101. The projection matrix, S, used to compute the position solution (Appendix 6B, 3.6.5.5.1.1.2) is computed based on σ_i computed using $\sigma_{pr\_gnd}[i]$ from message Type 1 or message Type 101 and $\sigma_{iono,i}$ based on $\sigma_{vert\_iono\_gradient}$ from message Type 2.

7.19.3 *Differential position solutions for approach service GAST D.* When GAST D is the active approach service type, the airborne equipment will compute two different position solutions, one based on 30-second smoothed pseudo-ranges and the other based on 100-second smoothed pseudo-ranges. The following characterizes the standard processing required by the MOPS:

a) the position solution used to develop deviations is based on 30-second smoothed pseudo-ranges corrected with corrections obtained from message Type 11;

b) the projection matrix, S, used for both position solutions is computed based on $\sigma_{w,i}$ computed using $\sigma_{pr\_gnd\_30s}$ from message Type 11 and $\sigma_{iono,i}$ based on $\sigma_{vert\_iono\_gradient\_D}$ from message Type 2 Additional Data Block 3;

c) a second position solution is computed using the projection matrix from b) and the 100-second smoothed pseudo-ranges corrected with corrections obtained from message Type 1; and

d) both position solutions are based on the same set of satellites as used for the position solution defined in a) above.

Additional information regarding the intended use of these dual position solutions is given in 7.5.6.1 of this attachment.

7.20 Type 11 message

A Type 11 message is required for FAST D ground subsystems. The Type 11 message contains differential corrections derived from pseudo-range data that has been carrier smoothed with a time constant of 30 seconds. The Type 11 message also includes alternative parameters for integrity bounding and for optimal weighting of measurements. Additional information regarding the standard processing of parameters in the Type 11 message is given in 7.19.

7.21 Slot occupancy

The slot occupancy requirement in Appendix 6B, 3.6.7.4.1.3 is for ground subsystems that support authentication. The slot occupancy is the length of a burst divided by the length of a single time slot. In more detail and expressed in number of bits:

slot occupancy = (88 bits + up to 1 776 bits application data + 57 to 59 bits for application FEC, fill bits and ramp down) / 1 968.75 bits

The numerator in the formula sums all bits that are included in a single burst of the ground subsystem. These are the first 88 bits from ramp up to training sequence FEC, up to 1 776 application data bits, 48 application FEC bits, 0 to 2 fill bits and 9 bits for ramp down. For the denominator 1 968.75 bits are the calculated number of bits that can be transmitted in 62.5 ms (Appendix 6B, 3.6.3.1) using the data rate of 31 500 bits/s (Appendix 6B, 3.6.2.5).

8. SIGNAL QUALITY MONITOR (SQM) DESIGN

8.1 The objective of the signal quality monitor (SQM) is to detect satellite signal anomalies in order to prevent aircraft receivers from using misleading information (MI). MI is an undetected aircraft pseudo-range differential error greater than the maximum error (MERR) that can be tolerated. For GAST D equipment, additional requirements are in place to assure detection before the differential pseudo-range error reaches a specified value (see Appendix 6B, 3.6.7.3.3). These large pseudo-range errors are due to C/A code correlation peak distortion caused by satellite payload failures. If the reference receiver used to create the differential corrections and the aircraft receiver have different measurement mechanizations (i.e. receiver bandwidth and tracking loop correlator spacing), the signal distortion affects them differently. The SQM must protect the aircraft receiver in cases when mechanizations are not similar. SQM performance is further defined by the probability of detecting a satellite failure and the probability of incorrectly annunciating a satellite failure.

. . .

8.11.4.2 For GBAS airborne equipment class D (GAEC D) receivers using early-late correlators and tracking GPS satellites, the precorrelation bandwidth of the installation, the correlator spacing and the differential group delay are within the ranges defined in Table D-11, regions 2, 3 or 4 only. In addition, in region 2 the range of average correlator spacing is 0.045 – 0.12 chips, and the instantaneous correlator spacing is 0.04 – 0.15 chips.

8.11.4.3 For SBAS airborne equipment using early-late correlators and tracking GPS satellites, the precorrelation bandwidth of the installation, the correlator spacing and the differential group delay (including the contribution of the antenna) are within the ranges of the first three regions defined in Table D-11.

...

8.11.5.1 For GBAS airborne equipment class D (GAEC D) aircraft receivers using early-late correlators and tracking GLONASS satellites, the precorrelation bandwidth of the installation, the correlator spacing, and the differential group delay are within the ranges as defined in Table D-12, regions 2 and 3 only. In addition, in region 2 the range of average correlator spacing is 0.05 – 0.1 chips, and the instantaneous correlator spacing is 0.045 – 0.11 chips.

...

