U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

ORDER 6884.1

Effective Date:
12/15/2010

SUBJ: Siting Criteria for Ground Based Augmentation System (GBAS)

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1. This order establishes procedures for determining, evaluating and approving the siting required to install a Ground Based Augmentation System (GBAS) Ground Facility.

2. Title Terminology - The Federal Aviation Administration' (FAA's) Local Area Augmentation System (LAAS), is also referred to as Ground Based Augmentation System (GBAS) in the international standards documents. GBAS will be used in this document. For the purpose of this document, the terms LAAS and GBAS can be considered interchangeable.

3. GBAS Siting Flexibility - The GBAS transmits a signal that carries a series of approach paths, and correction messages to the aircraft. The GBAS uses an omni directional antenna to transmit the message. GBAS is not fixed by function (e.g., proximity to runway centerline). This increases the siting location options and potentially reduces the need for an extensive site preparation effort typically associated with ground-based precision approach and landing systems. Other constraints are applicable to the installation and this order provides the information necessary to properly site the GBAS antennas.

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Vice President, Technical Operations Services

Distribution: Selected Air Traffic Organization Offices; A-W(AS/FS)-2; AST-1 (2 Copies); A-X(AS/FS)-2; A-FAF-0 (STD)

Initiated By: AJW-91

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Chapter 1 General Information

1. Purpose of This Order.

This Order provides guidance to engineering personnel engaged in the siting of the Federal Aviation Administration (FAA) Ground Based Augmentation System (GBAS) Ground Facility. The criteria contained in this document, along with requisite information collected during site visits and review of relevant equipment documentation, will enable the engineer to select the optimum siting of the GBAS Ground Facility to support precision approach procedures. The GBAS siting shall be in accordance with requirements specified in this order In addition, the document provides:

- Installation requirements.
- Facility requirements for the installation.
- Requirements for maintaining the areas around the antennas associated with the GBAS Ground Facility.

2. Audience.

Federal Aviation Administration (FAA) personnel responsible for the installation or approval of GBAS. This document provides information on GBAS components and expected configurations. It can also be used as a template for the development of the Siting Plan.

3. Where Can I Find This Order.

You can find this order on the Directives Management System (DMS) website: https://employees.faa.gov/tools_resources/orders_notices/.

4. Distribution.

This order is distributed in headquarters to director level in all Air Traffic Organization service units under the Senior Vice President for Operations; to group level in the Technical Operations Safety and Operations Support, Aviation System Standards, and Navigation Services directorates; to the Associate Administrator for Commercial Space Transportation; to division level in the Office of Airport Safety and Standards and the Flight Standards Service; to group level in the Technical Operations Service Areas and the Service Centers; to division level in the regional Airports and Flight Standards divisions; and to all Technical Operations field offices with a standard distribution.

5. Perquisites for Users of this Order.

The Order assumes that the reader has an engineering background and knowledge of the operating principles of GBAS and the GBAS Ground Facility. Additionally, this Order does not attempt to duplicate all information found in other applicable FAA documents. The user is expected to have access to and a working knowledge of those documents found in Chapter 1, Paragraph 6, Applicable Documents. The information and procedures described in this Order present methods for siting a GBAS Ground Facility.

6. Applicable Documents.

The following documents form a part of this specification to the extent specified herein.
In the event of conflict between the documents referenced herein and the contents of this specification, this document shall be considered a superseding requirement.

	Document Number	Title
[1]	FAA-E-3017	Non-Federal Specification Category I Local Area Augmentation System Ground Facility
[2]	FAA Order 8260.3	United States Standard for Terminal Instrument Procedures (TERPS)
[3]	Title 14 CFR Part 77	Title 14, Aeronautics and Space, Code of Federal Regulations (CFR), Part 77, Objects Affecting Navigable Airspace
[4]	Series 150 Advisory Circulars (AC) 150/5300-13	Advisory Circular, Airport Design
[5]	FAA Form 7460-1	Airway Notice of Proposed Construction or Alteration
[6]	DO-245A	Minimum Aviation System Performance Standards for Local Area Augmentation System (LAAS) [MASPS]
[7]	Advisory Circular 150/5340-1	Standards for Airport Marking, Marking of Paved Areas on Airports, for marking information
[8]	FAA Order 6950.2	Electrical Power Policy Implementation At National Airspace System Facilities

	Document Number	Title
[9]	FAA Order 5050.4	National Environmental Policy Act [NEPA] Implementing Instructions for Airport Projects
[10]	DO-246D	GNSS-Based Precision Approach Local Area Augmentation System (LAAS) Signal-in-Space Interface Control Document [ICD]

7. Application.

The criteria set forth in this Order apply only to new establishments or relocated facilities. Changes to existing facilities for the sole purpose of obtaining compliance with these criteria are not required.

8. Directive Verbs.

The material in this Order contains FAA criteria, policy, recommended practices, and other guidance material that require the use of certain directive verbs such as must, shall, should, will, and may. In this Order, the explicit meaning of the verbs is as follows:

- **Must** – The action is mandatory. For example: "Obstacle clearance requirements must be met in accordance with the United States Standard for Terminal Area Procedures (TERPS)."
- **Shall** – The action is mandatory. It is used for mandatory requirements with measurable results.
- **Should** – The action is desirable. For **example**: "Proximity of site access roads should be considered.
- **Will** – The action is to be taken in the future. For example: "The site survey will be conducted to provide quantitative data on the candidate sites chosen during the initial site selection process."
- **May** – The action is permissible. For example: "The site survey flight check may be necessary in difficult siting environments to assess the coverage volume impact of obstructions and terrain."

9. Safety.

Personnel should use caution in working on GBAS Ground Facility equipment, particularly radio transmitters, since the voltages presented are dangerous to life. Observance of precautions necessary to avoid electrical shock is the direct responsibility of the individual. No one should perform work on the equipment without full knowledge of the dangers involved. An individual should not attempt work on high-voltage circuits without the services of an assistant. The standards and tolerances for the GBAS Ground Facility are contained in the Commercial Instruction Book (CIB) generated by the equipment manufacturer.

10. Physical Requirement Considerations.

The location of the electronic systems should be considered when making the GBAS siting selection. The size of the airport needs to be considered so that coverage is provided to the entire airport. Siting within restricted areas should only be considered when standard installations are not practical.

a. Equipment Type and Configuration Considerations. Equipment type and configuration used in GBAS establishments should be carefully chosen for the environment in which it is installed. Consideration should be given not only to siting the GBAS Ground Facility equipment to account for current terrain, obstructions, etc., but also for airport expansion and other developments around the airport environment. See Chapter 3, Paragraph 2.a Initial Data Acquisition.

b. Key Factor 1. The GBAS system components need to be installed in a secure area. In general terms, this is usually the Airport Operations Area (AOA) of a given airport. For additional information, see Chapter 4, Paragraph 6, Equipment Siting Considerations.

c. Key Factor 2. The transmitting antenna, part of the Very High Frequency (VHF) Data Broadcast (VDB) Subsystem, should be within 3 nautical miles (NM) (3 kilometers) of the runway thresholds for which the system is providing service . For additional information, see Chapter 5, Paragraph 3.f (2), Location with Respect to Runway Threshold.

d. Key Factor 3. The 4 GBAS receive antennas as a group, arranged on a given area of land, will have a mathematical virtual center point that is referred to as the centroid. This centroid should be within 3.2 Nautical Miles (NM) (6 Kilometers) of any desired Decision Height (DH) points (measured at ground level). For additional information, see Chapter 3, Paragraph 3.c , RRA Centroid to DH Distance.

e. Key Factor 4. The VDB Antenna (VDBA) max field strength exclusion region must not exceed 656 feet (200 meters) in radius. For conservative siting, measures should be taken to site the VDBA 656 feet (200 meters) from any operational aircraft venues. These areas generally include runways, taxiways, and ramps. This Radio Technical Commission for Aeronautics (RTCA)/FAA requirement exists to preclude overdriving GBAS avionics. For additional information see Chapter 5, Paragraph 3 f (2) Maximum Field Strength.

f. Key Factor 5. The GBAS Reference Receiver antenna siting is flexible. See Chapter 5, Paragraph 2, Reference Receiver Siting for guidance.

g. Siting Criteria Deviations. If in the process of planning or locating a GBAS Ground Facility, it is determined that the siting criteria set forth in this Order cannot be followed, the deviation shall be documented in the facility approval documentation.

11. GBAS Components as Obstructions.

The siting engineer considers the effects of the GBAS Ground Facility components themselves as obstructions. These considerations should include guidance given in: Order 8260.3, United States Standard for Terminal Instrument Procedures (TERPS), Title 14 CFR Part 77, Advisory Circulars AC 150/5300-13 and Airway Notice of Proposed Construction or Alteration FAA Form 7460-1. Both the Airport Division Office and Flight Procedures Office should be consulted and provide approval and/or waiver for any penetrations as part of the required airspace review. Failure to obtain approval or a waiver will preclude installation of that component.

12. National Airspace Systems Changes.

Siting a GBAS Ground Facility component shall not result in an adverse affect on existing or planned instrument procedures at the level of minima desired for the procedure(s). See Order 8260.3, United States Standard for Terminal Instrument Procedures and/or associated directives. AC 150/5300-13 provides a description of the obstruction clearance and protection surfaces (i.e. Obstacle Free Zone (OFZ), Runway Safety Area (RSA), Object Free Area (OFA)) on the airport. If it is not feasible to design and install a GBAS Ground Facility without penetrating these surfaces, a configuration control decision will be required, resulting in a NAS Change Proposal (NCP).

Chapter 2 GBAS System Description

1. System Overview.

a. The GBAS provides guidance to pilots of properly equipped aircraft to assist them in landing safely under Category (CAT) I weather conditions. The use of a GBAS materially aids the service to airports under all weather conditions.The GBAS is categorized according to the minimum visibility conditions under which aircraft landings are permissible. The criteria specified in this Order only apply to GBAS CAT I systems. The requirements for the CAT II / III systems are being validated. Once the validation is complete, this document will be revised as required.

b. GBAS is based on the concept known as Differential Global Positioning System (DGPS). In addition to application of basic DGPS concepts, the GBAS utilizes hardware and software to ensure accuracy, integrity, continuity, and availability to support precision approach, area navigation (RNAV), and surface operations.

c. GBAS consists of three primary subsystems:

- Space Segment
- Ground Subsystem
- Airborne Subsystem

An overview of the subcomponents of GBAS and their interaction is provided in Figure A-1 Ground Based Area Augmentation System (GBAS).