8.11.6.1 For GBAS airborne equipment class D (GAEC D) receivers using double-delta correlators and tracking GPS satellites, the precorrelation bandwidth of the installation, the correlator spacing and the differential group delay are within the ranges defined in Table D-13, regions 2 and 3 only.

...

8.11.7.1 For GBAS airborne equipment class D (GAEC D) receivers using the early-late or double-delta correlators and tracking SBAS satellites, the precorrelation bandwidth of the installation, the correlator spacing and the differential group delay are within the ranges defined in Table D-14, region 2 only. In addition, for GAEC D receivers using early-late correlators and tracking SBAS satellites, the average correlator spacing is 0.045 – 0.12 chips, and the instantaneous correlator spacing is 0.04 – 0.15 chips.

. . .

12. GNSS PERFORMANCE ASSESSMENT

12.1 GNSS performance assessment is a periodic offline activity that may be performed by a State or delegated entity, aiming to verify that GNSS performance parameters conform to the relevant Annex 10 Standards. This activity can be done for the core constellation, the augmentation system or a combination of both.

Note.— Additional guidance material on GNSS performance assessment is provided in the Global Navigation Satellite System (GNSS) Manual *(Doc 9849).*

12.2 The data described in section 11 may also support GNSS performance assessment.

. . .

14. MODELLING OF RESIDUAL ERRORS

. . .

14.2 One method of ensuring that the protection level risk requirements are met is to define the model variance (σ^2), such that the cumulative error distribution satisfies the conditions:

$$\int_{y}^{\infty} f(x)dx \leq Q\left(\frac{y}{\sigma}\right) \text{ for all } \left(\frac{y}{\sigma}\right) \geq 0 \text{ and}$$

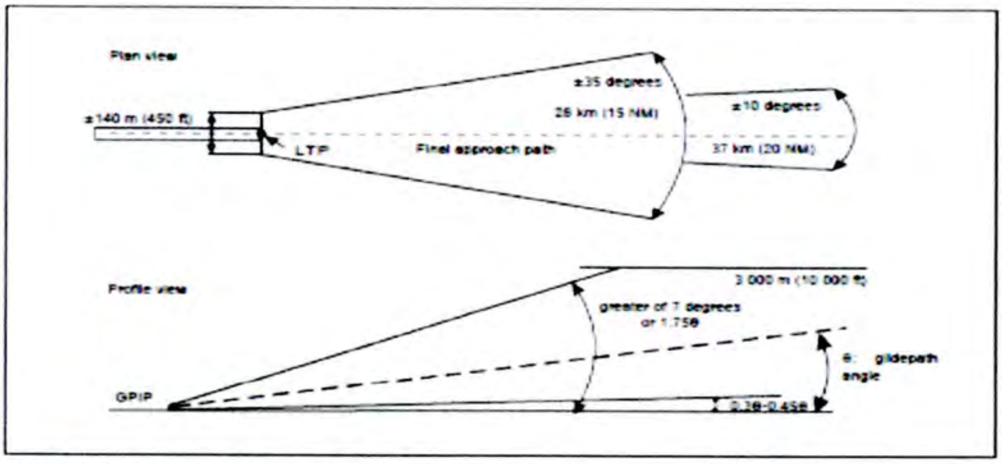
$$\int_{-\infty}^{-y} f(x)dx \leq Q\left(\frac{y}{\sigma}\right) \text{ for all } \left(\frac{y}{\sigma}\right) \geq 0 \text{ and}$$

where

f(x) = probability density function of the residual aircraft pseudo-range error component; and

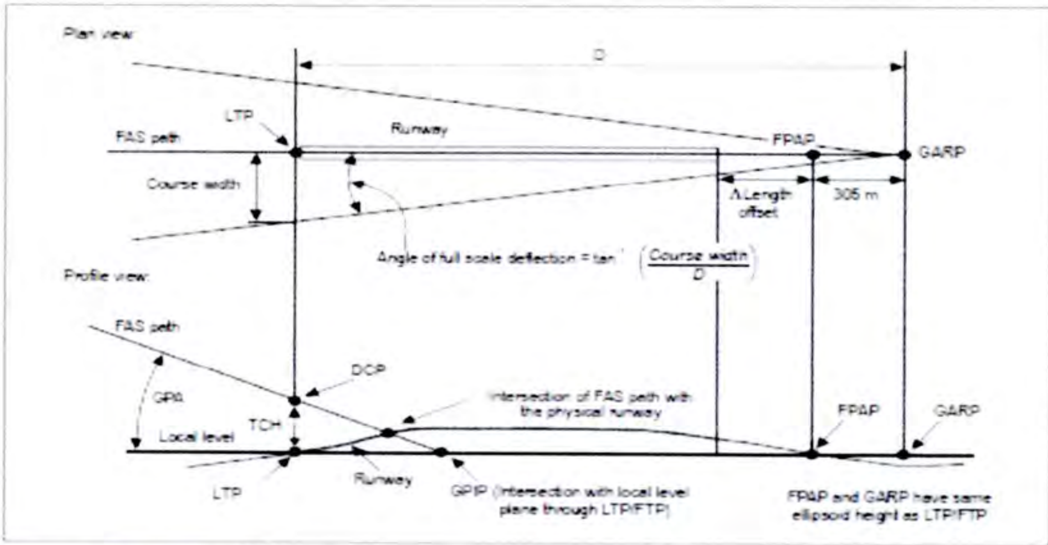
$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_{x}^{\infty} e^{-\frac{t^2}{2}}\, dt.$$

. . .