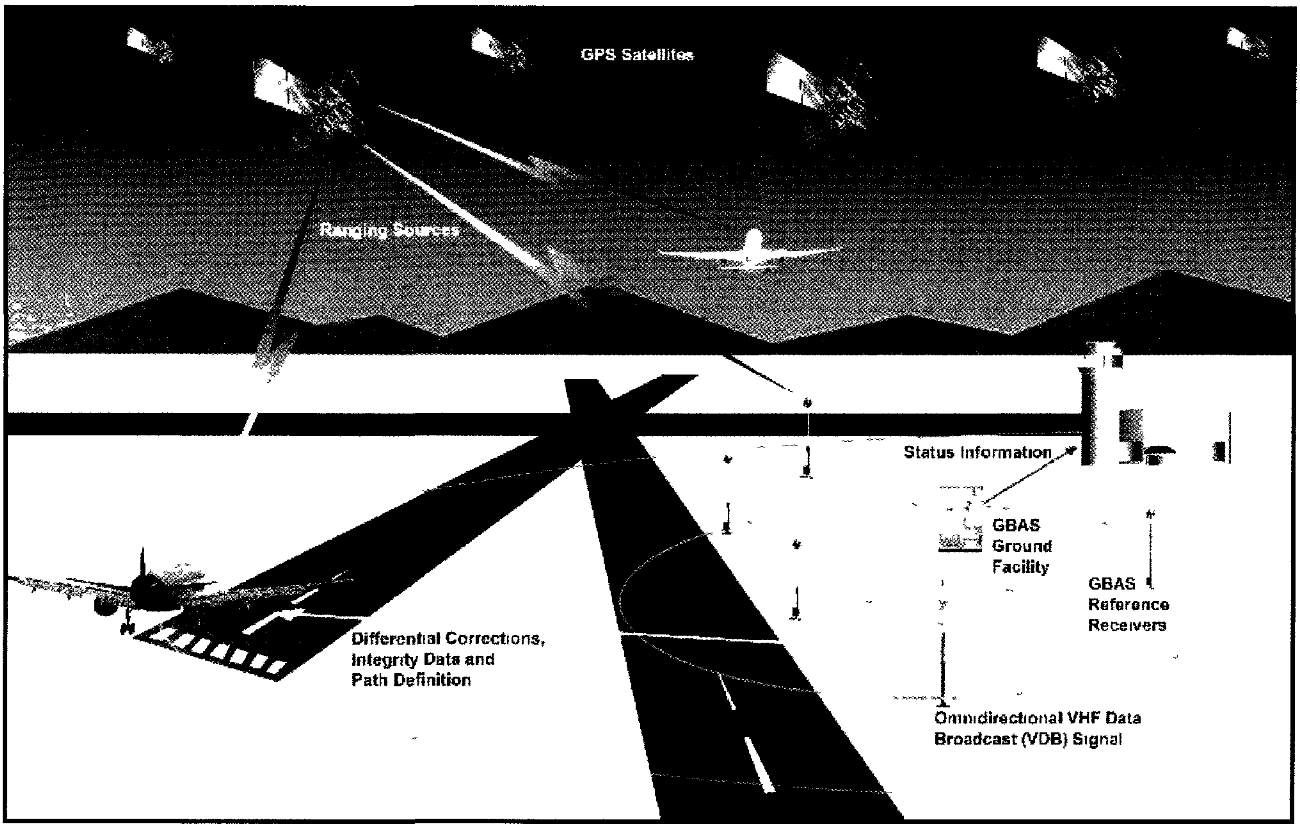

Figure A-1 Ground Based Area Augmentation System (GBAS)

d. The space segment consists of the GPS satellites, which transmit ranging signals and navigation messages to airborne receivers. The GPS signals are received by the ground station via a set of Reference Receiver (RR) Antennas (RRA's). The reference receivers decode the GPS signal to obtain the ranging source and navigation data for each of the satellites tracked. The Differential Corrections Processor (DCP) computes a pseudorange to the satellite, generates differential corrections for pseudoranges computed for GPS, performs integrity checks, and transmits corrections, integrity parameters, and path point data to the user via a Very High Frequency (VHF) Data Broadcast (VDB) transmitter/antenna. The GBAS Ground Facility employs multiple reference receivers to increase accuracy and provide integrity. The GBAS Ground Facility computes an average of the corrections from the multiple RR's and broadcasts this average correction to the user. This improves the accuracy of the correction over that of a single RR. The use of multiple reference receivers is also used to provide fault isolation by performing measurement consistency checks. These checks are performed through the computation of an integrity parameter termed a B-value. B-values are described in Appendix A, Paragraph 2..b, B-Values. .Differential GPS (DGPS) uses the commonality of measurement errors between the Ground Subsystem in a local area DGPS system such as GBAS; many errors are highly correlated between the Ground Subsystem and the Airborne Subsystem. The broadcast DGPS correction will not correct for errors which are uncorrelated between the Ground Subsystem and the Airborne Subsystem. These errors can be mitigated through other techniques including proper siting of the GBAS Ground Facility RRA's. These uncorrelated errors, if not mitigated through other techniques, introduce errors in the user position solution. These uncorrected errors are known as pseudorange correction errors. Following is a list of some of these uncorrected errors, which are uncorrelated between the air and ground and are not compensated by the uplinked correction factors alone.

- Multipath error observed at the GBAS Ground facility RRA's.
- Radio Frequency Interference (RFI) induced errors.
- Spatial decorrelation due to Ionosphere and Troposphere.
- Multipath error observed at the airborne GPS antenna.
- Surveying errors of the RRA's.
- Rare satellite signal anomalies (that cause dissimilar errors at the Ground Subsystem and the Airborne Subsystem when there are differences in receiver signal processing techniques).

e. The GBAS is designed to minimize the effect due to most of the aforementioned error sources. However, some of these error sources, such as multipath observed at the GBAS Ground Facility RRA, are site specific and their effect can be minimized using proper siting procedures The Airborne Subsystem also decodes the satellite navigation messages, applies the differential corrections transmitted from the GBAS Ground Facility to the satellite messages, computes a position solution and generates deviations based on the broadcast path point data. The Airborne Subsystem also computes an estimate of vertical and lateral position error based on the integrity parameters broadcast from the GBAS Ground Facility and the current satellite geometry.

2. GBAS Equipment Subsystems

The GBAS is composed of the following equipment:

- Reference Receiver Subsystem
- Processor Subsystem
- VHF Data Broadcast Subsystem
- Operations and Maintenance Subsystem
- Infrastructure / Ancillary Equipment

a. Reference Receiver Subsystem. The Reference Receiver Subsystem consists of a minimum of four Reference Receiver Stations (RRS) each containing a Reference Receiver (RR) and Reference Receiver Antenna (RRA). The RRS provides a weatherproof enclosure to protect the References Receiver (RR) and is mounted in close proximity to the Reference Receiver Antenna (RRA). In addition, the enclosure contains the power supply, and lightning protection circuits. The Reference Receiver Subsystem is responsible for providing 4 pseudorange measurements (typically) for each visible GPS satellite. It also provides basic health status of each satellite.

(1) Reference Receiver (RR). The Reference Receiver processes the Global Positioning System (GPS) signal from the RR and sends it to the processor Subsystem.

(2) Reference Receiver Antenna (RRA). The RRA is a Multipath Limiting Antenna (MLA). The MLA design minimizes GPS signal reflections that cause measurement errors.

b. Processor Subsystem. The Processor Subsystem consists of the GBAS Ground Facility processors that perform the correction computations, integrity processes, and message generation functions. The Processor Subsystem is housed in the Primary Equipment Shelter. The processors are mounted in a 19 inch wide rack. The Processor Subsystem is also responsible for critical safety and integrity monitoring of both incoming pseudorange and satellite status and outgoing correction data.

c. VDB Subsystem. The VDB Subsystem consists of the Primary VDB Subsystem (PVS) and any optional / required (also referred to as Additional) VDB Subsystem (AVS). The utilization of the two subsystem types is to allow for configurations that mitigate coverage-related siting issues. The GBAS Ground Facility design allows for multiple VDB configurations. The VDB configuration options are described in Appendix B, Subsystem Configurations.

(1) VDB Antenna. The VDB antenna is a VHF antenna (single or multi-bay) designed to reduce the gain pattern in the direction of the ground plane in order to minimize multipath. The antenna is located with line-of-sight to all approaches.

(2) VDB Electronic Equipment.A fully redundant set of VDB Electronic Equipment consists of two VHF transmitters, and two VDB monitor receivers. The equipment is housed in a single standard 19 inch wide rack.

d. Operations and Maintenance Subsystems. The Operations and Maintenance Subsystem includes the following equipment:

- Local Status Panel (LSP)
- Maintenance Data Terminal (MDT)
- Air Traffic Status Unit (ATSU)

(1) Local Status Panel (LSP). The LSP is physically located in the equipment cabinet. The LSP is mounted in a standard size 19 inch wide rack. The Local Status Panel provides visual and audible indicators of the system status. System mode and fault conditions are indicated via colored Light Emitting Diodes (LED's), with fault conditions also have audible indication.

(2) Maintenance Data Panel (MDT). The MDT is a typical laptop computer, and may be physically located with the GBAS equipment rack. The Operations and Maintenance Subsystem is responsible for *p*roviding an interface to operator and maintainers of the GBAS Ground Facility.

(3) Air Traffic Status Unit (ATSU). The ATSU provides an interface between the system and Air Traffic Controllers (ATC) with only the status of the system (there are no provisions for ATC to control the GBAS).

Chapter 3 Siting Procedures

1. GBAS Ground Facility Equipment Siting Overview.

Siting a GBAS Ground Facility involves finding suitable locations for the following major components:

- Reference Receiver Stations (RRS) - The RRS is comprised of a Reference Receiver (RR), Reference Receiver Antenna (RRA), and control and interface equipment. The RR and RRA are collocated.
- VDB transmitting equipment, processing equipment - The VDB transmitting equipment consists of a transmitter, antenna, and control and interface equipment. The VDB antenna may be located adjacent to the shelter housing the VDB transmitter. In complex locations the transmitter and VDB antenna may be located remotely from the shelter. The siting of multiple VDB transmitters and/or antennas may be required at difficult or complex sites. The GBAS processing equipment consists of the GBAS computers and interface equipment. The GBAS processing equipment will typically be sited in the GBAS equipment shelter although existing shelters or facilities may be used to house the processing equipment in some cases.
- Remote control and status units.

a. Reference Receiver Station Siting. The siting of the RRS involves finding suitable locations for the multiple RRA's. A minimum of four RRA's will be required to be installed at each GBAS installation. It may be determined during the site survey that an additional RRA is required to meet system performance requirements. In addition to installation of the designated equipment, the potential for upgrade of the GBAS in the foreseeable future, which may require the installation of additional RRA's, should be determined. There are two fundamental criteria for selecting a RRA location. The first criterion ensures sufficient real estate is available for installation of the RRA. The required real estate should take into account the minimum required separation distance between the RRA's. The second is the actual location. It should be free of sources of multipath and shadowing which may cause unacceptable degradation of the RRS performance. Having met these fundamental criteria, the next steps involve assessing the potential for designated critical areas to impact surface operations and evaluating the potential for Radio Frequency (RF) interference at the candidate RRA location. These topics are addressed in the following subsections. Selecting candidate RRA locations should take into consideration the feasibility and cost of routing electric, communication, and RF cables between the RR, RRA, and shelter. Further, the location of existing underground facilities (electric, communication, RF, gas, sewer, water lines, etc) should be determined and assessed to ensure that these will not be problematic.

(1) Separation Distance Criteria. Determining the minimum separation between the RRA's requires consideration of the following factors:

- RRA near-field boundary and / or the intermediate Local Object Consideration Area (LOCA) boundary.
- Mitigation of common multipath error sources.

b. Separation Distance – Depending on the equipment configuration to be deployed, the separation distance required to satisfy each of these factors may differ. Proper integrity monitoring requires that there are no common-mode (correlated) multipath error sources among the RRS or that the magnitude of such errors is controlled so that the system error budget is not violated. This statement does not mean that any single object cannot cause multipath at multiple RRA locations. It means that the characteristics of significant multipath error caused at multiple RRA locations at the same instance in time must be dissimilar. Ground reflections are always a potential source of correlated multipath errors. Similarly, a large building in close proximity to the RRA's has the potential to generate correlated multipath errors in certain instances. Since real-time detection of correlated multipath errors may be difficult to achieve during normal GBAS operations, application of the GBAS multipath model or data collection and analysis shall be performed to ensure suitability of the candidate RRA locations. Mitigation of the common-mode multipath problem in this case is achieved by both using a sufficient separation between RRA and selecting an appropriate RRA phase center height (PCH) or installing RRA's that provide significant rejection of ground reflections. Determining the RRA PCH to be used is addressed in Chapter 4, Paragraph 2, Antenna Phase Center Height (PCH) Considerations. For antennas that do not provide significant rejection of ground reflections, irregularities that may be present in the ground plane will result in decorrelation of the multipath error. In addition, separation should be provided between the RRA's to ensure that multipath from service vehicles and aircraft, for example, are not correlated at multiple RRA locations. In some instances, the use of a separation distance that is larger than the minimum distance determined by consideration of the above three factors may be required. For example, a larger separation may be required to satisfy critical area requirements such as, when two RRA's straddle a service road.

c. Remote Units – Air Traffic Status Unit (ATSU). The GBAS provides a status output intended for use by Air Traffic Control. A given airport may install an Air Traffic Status Unit (ATSU) to display this information, as required. This status output is available for connection to additional display interfaces as those systems develop.

d. VDB Transmitter Siting – There are two possible locations for the VDB transmitter. The transmitter could be located near the antenna and be connected to the GBAS processor via a data line or the transmitter could be located with the GBAS processor and coaxial cable used to supply RF to the antenna. The size of the enclosure will be dictated by the amount of equipment at the location and the required area around the equipment for service personnel. An existing equipment shelter may be used if available. If a new shelter must be installed, there are no specific requirements for its location. It should be located outside the GBAS Ground Facility Local Object Consideration Area (LOCA) where possible and as close to the transmit antenna as practical. Refer to Chapter 5, Paragraph 1 GBAS Ground Facility Local Object Consideration Areas (LOCA's) and c VDB Antenna Installation Consideration Area, for further information regarding LOCA. Transmission line losses will dictate the maximum distance from the antenna. Although the presence of fixed structures within the GBAS Ground Facility LOCA should be avoided, the impact of fixed structures should be analyzed through data analysis and/or math modeling. The GBAS Ground Facility configurations are described in Appendix B VDB SUBSYSTEM CONFIGURATION OPTIONS

e. Criteria for siting any one of these configurations is provided in this chapter. In addition, various GBAS components may need to be installed in a building or shelter. Criteria for determining if an existing building or shelter may be used, as well as criteria for installing a new equipment shelter, are provided.

f. Processor Siting. A location for housing the processing equipment will need to be identified. This equipment may be housed in an existing building, an existing equipment shelter, or a shelter may need to be installed. When considering the use of an existing building or shelter, the criteria contained in Chapter 5, Paragrph 2.c., VDB Antennna Installation Considerationscmust be applied to determine the minimum separation required between the building or shelter and each RRA. The required minimum separation of RRA's shall be assessed against the maximum length permitted for the communication cables running between the RR and the processing equipment. If the separation results in unacceptable cable lengths, an equipment shelter may be installed in a manner compliant with **Appendix B** VDB SUBSYSTEM CONFIGURATION OPTIONS

g. An alternative location for the processing equipment may be identified, or the location of the RRA may be adjusted when possible. Similarly, when the VDB transmitter is collocated with the VDB antenna, the required minimum separation of the VDB transmitter and the VDB antenna shall be assessed against the maximum length permitted for the communication cables running between the transmitter and processing equipment. The existing building or shelter shall have sufficient space available for housing the processing equipment. The availability of electrical power, cable access and routing, environmental control, and security shall be assessed when determining the suitability of the building or shelter.

2. Initial Site Inspection.

The purpose of the initial site visit is to better define the siting environment in order to perform comparative trade-off studies between potential sites. The data collected will include required service, terrain features, and potential sources of multipath and shadowing, land availability, proximity of power, environmental impact, and site access. This initial data collection should include an initial horizon profile (using a portable or handheld instrument such as clinometers) and a panoramic photograph at the proposed antenna sites. The initial phase of the project engineering is to gather information necessary to make informed decisions regarding initial site selection. The siting engineer should consult the cognizant authorities to obtain the required information. These authorities should include airport officials, Flight Standards, Air Traffic, Airports, and Technical Operations. The information gathered should include: The airport authority and terminal services should provide operational requirements (e.g. runways to be served, threshold/decision height locations), priorities, and specific equipment requirements related to status and control of the GBAS (e.g., number and location of status units) for the airport. This information will be used by the siting engineer to identify initial GBAS installation sites that lead to formal site surveys. The inputs to the initial site inspection are listed in Chapter 3, Paragraph 2.a Initial Data Acquisition.
The output of the initial site inspection is an Initial Site Assessment Report. As a minimum, the Initial Site Assessment Report includes:

- Results of the initial site inspection.
- Evaluation of the map and paper study.
- Evaluation of the following:
    - Availability of power.
    - Availability of communications lines.
    - Trenching considerations.
    - Site access.

a. Initial Data Acquisition. During the initial data gathering activities, the siting engineer meets with the airport authorities and other project stakeholders on the GBAS siting and installation plans. Prior to the site visit the documentation needed to assist in the initial site assessment needs to be obtained and reviewed. Prior to the site visit the siting engineer will request that the following information be made available

(1) Airport Layout Plan (ALP), including:

(a) Airport Property Lines
(b) Obstacle Free Zones (OFZ)
(c) Runway Safety Areas (RSA)
(d) Object Free Areas (OFA)
(e) Location of Navigational Aids
(f) Run-up and Jet blast areas
(g) All Building locations.
(h) Location of National Geodetic Survey (NGS) survey monuments, i.e. Primary Airport Control Stations (PACS) and Secondary Airport Control Stations (SACS).

(2) Airport Master Plan (5-10 year planning document).

(3) Airport Clearance Charts (Department of Commerce publication).

(4) Topographic Charts (U.S. Geological Survey publication) and aerial photographs of the airport and GBAS terminal service area.

(5) Locations of environmentally-sensitive areas within the Airport Operations Area (AOA).

(6) Description of existing Air Traffic Control (ATC) facilities, Navigation Aid (NAVAID) lighting and power sources.

(7) Airport conduit and cable information.

(8) Ground traffic patterns.

(9) Determination of the Landing Threshold Point (LTP) and minimum glide path (Flight Procedures Office (FPO).

(10) Visual Flight Rules (VFR) Terminal Area Chart.

(11) GBAS equipment configuration options and configuration-unique characteristics pertinent to siting.

(12) United States (U.S.) Instrument Approach Procedures (IAP's) defining existing and proposed approach procedures to the airport and identifying obstacles in the terminal area. (Flight Procedures Office).

(13) Noise abatement regions, procedures, and plans.

(14) Restricted airspace.

(15) Existing and future traffic procedures.

(16) Any required alteration to proposed flight paths. (Flight Procedures Office).

b. Initial Site Analysis The initial site analysis will involve the review of data collected during the real estate assessment (refer to Chapter 4, Paragrph 8, Real Estate Assesment and the initial site inspection. This analysis will be comparative in nature since the data gathered to this point is primarily qualitative. The quantitative analysis will be availability and coverage comparisons based on the initial horizon profiles at the RRA and VDB antenna sites respectively. The RRA centroid to DH distance Chapter 3 Paragra 3.c RRA Centroid to DH Distance for each supported runway end will also be considered in the initial availability assessment. The results of the initial site analysis will determine which sites deserve further survey and investigation. The Initial Site Analysis will identify the sites that will be considered in the final site selection process. The analysis will refine the analysis work performed during the initial site assessment and site inspection efforts. The analysis should be provided to the airport authority in a report that documents potential sites identified in earlier investigative efforts. The reason for eliminating sites from consideration should be included in the report. If any proposed locations critically impact airport operations, or where buildings (objects) fall within the GBAS Ground Facility LOCA boundaries and are a potential multi-path source, these items will be highlighted in the report for further discussion with the airport authority, and as areas for analysis during the Formal Site Survey. The report should identify a minimum of three prospective sites to address as many of the Formal Site Survey Requirements as possible realizing that each site contains its own set of trade-offs. Off-airport locations will be considered if on-airport locations are infeasible or fail to meet significant operational requirements.

c. Initial Site Review After the potential sites for system installation have been identified. The siting engineer will meet with the airport authority to review the sites identified in the initial report. This will be an opportunity for airport authorities to eliminate sites which they feel will not work. It is possible they may suggest other locations, which must be evaluated to determine if they satisfy the siting requirements.