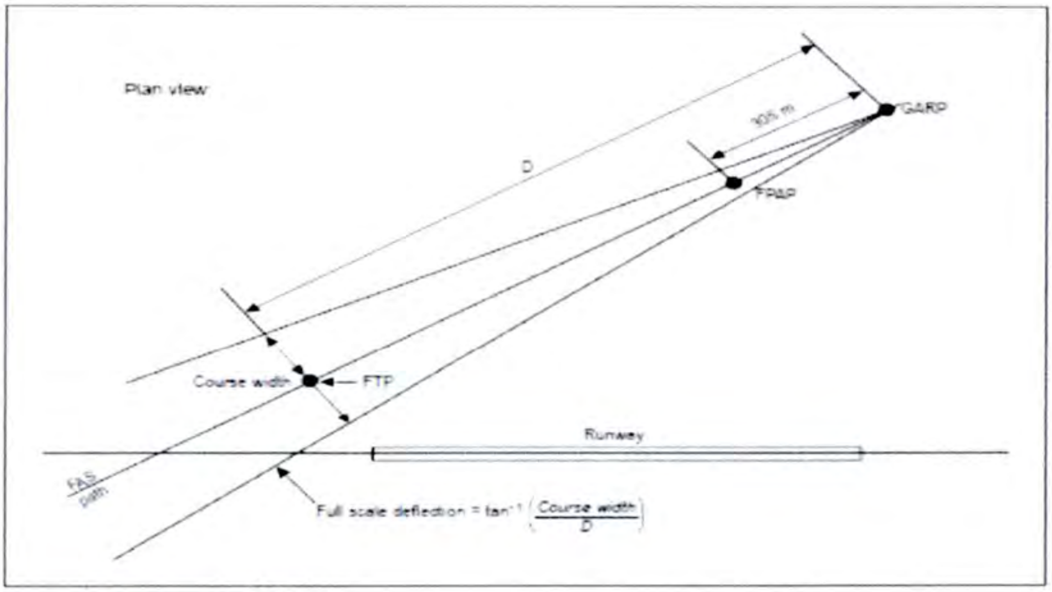
GPIP — glide path intersection point
LTP — landing threshold point

Figure D4. Minimum GBAS service volume



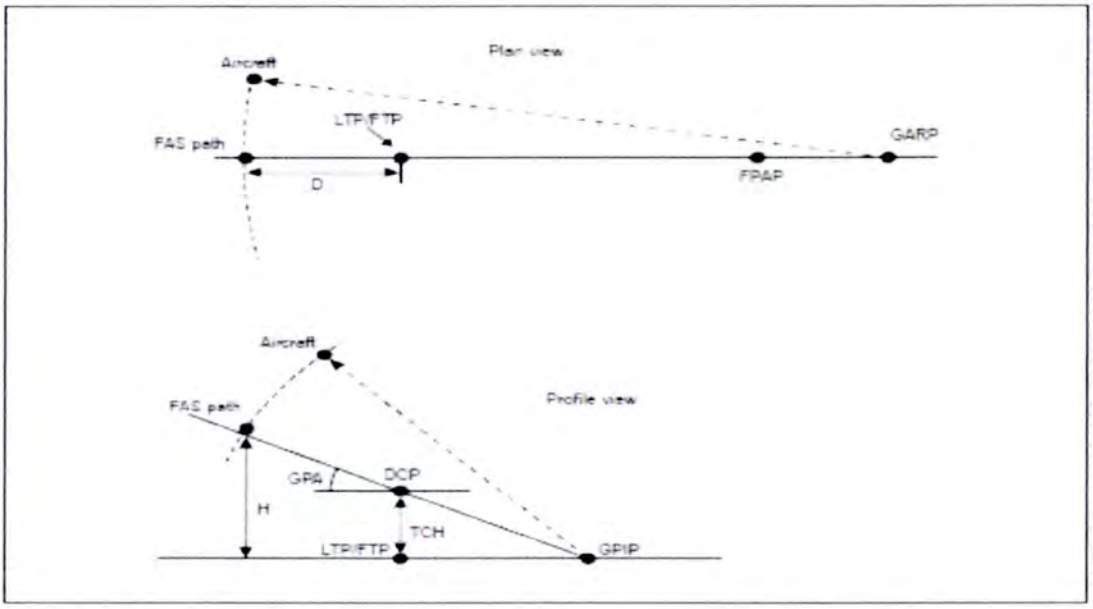
DCP — datum crossing point
FAS — final approach segment
FPAP — flight path alignment point
FTP — fictitious threshold point (see Figure D-7)
GARP — GNSS azimuth reference point
GPA — glide path angle
GPIP — glide path intersection point
LTP — landing threshold point
TCH — threshold crossing height