3. Site Trade-Off Analysis

The Site Trade-off Analysis reviews the data collected during the Initial Site Inspection in order to provide the following site specific information:

a. Global Positioning System (GPS) Reception Mask / Ranging Source Broadcast Mask Determination. The GBAS Ground Facility GPS Reception Mask is used as an input to the Availability Model. The GBAS Ground Facility GPS reception mask is based on the precise horizon profile described in Chapter 3, Paragrph 4.a (6) Precise Horizon Profile. The horizon profile should be inflated, where applicable, to account for a five-year nominal tree growth of six inches per year. The distance from the RAA to the trees that was recorded during the Site Survey will be used to determine the inflated elevation angles. The Ranging Source Broadcast Mask is computed from the GBAS GPS Reception Mask by taking into account the time required for the RR data to be able to be used for the computation of measurement blocks after a satellite is acquired.

b. RRA Performance Curve Determination. The RRA performance curve is an input to the Availability Model. The RRA performance curve is based on the estimation of $\sigma_{pr\text{-}gnd}$, using the GBAS RRS model results and ranging source data collected during the Site Survey. The ranging source data analysis techniques are based on Government-approved $\sigma_{pr\text{-}gnd}$ data analysis and processing techniques. The data analysis techniques will be the same as the Government-approved techniques to minimize the risk of meeting the requirements during Site Survey and not at Final Installation and Checkout

c. RRA Centroid to DH Distance. The distance between the RRA centroid and the DH shall be computed for each supported runway end during the Real Estate Assessment described in Chapter 4, Paragraph 8 Real Estate Assessment. If the distance is greater than the nominal separation distance determined through analysis, the availability impact shall be computed using the equipment manufacturer's Availability Model. Based on the understood behaviors of the Ionosphere on GPS/Differential GPS (DGPS) there is a restriction on the radius from the RRA centroid (the RRA centroid is the geometric center of the RRA's) to any desired Decision Height point (measured at ground level). For the Honeywell SLS-4000 system refer to Appendix D Appendix D HONEYWELL SLS-4000 SPECIFIC PARAMETERS

d. Contunuity Analysis. The siting engineer performs a continuity analysis for each of the potential sites identified. For further information, see Appendix A, Paragraph 3, GBAS Continuity.

e. Availability Analysis. The siting engineer performs an availability analysis for each of the potential sites identified. For further see Appendix A, Paragraph 4, GBAS Availability.

f. RRS Tracking Perfromance Evaluation. The RRS tracking performance should be evaluated and the impact to continuity assessed. The RRS continuity fault occurs when the number of valid B-values is reduced below three (3) for any valid ranging source. Since the optimum number of RRS's is four, this allows for a loss of data from a single RRS at each epoch for any or all ranging sources.

g. VDB Coverage Analysis. The assessment of VDB continuity during siting is primarily based on the VDB coverage analysis. It is assumed that a VDB site that provides the minimum field strength within the required coverage volume (s) is an acceptable site with respect to continuity. The VDB coverage analysis is based on the VDB model results and precise horizon profile. The actual coverage volume is verified as part of the flight inspection for the site. An initial assessment of the quality of each proposed VDB site shall be made based on the line-of-sight (LOS) to the primary runways' approach coverage volume and other required coverage areas. The proper antenna height shall be chosen to meet field strength requirements throughout the required coverage volumes. Although this initial analysis is based on LOS, it is recognized that there may be constructive and destructive interference which may impact the VDB coverage volume.

h. Ranging Source Pseudorange Error Analysis. An analysis of the pseudorange errors at each antenna site is performed using the guidelines in Chapter 3, Paragraph 3.b RRA Perfromance Curve Determination. The analysis includes the generation of error statistics that will be compared to the requirements curves. Analysis is also conducted to identify sources of excessive multipath, to evaluate error correlation between RR's, and to estimate the distribution of the errors. In addition, if the proposed equipment shelter location is within the RRA LOCA, its effect on system performance should be evaluated using the equipment manufacturer's RRS Model.

i. Interference Analysis.

(1) RRA Interference Analysis. An analysis of the interference environment is performed using the data collected. This data should be compared to the interference mask in Appendix A GBAS PARAMETERS CRITICAL TO ATC OPERATIONS If the interference environment does not meet the interference mask, the interference source must be identified and mitigation strategies developed. If the interference signal is in conformance with its licensed operating signal parameters, and mitigation of the interference is not feasible, the RRA will need to be relocated or additional filtering added.

(2) VDB Interference Analysis. An analysis of potential interference to other airport systems must be performed using the data collected in VDB Interference Data Collection. If is determined that the VDB is interfering with other airport system, corrective action must be identified to mitigate the interference to levels acceptable to airport and FAA authorities.

j. Site Environmental Analysis. The Site Environmental Analysis involves identification of locations of environmentally sensitive areas such as wetlands, floodplains, historical or archeological sites, and endangered species habitats. Whenever possible, siting engineers should select alternative sites to avoid these environmentally sensitive areas. During the initial airport survey, and before selecting a site for the GBAS Ground Facility, the locations of environmentally sensitive areas such as wetlands, floodplains, historical or archeological sites, and endangered species habitats within the AOA should be noted. Whenever possible, siting engineers should select alternative sites to avoid these environmentally sensitive areas. FAA Order 5050.4B, National Environmental Policy Act [NEPA] Implementing Instructions for Airport Projects has detailed information on these and other environmental requirements that the sponsor must meet to assess the proposed project's environmental effects. Engineers and other reviewers should follow the instructions it contains. To expedite this process, the airport sponsor should be able to provide to the engineers and other interested parties the locations of these or other areas of environmental concern.

k. Cost Analysis. All data necessary to estimate the cost of establishing a GBAS Ground Facility at each proposed location is collected during the Formal Site Survey. Some of the items that require special attention due to their potential impact upon the cost of site development include: GBAS configuration, soil analysis and bearing capability, trenching, drainage, grading, access roads, utility service, and earth resistivity.

l. Trade-Off Analysis Reporting. The siting engineer will create a trade-off analysis report of each candidate site analyzed during the site survey. This process takes into account all the topics presented in Chapter 3, Paragraph 3 Site Trade-Off Analysis. The siting engineer presents the comparison analysis between a minimum of three prospective GBAS sites / layouts. The siting engineer will provide the results of the siting trade-off analysis in a Final Site Survey Report. The siting engineer shall use all pertinent data and analysis for each prospective site to generate a trade-off analysis between the sites. The siting engineer identifies any requirements that are at a high risk of not being met at the prospective sites. The siting engineer proposes siting mitigation strategies that may improve the performance at any of the prospective sites. The customer will select the site for GBAS Ground Facility installation. Weighting for this process is somewhat subjective and will be mostly based on the predicted system performance/availability and the objectives of the customer. It is recommended that the siting engineer generate a scale based on predicted overall system performance/availability criteria and the customer's desired outcomes for each prospective site. Major factors in order of importance are:

- Security / Airport Operations Area (AOA) locations
- System Availability.
- RRA Multipath Performance.
- VDB coverage / procedures gained.
- Infrastructure Concerns.
- Signal in Space Lead Time.
- Access.
- Cost.

4. Formal Site Survey

After the Initial Site Survey Report is accepted by the customer, the siting engineer will proceed with a Formal Site Survey of the prospective sites. The purpose of the Formal Site Survey is to gather technical data at each prospective site to aid in the trade-off analysis. The Formal Site Survey will consist of VDB and RR antenna location surveys including recording 360 degree horizontal profiles, VDB and RRS data collection, and survey of shelter layout. The Formal Site Survey provides the following data:

- Measured Multipath Error Data (for each prospective site)
- LOS Measurements/Estimates (for each prospective site)
- Formal Site Survey Report

a. RRA Candidate Site Survey Procedure. The siting engineer will locate and position a RRA at each candidate site identified from the initial site assessment results. Antenna stands are set on these points and setup with GBAS GPS antennas mounted on the stands. The output of each RR is fed to a dedicated data recorder and the recorder is set to record data for a period of at least 24 hours. The data is then analyzed.

(1) Ranging Source Data Collection. The ranging source data collection will include temporary setup of the GBAS RR/RRA for any RRS site, which has been identified with concerns from the previous steps (for any of the proposed sites). The ranging source data collection will be used to evaluate the pseudorange errors at the prospective sites. It is anticipated that this additional data collection will be required for early GBAS Ground Facility installations. For later installations, the mature RRS math model will be used predominantly while the ranging source data collection will be used to assess pseudorange errors due to scatterers and terrain in difficult siting environments. Twenty-four (24) contiguous hours of ranging source data will be collected for each site to be analyzed. The data will be analyzed for the presence of multipath at the site using a code-minus-carrier technique. The horizon profile will be established based upon the elevation that ranging sources were acquired and lost during the data collection period. The statistical confidence of the data collected during this step will be quantified based on the number of measurements taken in each elevation bin.

(2) Recommended Equipment. The following equipment is typically required to perform Ranging Source Data Collection. The specific equipment will be identified by the siting engineer.

(a) Reference Receiver Data Collection

1 DGPS receiver, same design as the GBAS RRS

2 GPS antenna, same design as GBAS GPS antennas

3 Dedicated data recorder

4 Power supply for the DGPS receivers and data recorder

5 Antenna stand

6 Dual-frequency GPS receiver and antenna (used for Iono data collection, removal) i.e. total station with ranging

(b) Additional Survey Equipment

1 Portable generator if local power is not available. If a portable generator is used, the fuel tank should be sufficiently large to run the generator 30 hours without stopping.