Figure D-6. FAS path definition



FAS — final approach segment
FPAP — flight path alignment point
FTP — fictitious threshold point
GARP — GNSS azimuth reference point

Figure D-7. FAS path definition for approaches not aligned with the runway



DCP — datum crossing point
FAS — final approach segment
FPAP — flight path alignment point
FTP — fictitious threshold point (see Figure D-7)
GARP — GNSS azimuth reference point
GPA — glide path angle
GPIP — glide path intersection point
LTP — landing threshold point
TCH — threshold crossing height

Figure D-8. Definition of D and H parameters in alert limit computations

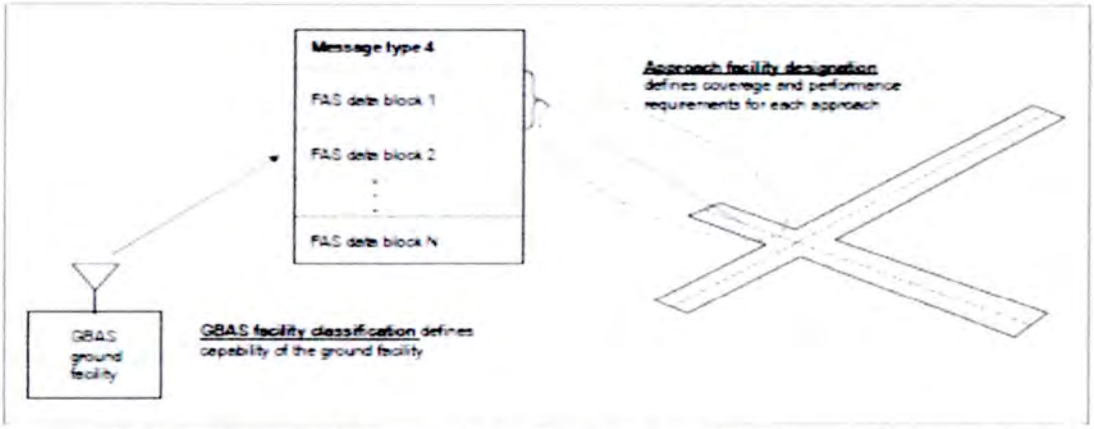


Figure D-10 Relationship between GBAS facility classification and approach facility designation

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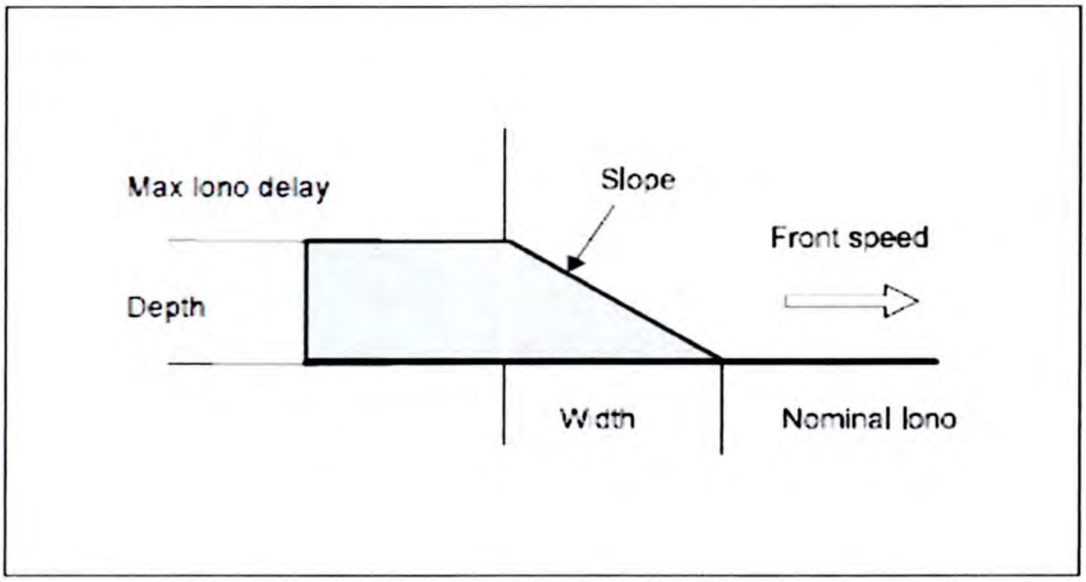