2 Hand and power tool (i.e. Cordless Drill/Screwdriver) as required.

b. RRA Precise Horizon Profile. The RRA site survey consists of the precise horizon profile described in d(1)Precise Horizon Profile The precise horizon profile will be used as an input to the availability and RRS math models. Further details regarding the availability analysis and RRS math models are contained in Appendix C Data ANALYSIS and MATH MODELING.

c. RRA Interference Data Collection. The RRA interference data analysis will be done on the same data collected for the ranging source performance above. The signal-to-noise of the measurements will be reviewed to ensure signal blockages or attenuations are minimized, and reviewed for the presence or absence of interference. It should be determined that the selected RRA site is free from interference to the GPS signal. A spectrum analyzer with either automated data collection or an operator will be required. To characterize the RF environment, an RRA should be located at the proposed site on a temporary support and data collected. The test RF components should consist of the antenna, bandpass filter, and preamp that will be used at the selected site. It is important to use the same components that will be installed at the site for this test. The antenna pattern and/or pre-amp design may contribute to interference susceptibility at a particular location. The output from the preamp should be input to a spectrum analyzer with suitable attenuation. Set up the spectrum analyzer to look at the GPS center frequency (1575.42 Megahertz (MHz)) and + / - 10 MHz. The frequency should be monitored for at least 24 hours to ensure that there are no intermittent interference sources.

d. RRA Location Survey Precision. The antenna position is to be determined for each prospective antenna site considered for the site survey. The survey accuracy is defined in the Commercial Instruction Book. The survey coordinates will be used to identify prospective antenna sites, as an input to the GBAS models, and by the installation team to identify selected site locations.

Note: The antenna location survey refers to both the horizontal and vertical survey required for antenna locations during formal site survey. Precise survey positions for the GBAS antennas are determined after installation.

(1) Precise Horizon Profile. A precise horizon profile is generated for each prospective antenna site using precise survey equipment. The precise horizon profile includes distance measuring to objects that are within visual range of the candidate antenna sites. The recording instrument should be set up at the candidate antenna phase center location. Readings should be recorded for any object that is greater than 2^0 (objects below 2^0 are assumed to be insignificant unless present in the LOCA) in elevation relative to the recording instrument. In addition, these objects should be identified by name and salient characteristics (e.g., materials, roof pitch). The recording of the azimuth and vertical angles should be taken to the nearest minute. The horizon profile will be used as an input to the

GBAS math models (refer to Appendix C Data ANALYSIS and MATH MODELING for further details on math modeling).

5. VDB Interference Data Collection.

The VDB equipment can be a source of RF interference to other systems. The siting engineer must consider the electromagnetic impact of the siting of the VDB antenna on other systems when considering a potential site. Controlled tests are conducted to determine if there is any interference from the VDB to other airport systems, especially those systems that are close to or within the equipment manufacturer's -developed separation distance criteria for that system. The tests include interference testing with ATC communications, and airport NAVAIDs. The tests are conducted with the VDB antenna installed temporarily at the proposed location and height. The VDB test setup includes the same type equipment (i.e., same part number) that will be installed at the site. In addition, the power budget variables (e.g., RF cable loss, transmitter output power) should be the same as the proposed installation. The siting engineer should provide the VDB Interference Test methodology. The test description includes the test setup, data collection, and test duration. For the installation of a non-Federal system the frequency assignment must be obtained from the Federal Communications Commission (FCC) prior to testing. For the installation of a Federal system the frequency assignment must be obtained from the local FAA Spectrum Engineering Office.

6. Equipment Shelter Site Survey

The location of the equipment shelter will be surveyed. If the location of the shelter violates the GBAS equipment siting criteria (i.e., LOCA), an analysis will be performed to ensure the site meets GBAS performance requirements.

7. Formal Site Survey Report

The formal site survey report provides an evaluation of each of the candidate sites recommended GBAS site. The site survey report, as a minimum, should include the review of the following items:

(a) VHF Data Broadcast (VDB) Antenna

- VDB coverage (far field): Within 3 nautical miles of decision height for each approach Runway end.

- Coverage (near field):
- Line of Sight along approach path, Final Approach Fix (FAF) or 6 nautical miles.
- Phase center Height Range: 5 to 45 feet (above Ground Plane).
- Signal quality – VDB height in the optimal range.
- Signal quality Object Free Area.
- System separation – VDB is located a minimum of 656 feet (200 meters) from any existing systems).

(b) Reference Receiver (RR) Antenna

- Antenna separation.
- Antenna geometry (Common reflector mitigation).
- RF Interference (Are the GPS Antennas close to other transmitting antennas at or near the airport, take into account the frequency and power along with distance.
- Height at optimal range to (to reduce ground common multipath)
- Local Object Consideration Area (LOCA), Area extends 508 feet (155 meter) radius at the 3° slope

(c) Primary Equipment Shelter

- Proximity of VDB antenna and Reference Receiver antennas to the primary shelter.
- Security.
- Environmental impacts, results of the environmental survey.
- Siting outside of safety/obstruction surface region (Part 77 surfaces).
- Access to the site from existing infrastructure.
- Access to primary power.
- Access to communication lines.
- Access to the VDB antenna.
- Access to the reference receiver antennas.

Chapter 4 General Considerations for Siting

1. Analysis of Operational Requirements.

The Analysis of Operational Requirements must be performed to ensure that the operational needs of the airport are considered in the siting evaluation. These requirements include the runways in which Category I (CAT I) coverage is required.

2. Antenna Phase Center Height (PCH) Considerations.

The antenna should be installed at the manufacturer's specified height above local ground, wherever possible, to provide the required coverage volume. Trade-offs between coverage and multipath that can cause nulls in the pattern should be considered when using antenna heights outside of the manufacturer's suggested height range. Several RRA types may be available for installation. All of these antennas have vertical pattern shaping that favor reception above the horizon while suppressing ground reflections from flat terrain. The amount of the vertical pattern shaping varies with antenna type. The antenna performance characteristics relevant to determining antenna PCH requirements are:

- The slope of the vertical pattern about the horizon
- The vertical pattern side lobe levels below the horizon.

In general, determining a suitable PCH height involves making a careful trade-off between the following opposing requirements. The phase center must be high enough to prevent unacceptable RF coupling to the ground, which may inadvertently degrade antenna performance. The range (minimum to maximum height) of the PCH is specified in the Commercial Instruction Book (CIB).In addition, the height should allow for snow accumulation where applicable, as well as reasonable margin for vegetation grown in between scheduled mowing. Increased PCH generally provides better protection against multipath from transient vehicles. For antennas that provide both significant vertical pattern shaping at the horizon and substantial sidelobe suppression, limiting the PCH to control the error due to multipath from ground reflections is not a consideration. Such antennas provide the greatest flexibility in siting and are generally the best option for building top installations. However, additional structural precautions may be required to ensure the physical stability of the installation as the PCH is increased. The installation manual for the particular antennas to be installed should be consulted to determine PCH limitations. In extreme cases, installation-specific analysis may be required.

3. Power Considerations.

Proximity of power should be considered when making the GBAS Ground Facility siting decision. The impact of proximity to power on the siting decision is primarily a cost impact. The cost of obtaining power at a prospective location from a prospective power source must be weighed against other siting considerations when conducting the trade-off analysis between prospective GBAS Ground Facility sites. The power at the site shall be in accordance with the GBAS power requirements as specified by the equipment manufacturer, FAA Order 6950.2 Electrical Power Policy Implementation at National Airspace System Facilities, local and state requirements.

4. Cable Run Considerations

Trenching and maximum cable length requirements should be considered when making the GBAS Ground Facility siting decision

a. Trenching Considerations. The impact of trenching on the siting decision is primarily a cost impact. The cost of cable trenching should be weighed against other siting considerations when conducting the trade-off analysis between prospective GBAS Ground Facility sites.

b. Maximum Cable Length Considerations. Maximum cable lengths will be determined as part of the system design process for all GBAS Ground Facility configuration options. The maximum cable length will be dictated by the maximum acceptable signal loss and is dependent on the type of cable and the nature of the transmitted information (i.e., digital or RF). The details are included in the Commercial Instruction Book (CIB) for the GBAS Ground Facility. Consideration is given to both radio frequency (RF) and data cables. Data cables are typically copper cable and will be used to connect RR's to the GBAS Ground Facility equipment. The maximum cable lengths may impose restrictions on the prospective locations for any equipment connected to the cables. This may include the RR's, RRA's, VDB antennas and the ATSU.

5. Site Access Considerations.

Proximity of site access roads should be considered when making the GBAS Ground Facility siting decision. The impact of proximity to site access roads on the siting decision is primarily a cost impact. The cost of building new access roads at a prospective location must be weighed against other siting considerations when conducting the trade-off analysis between prospective GBAS Ground Facility GBAS Ground Facility sites. Access to the GBAS Ground Facility equipment may require site access roads. The access to roads, driveways and parking area will be designed in accordance with FAA standards.

6. Equipment Siting Considerations

The GBAS equipment is not fixed by function; this provides flexibility in locating the GBAS components. A list of equipment siting considerations has been established to guide the siting engineer in choosing potential sites. GBAS equipment should be sited such that:

- The equipment is located on airport property, preferably within the Airport Operations Area (AOA). Equipment locations that are not under airport control will require a deviation or waiver to the GBAS siting requirement.
- Adequate VDB coverage is provided so that no restrictions are required for the primary CAT I approach.
- Adequate reception of GPS / SBAS ranging sources is provided for sufficient availability.
- There are no objects in the GBAS Local Object Consideration Areas and no potential for transient scatterers in the GBAS Critical Areas.
- There are no penetrations of airport obstruction surfaces. Any penetrations of the airport obstruction surfaces will require a deviation or waiver (for example OFZ, OFA and RSA)
- Installation issues are considered (e.g., proximity of power, site accessibility).
- Environmental Issues are considered.