Figure D-11. Moving wedge ionospheric anomaly model

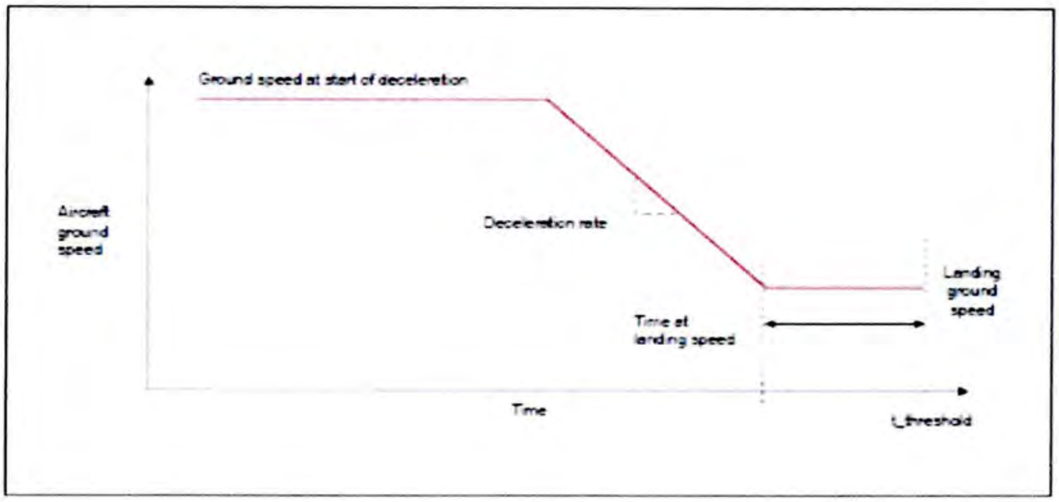

Figure D-12. Aircraft speed profile model

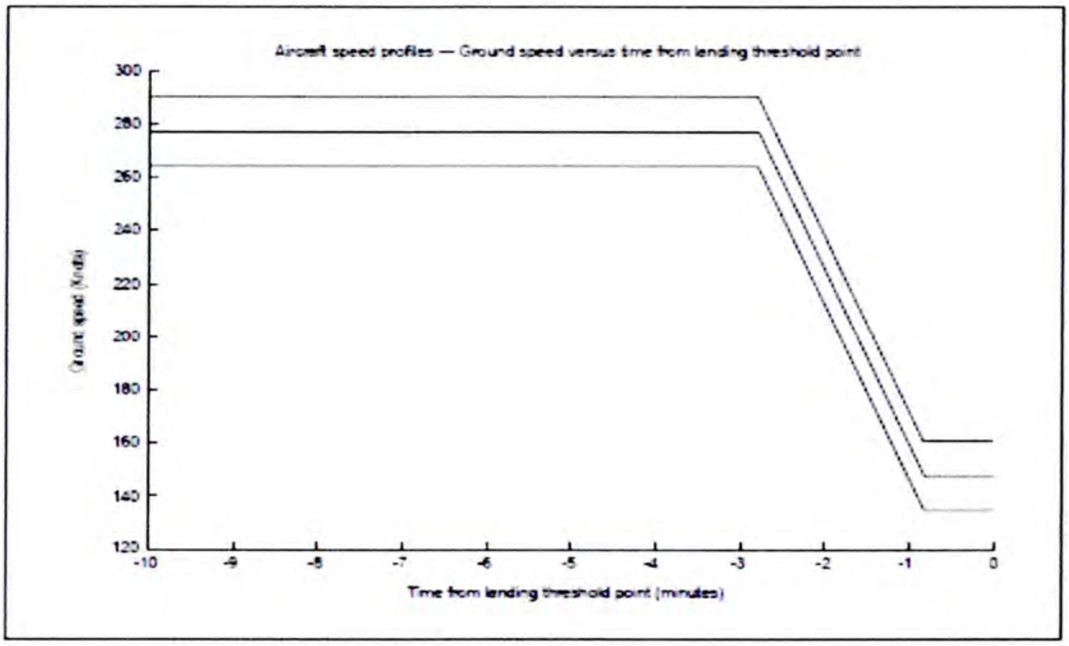

Figure D-13. Family of aircraft speed profiles

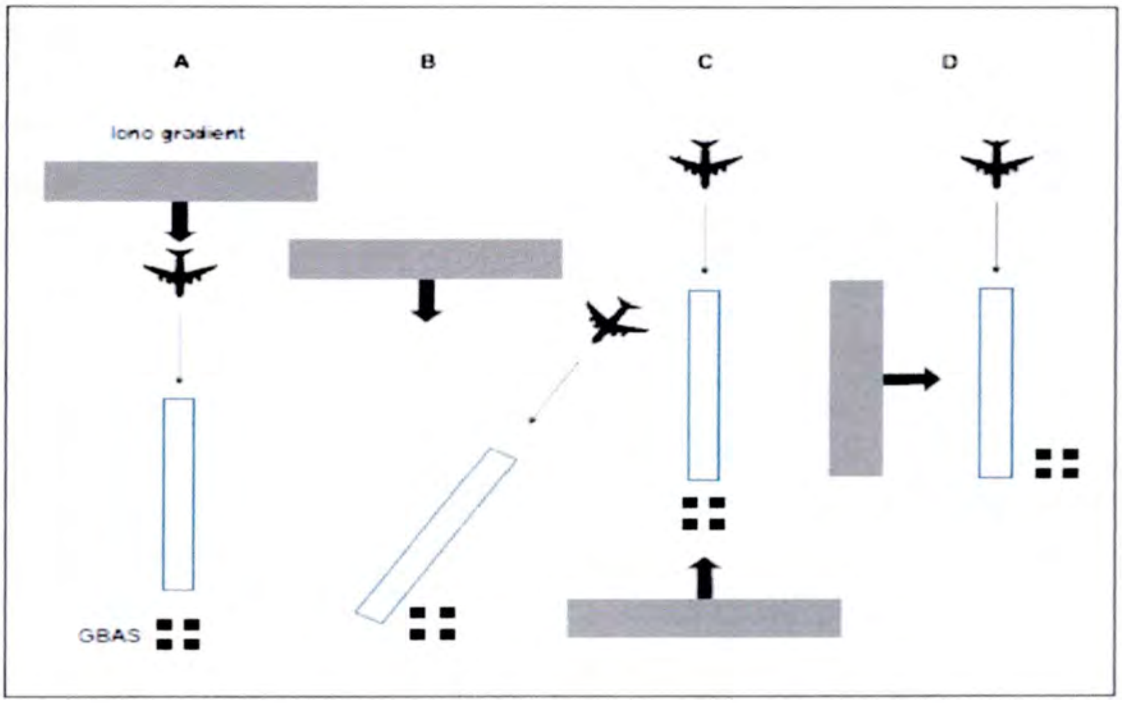

Figure D-14. Ionospheric gradient air/ground/approach orientations

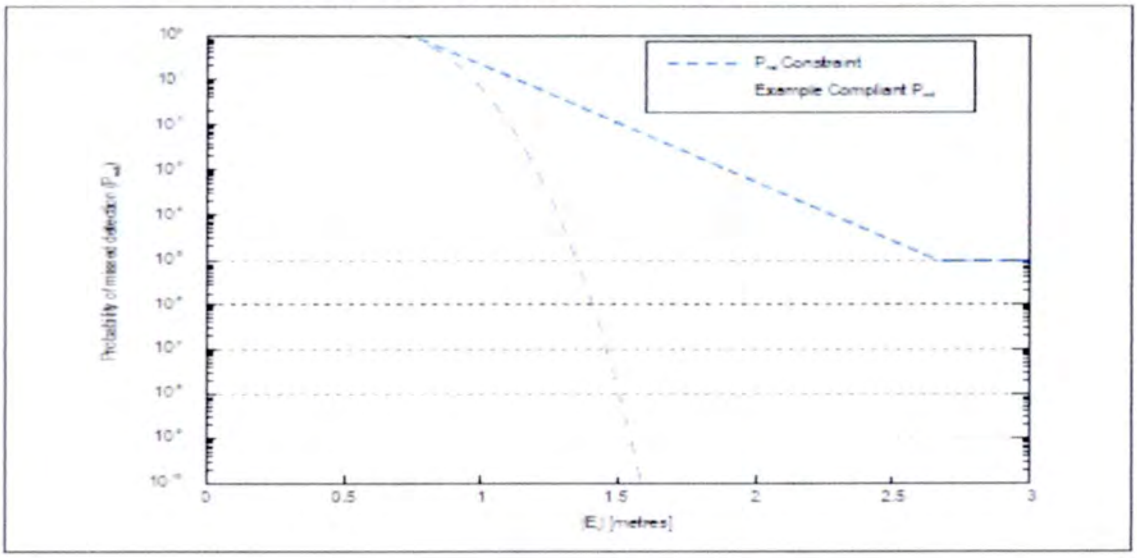

Figure D-15. Example P_{md_limit} constraint region

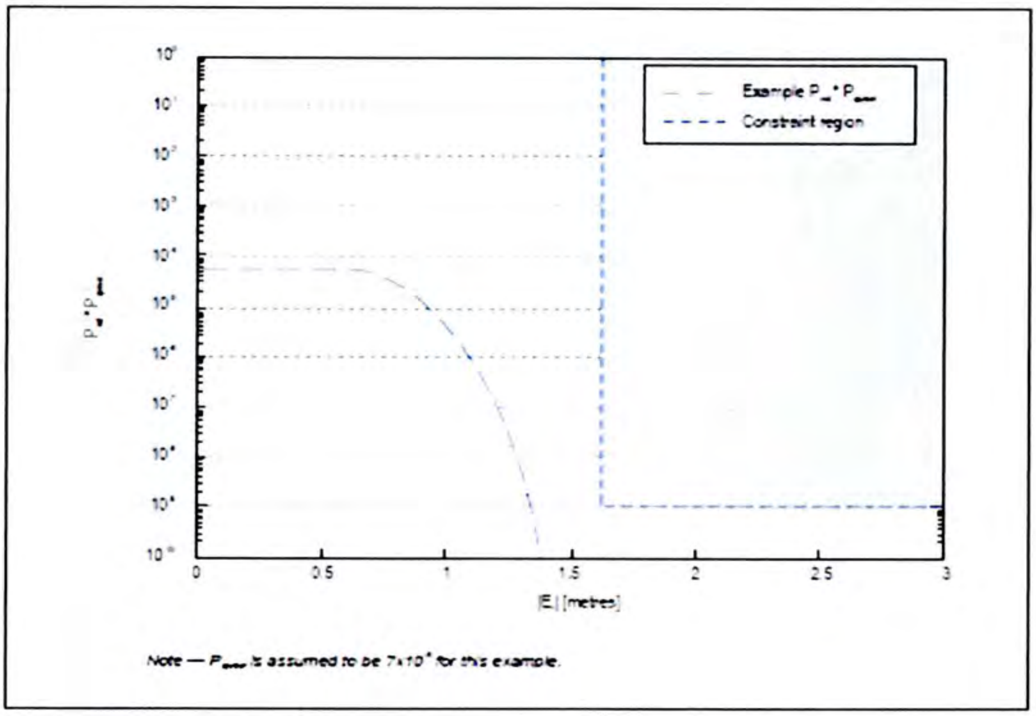

Figure D-16. Example P_{md_limit} constraint with a priori probability

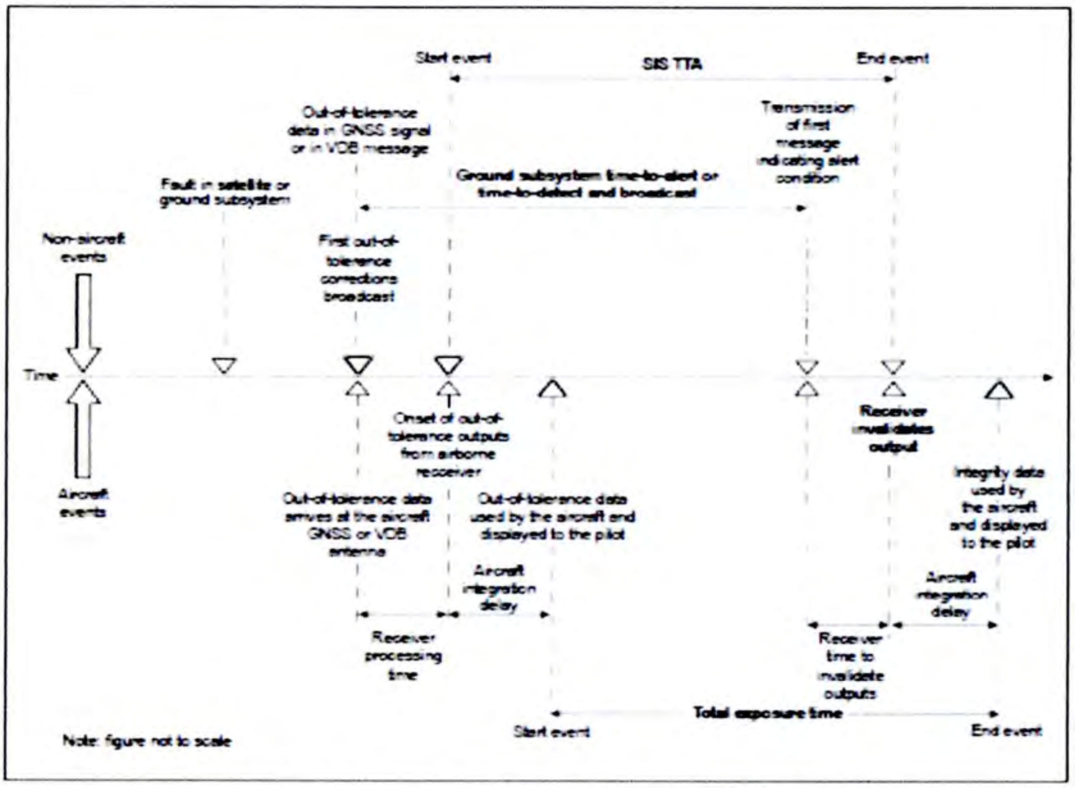

Figure D-17. Nominal GBAS time-to-alert illustration

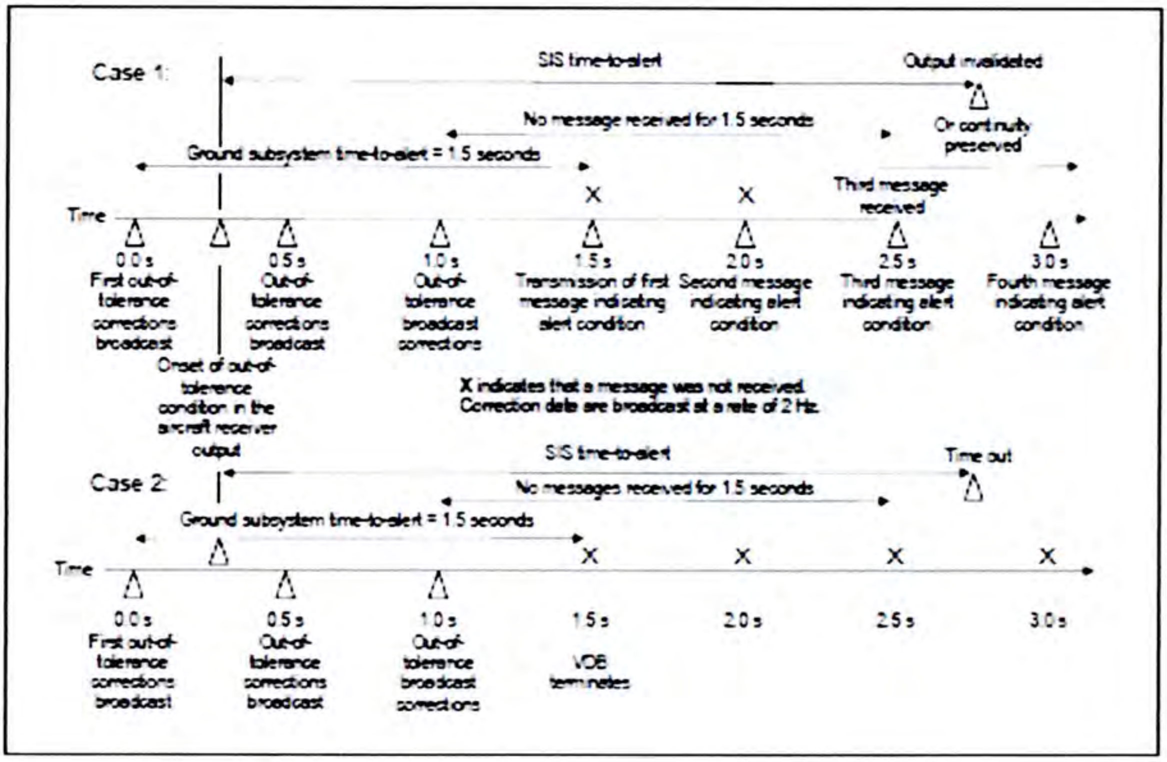

Figure D-18. Effect of missed messages on the GAST D GBAS time-to-alert below 200 ft
Case 1 describes the situation for missed messages, Case 2 the one for VDB termination

---END—

i. ***Separability Clause.*** - If, for any reason, any provision of this Memorandum Circular is declared invalid or unconstitutional, the other part or parts thereof which are not affected thereby shall continue to be in full force and effect.

ii. ***Repealing Clause.*** - All orders, rules, regulations and issuances, or parts thereof which are inconsistent with this Memorandum Circular are hereby repealed, superseded or modified accordingly.

iii. ***Determination of changes.*** – To highlight the amendments and/or revisions in the Memorandum Circular, the deleted text shall be shown with strikethrough and the new inserted text shall be highlighted with grey shading, as illustrated below:

1. Text deleted: ~~Text to be deleted is shown with a line through it.~~
2. New text inserted: New text is highlighted with grey shading.
3. New text replacing existing text: ~~Text to be deleted is shown with a line through it~~ followed by the replacement text which is highlighted with grey shading.

iv. ***Effectivity Clause.*** - This Memorandum Circular shall take effect after fifteen (15) days following the completion of the publication in a requisite single newspaper of general circulation or the Official Gazette and a copy filed with the U.P. Law Center - Office of the National Administrative Register.

So Ordered. Signed this 13 day of FEB 2020, at the Civil Aviation Authority of the Philippines, MIA Road, Pasay City, Metro Manila, 1301.

CAPTAIN JIM C. SYDIONGCO
Director General