7. Equipment Environment and Maintenance Considerations

Equipment environmental considerations (Heating Ventilation, Air Conditioning (HVAC), etc.) should be reviewed when the proposed equipment site is other than the standard GBAS Ground Facility equipment shelter. The impact of equipment environmental considerations on the siting decision is primarily a cost impact. Prospective non-standard GBAS Ground Facility equipment sites may be unsuitable or may require modifications to meet the equipment environmental and maintenance requirements. The GBAS Ground Facility will be housed in an environmentally controlled building/structure that is compliant with current OSHA requirements. The building/structure must have as a minimum, sufficient room for routine maintenance and repair to be performed within the required time period.

8. Real Estate Assessment

The site selection process will involve the study of maps, charts and other data delineated in Chapter 3, Paragraph 2, Site Inspection. These studies will start with the identification of areas that can support the physical footprint, including consideration of the LOCA and critical area criteria, of the GBAS equipment. The RRA centroid for each candidate RRA configuration to DH distance for all of the primary runway ends will also be estimated. Information on the object consideration areas is given in Chapter 5, Paragraph 1 GBAS Ground Facility Equipment Local Object Consideration Areas

(LOCA's). Other information such as the required coverage volume and location of significant obstructions (e.g., hangars, terminals, access roads) will also assist in defining eligible siting locations for the GBAS Ground Facility. This process will assist in defining potential siting areas in preparation for an initial site inspection.

Chapter 5 System Sitting Criteria

1. GBAS Ground Facility Equipment Local Object Consideration Areas (LOCA's).

a. Description. The GBAS Ground Facility Equipment Local Object Consideration Area (LOCA) is a clearance volume near the GBAS Ground Facility Reference Receiver Antennas (RRA's) Figure 5-1, RRA LOCA and Figure 5-2, VDB Safety and LOCA, shows the safety area and LOCA for the GBAS VDB antenna. Antenna(s) should be free from stationary objects (e.g., trees, equipment shelters) to ensure GBAS accuracy, integrity, and continuity. There are two separate LOCA's; one for the RRA's and one for the VDB antenna(s). Although the presence of fixed structures within the GBAS Ground Facility LOCA should be avoided where possible, the impact of fixed structures on GBAS Ground Facility accuracy, integrity, and continuity should be analyzed through data analysis, or math modeling, or both.

b. LOCA Penetration. Although it is desirable to completely restrict the surface traffic from all critical areas, this is generally not feasible since access to and from the runway, terminal areas, ramp, and hangar areas may necessitate traffic movement through these regions. The restrictions must therefore be sufficiently permissive, as delineated in the following subparagraphs, to permit this traffic flow under controlled conditions.

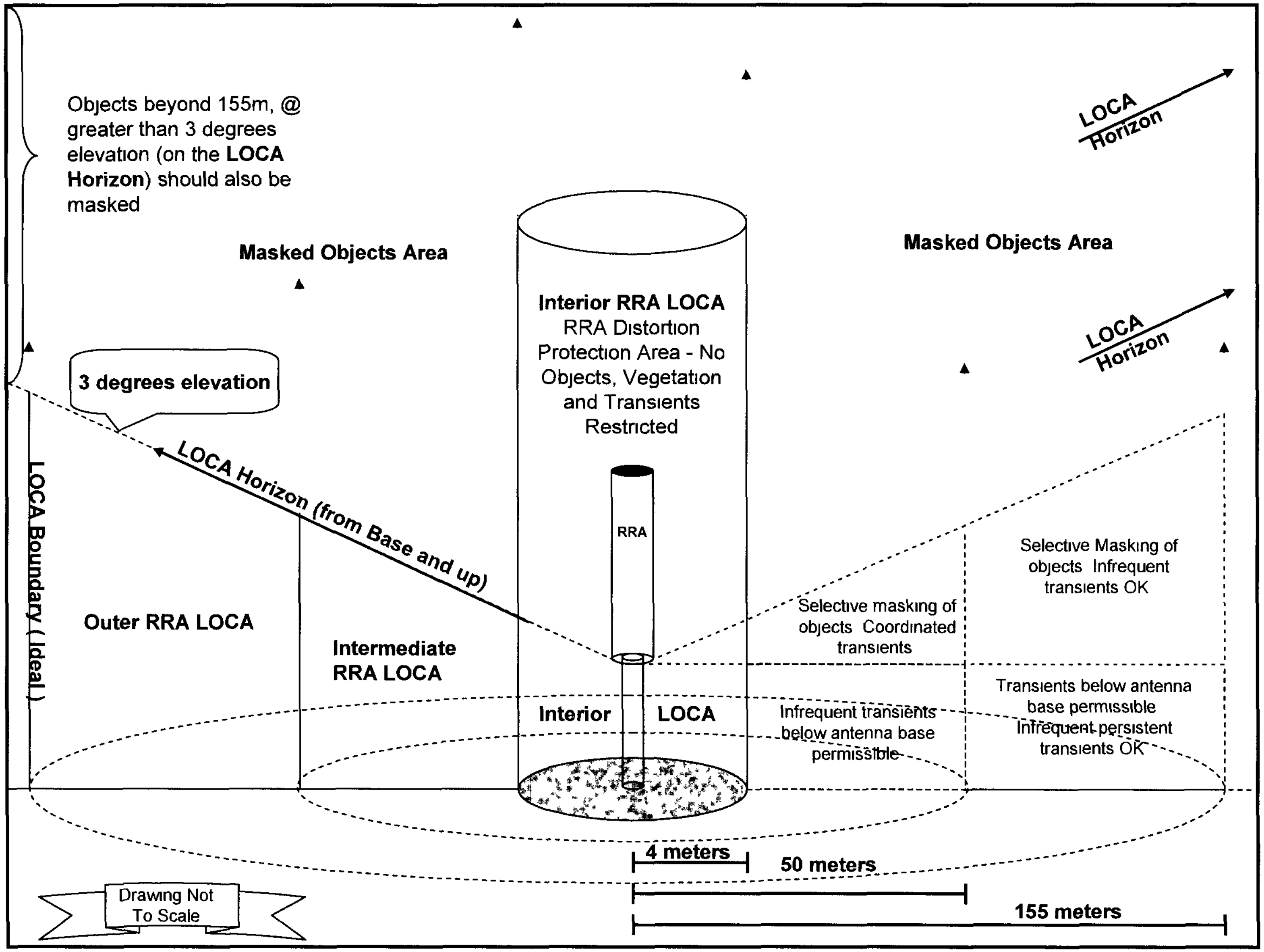

Figure 5-1 RRA LOCA

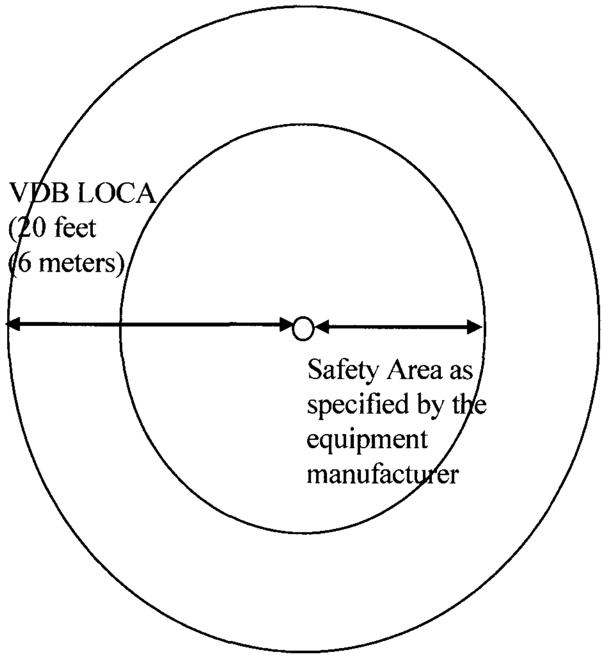

Figure 5-2 VDB Safety Area and LOCA

(1) On Airport Surface Traffic. All on airport surface traffic shall remain clear of RRA interior LOCA (Figure 5-1, RRA LOCA). On airport surface traffic may pass through the RRA intermediate LOCA and the VDB LOCA (Figure 5-2, VDB Safety Area and LOCA) whenever the equipment is in operation. Parking of unattended vehicles or aircraft within these areas shall be prohibited at all times, except for maintenance technician vehicles, which may be parked adjacent to the equipment shelter.

(2) Off Airport Non-Aviation Traffic. Off airport Non-aviation traffic shall not pass through the RRA interior intermediate and outer LOCA (Figure 5-1, RRA LOCA)) and VDB LOCA Figure 5-2, VDB Safety Area and LOCA) as unacceptable degradation is expected from traffic movement along these routes (e.g., on roads, highways, railroad tracks, etc.). In the event where LOCA intersection with non-aviation traffic routes is unavoidable, effective measures shall be taken to overcome the condition. Such measures may include masking (refer to Chapter 5, Paragrph 1.c (1) Selective Masking). If selective masking cannot be fully implemented then, alternate measures should be considered, such as math modeling and / or field testing (to determine the magnitude of the degradation), controlling traffic along the route, elevation or relocation of the antenna array.

(3) Aircraft Over Flight and Over Head Movement. Areas where aircraft will be frequently flying overhead, especially nearby overhead, should be avoided. While occasional over-flights can be tolerated by the system, frequent traffic, such as high volume rush hours, may result in reduced availability of the GBAS system due to disruption of satellite signal reception at the reference receivers. Attempt should be made to avoid siting an RRA so the LOCA intersects the region anywhere between a touchdown, threshold, or decision height point or other frequent overhead movement areas/objects (i.e. cranes, monorails, gondolas, helicopters).

(4) Maintenance Vehicles. Maintenance vehicles may pass through the RRA intermediate and outer LOCA and VDB LOCA, along access roads when traveling to and from the equipment shelter, provided they do not stop and the route does not pass in the RRA interior LOCA. Refer to Figure 5-1 RRA LOCA. The airport authority should provide proper signage along access roads to indicate that maintenance vehicles should not stop. There are no access roads in the RRA interior LOCA and the area is fenced / marked.

(5) Critical Jet Blast Areas. In addition to safeguarding the GBAS Ground Facility information from surface traffic interference, the system must be protected from long term deterioration resulting from accumulation of jet engine exhaust residue. Therefore, jet aircraft must not be permitted to operate with its jet exhaust directed toward the facility, within 600 feet (183 meters) of the GBAS Ground Facility equipment shelter and antennas.

c. Evaluation of Permanent Objects. The detrimental effects of permanent objects planned for placement in the RRA intermediate and outer LOCA and VDB LOCA should be analyzed and/or mathematically modeled prior to construction. If this is not possible prior to construction, a confirming flight inspection must be conducted to determine the effects, if any, on the GBAS subsystems. Note that placing an object outside the LOCA does not guarantee non-interference with the GBAS signal in space. Significant objects beyond the LOCA that penetrate 3 degrees elevation (i.e. Air Traffic Control (ATC) tower, Airport Surveillance Radars (ASR's), etc.) shall also be masked. These objects and obstructions will be first recorded during the precise horizon profile. Momentary blockages of a Space Vehicle (SV) behind permanent un-masked structures can be misevaluated as a failing SV, and the GBAS system may eliminate that SV for suspect behavior.

(1) Selective Masking. The GBAS has the capability to mask off the areas the reference receiver includes in the calculations for differential correction. Refer to the equipment manufacturer's instructions on the proper procedure for excluding an object in the reference receiver's antenna reception area. This will allow the placement of an antenna in an area that is in the vicinity of an obstruction. The need for the masking must be weighed against the reduced availability of the receiver by masking too large an area.

2. Reference Receiver Siting

a. RRA Siting Environment Evaluation (Multipath/Shadowing).Objects in the airport environment can produce multipath and shadowing, and these objects are commonly referred to as scatterers. For the purpose of this discussion, there are two main classes of scatterers: permanent and transient. A permanent scatterer refers to fixed objects whose signal reflections and/or blockage can cause multipath and/or shadowing at the RRA locations. Examples of permanent scatterers are aircraft hangars, equipment shelters, and sloping terrain. LOCA criteria are used to establish an area about the RRA, which forms the basis for the evaluation of multipath from permanent scatterers. A transient scatterer refers to an object, which is in the LOCA for a short period of time but whose signal reflections and/or blockage can cause multipath and/or shadowing at the RRA locations. Examples of transient scatterers are an airborne aircraft, moving service vehicles, taxiing aircraft, parked/holding aircraft, and parked vehicles. Critical areas are established to limit the movement of transient scatterers during CAT I operations. These critical areas are developed based on the LOCA.

b. RRA LOCA. The LOCA's are defined volumes about the RRA's within which stationary objects have a high potential to cause unacceptable degradation of system performance. Objects located within the RRA LOCA can cause either blockage of the GPS satellite signals resulting in the potential for the RR to lose lock, or reflection/diffraction of the GPS satellite signals resulting in an inability to generate sufficiently accurate range corrections. All areas of the RRA LOCA are important and should be carefully evaluated when choosing a prospective RRA site. Ideally, a clear area of 508 feet (155 meters) is desired around each RRA site. At those airports where this is not possible, some areas within the LOCA offer limited flexibility given the understood behaviors of DGPS grade antennas. The following text describes these areas; see Figure 5-1. RRA LOCA for a pictorial of the RRA LOCA.

(1) Interior RRA LOCA . The Interior RRA LOCA is a cylinder about the antenna (from the ground up), with a radius equivalent to the maximum RRA Phase Center height 13 feet (4 meters). The area immediately around the RRA is the RRA's near-field and must be protected from distortion. No stationary objects or transients (i.e. objects moving through) are allowed. Movement and unmitigated vegetation is restricted in the Interior LOCA, and it is desirable to utilize a non-metallic perimeter barrier or markings to protect the interior LOCA. Any perimeter protection method shall be lower than the antenna's base.

(2) Intermediate RRA LOCA. The Intermediate RRA LOCA is also a cylinder with a cone at the top centered about the antenna base with an angle of 3 degrees. The base of the cylinder (at ground level) has a radius of 164 feet (50 meters). The Intermediate RRA LOCA From 13 feet to164 feet (4 meters to 50 meters) out laterally. Ideally, the Intermediate LOCA should be object free. Coordinated transient objects only may penetrate the Intermediate RRA LOCA above the base antenna height. Siting minimizes inclusion of roads, taxiways and other transient venues. Nothing may be allowed to persist in this area. Selective RRA reception masking can be utilized if an object must exist or is expected to wander into predicted sections of this area. Transients below the base of the antenna can be tolerated for short durations.

(3) Outer RRA LOCA. The Outer RRA LOCA is also a cylinder with a cone at the top centered about the antenna base with an angle of 3 degrees. The base of the cylinder (at ground level) has a radius of 508 feet (155 meters). From 164 feet to 508 feet (50 meters to 155 meters) out laterally is the Outer RRA LOCA. Infrequent parked transients below the antenna base height are permissible. Any permanent objects and areas where transient object movement would be known to occur must be selectively masked.

(4) RRA LOCA Horizon. The RRA LOCA Horizon refers to the region beyond 508 feet (155 meters) above 3 degrees. Significant objects that penetrate 3 degrees elevation should be selectively masked.

(5) RRA Placement Considerations. A standard GBAS Ground Facility configuration includes 4 RRA's. The relative placement / separation criteria of the RRA's must be considered in the siting. These criteria are derived from commonly understood GPS / DGPS existing equipment and system behaviors. Each antenna shall be separated from any adjacent antenna by a minimum of 328 feet (100 meters), 508 feet (155 meters) is desirable for installations that must be collocated. Much longer baselines are permissible, provided other system requirements are not violated (i.e. RRA Centroid to DH Distance). The RRA's shall be placed to exclude collinear placement of the RRA's (applies to 3 or more). For flat installation areas (roof tops, tarmac areas within the LOCA(s), etc.) that vary less than ¼ wavelength (λ) of L1 1.87 inches (4.75 centimeters (cm)), the Phase Center (PC) heights shall not be placed so any are equal in height, or vary by 7.48 inches (19 cm) increments (1λ) in height. Ellipsoid heights shall be used for confirmation. Flat installation area PC heights ideally should be staggered in ¼ λ increments (without violating previous text). Phase center heights above immediate local terrain shall be limited to a height specified by the equipment manufacturer. For the Honeywell SLS-4000 system see Appendix D, Appendix D HONEYWELL SLS-4000 SPECIFIC PARAMETERS. In order to mitigate the chance of 2 RRA's experiencing common multi-path errors, no 2 RRA's shall be sited parallel to or equidistant from, common large multi-path sources or transient venues. Common sources include: runways, building edges, metallic fences, roads, taxiways, concrete barriers, jet blast diverters, equipment and shelters, water canals, highways and railings. A constrained GBAS siting example, with above criteria included, is shown figure 5-3, GBNAS Contrained Siting Examples.

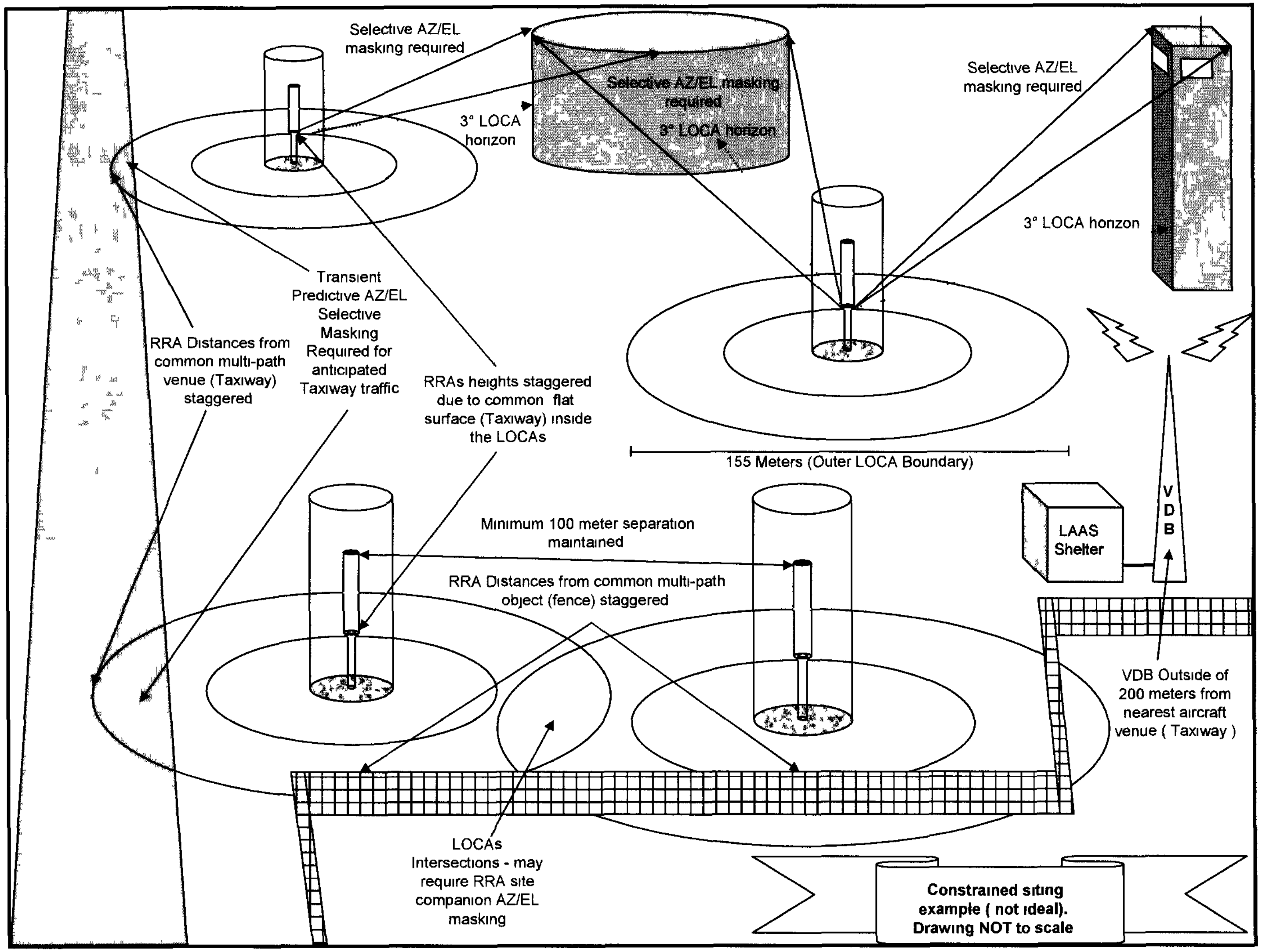

Figure 5-3 GBAS Constrained Siting Example

c. RRA Physical Antenna Installation Considerations (Interior RRA LOCA). The candidate sites for installing the RRA antennas should be chosen with the following considerations for the interior LOCA region:

(1) Provide an area around the RRA with minimum radius of 13 feet (4 meters)

(2) A fence or non-metallic barrier/ marking may be placed around the antenna to mark the area.

(3) The ground in the enclosed area should be prepared to eliminate the growth of vegetation.

(4) Ground reflections are dictated by the material at the base of the interior LOCA. If the material below the antenna is highly reflective properly graded gravel may be used to disperse the reflected undesired signals. Other appropriate materials may be substituted for gravel.

(5) The ground in the enclosed area should be prepared to eliminate standing water and provide the proper drainage away from the foundation of the antenna pedestal. Properly graded gravel can be used to satisfy this requirement.

(6) Any lease or installation agreements should contain provisions to control vegetation growth.

(7) Growth of crops of any type must not be permitted.

(8) Piling snow in the Interior area LOCA should not be allowed.

d. Maintenance of the LOCA (Intermediate and Outer LOCA). Monitors within the system will detect out-of tolerance RRA Multi-path performance in all cases and will protect the user if maintenance activates degrade the system performance. The RAA LOCA diagram Figure 5-1 RRA LOCA provides guidance on allowable transgressions of the LOCA. If the planned maintenance activities are expected to degrade system performance to unacceptable levels, the system should be NOTAM'ed out of service. The candidate sites for installing the RRA antennas should be chosen with the following considerations for the intermediate and outer LOCA regions:

(1) Vegetation should not be permitted to exceed 3.3 feet (1 meter) in height in an area with a radius of 20 feet (6.1 meters) around the RRA's.

(2) Snow depth below the RRA is not an issue for single reflection Multi-Path. The RRA should be installed so that naturally-accumulated snow does not cover any part of the RRA (the maximum RRA height restrictions should not be violated, the RRA mast is excluded). If snow accumulation overcomes the RRA, then it must be removed. Vegetation has a different impact (diffuse Multi-Path) and is therefore limited to 1 meter.

(3) Action must be initiated when observed vegetation growth exceeds 3.3 feet (1 meter).

(4) A fence using non-metallic material may be placed around the antenna to mark this area.

(5) Mowing operations should be coordinated for a time to coincide with scheduled facility maintenance.

(6) Should plowing operations be required, this should be coordinated for a time to coincide with scheduled facility maintenance.

(7) Piling snow in the Intermediate area LOCA should not be allowed.

(8) Piling snow in the Outer area LOCA is acceptable with the conditions: Refer to Figure 5-1 RRA LOCA.

(9) The movement of the equipment is limited to infrequent persistent transients (parking equipment or allowing the equipment to remain stationary for long periods is not permitted)

(10) Total height of the of the naturally accumulated snow and piled snow is not higher than the antenna base

e. RRA LOCA's, Selective Masking vs. Critical Areas. Critical areas, as defined in ILS terms (for example – hold short lines), are not normally required for GBAS installations. However, there may be situations due to constrained siting where "critical areas" may be necessary. RRA LOCA's are defined as volumes about the RRA's within which transient objects have a high potential to cause unacceptable degradation of system performance. The criteria for defining the Critical areas is to provide zoning requirements intended to protect the RRA from multipath and shadowing caused by transient scatterers. Protection from transient scatterers requires that the appropriate critical area be defined for each RRA location. These critical areas will be based on the RRA LOCA criteria and will differ from airport to airport. The LOCA criteria are determined by those airport surface movement areas where an object of specified size penetrates a surface of the LOCA. These areas will either need to be selectively masked (preferred method), or be designated as a critical area (not preferred). The LOCA area criteria consider a stationary worst-case user with respect to size in the airport surface movement areas. The airport surface movement areas include runways, taxiways, and roadways. In addition to surface movement areas, areas where hovering rotorcraft are present should be considered. It will be conservatively assumed that any aircraft or vehicle passing near the LOCA is causing the worst-case response at the reference antenna. This implies that there would be no filtering of multipath variation due to vehicle motion and that the penetrated area would effectively be the intersection of the RRA LOCA with all surface movement areas. Extensive modeling, of known aircraft speeds and geometries may help reduce this requirement in the future. Selective masking is also a well understood method that could preclude measurements ever being taken from a LOCA penetration or multipath object (transient or stationary). The physical dimensions of vehicles on the airport surface must be taken into account when determining critical areas, see Figure A-1 Guidance for Determining RRA Selective Masking or Critical Areas at the Intersection of the LOCA and Movement Area

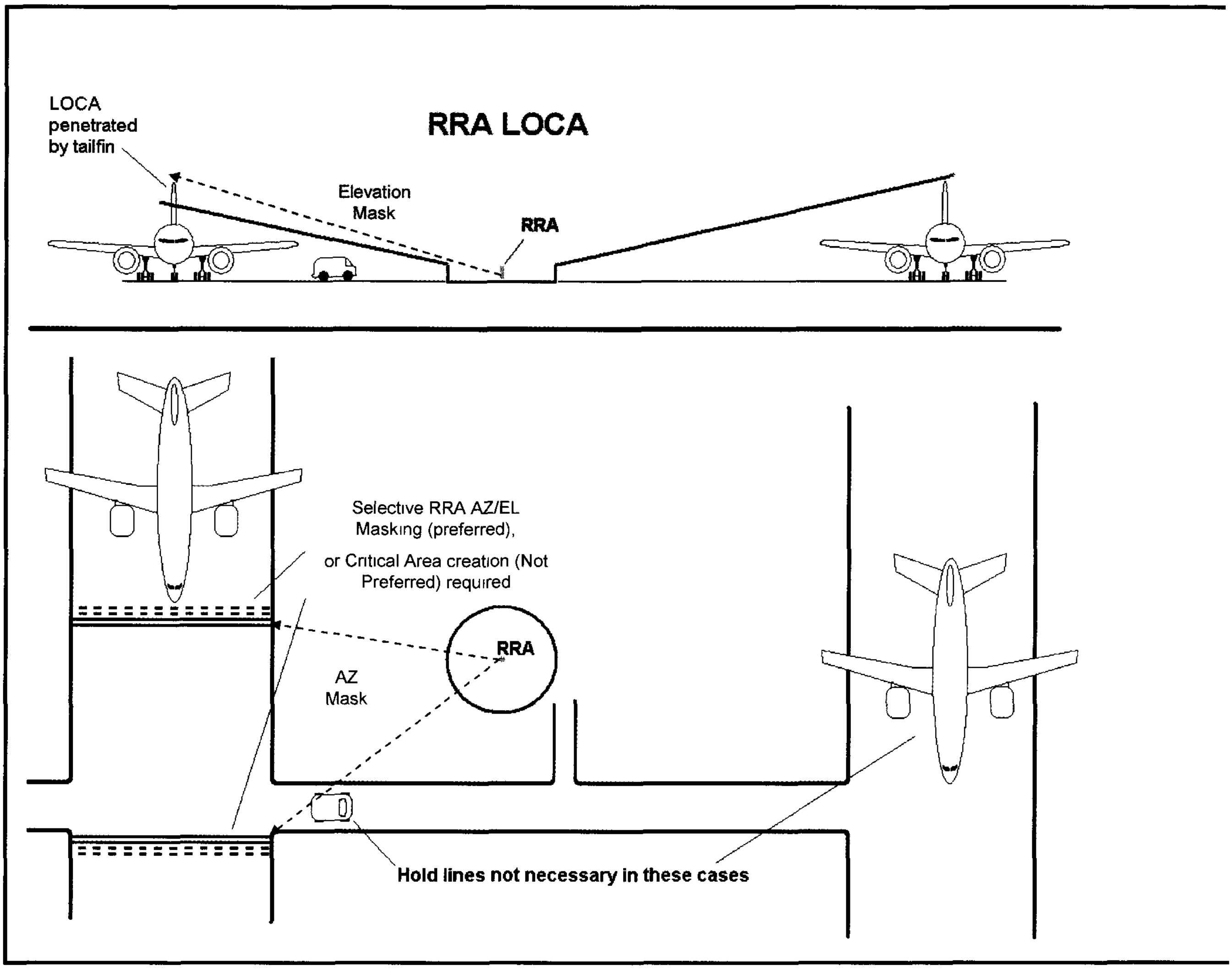

Figure 5-4 Guidance for Determining RRA Selective Masking or Critical Areas at the Intersection of the LOCA and Movement Area

Parked vehicles or aircraft are prohibited from being in the critical area. At a minimum, the movement of surface traffic through the critical area is controlled, and it may be prohibited entirely, depending on the location of the road/taxiway relative to the RRA locations. Accordingly, the selection of RRA locations should take into consideration the impact of critical area requirements on surface operations. The objective is to find RRA locations that provide an acceptable multipath/shadowing environment and critical areas that do not impact surface operations. Selective masking can be applied to objects that will pass through the critical area. See Chapter 5, Paragraph 1.c (1) RRA LOCA's, Selective Maksing vs Critical Areas for additional information. The GBAS performance can be adversely affected by the presence of strong multipath / shadowing at one or more RRA locations. The presence of strong multipath at any given RRA location can cause the RR to lose track of a satellite or degrade the ranging accuracy of the RR. The presence of shadowing sources at any given RRA location can cause the RR to lose track of the satellite. The selection of the appropriate

RRA siting is essential to avoid unacceptable multipath signal levels and shadowing at the RRA location, as well as errors due to correlated multipath at two or more RRA locations. In general, the satellite-RRA-scatterer geometry, as well as the scatterer size, orientation, and composition are all factors that influence the magnitude, duration, and scalloping characteristics of the multipath error. However, certain satellite-RRA-scatterer geometries are not capable of generating detectable multipath error levels regardless of scatterer size, orientation, and composition. These geometries form the basis for the RRA LOCA criteria used for evaluation the of multipath environment around the RRA location. The siting engineer provides the methodology for defining the RRA selective masking or Critical Areas. The siting engineer provides simulation results, analysis, and test data to demonstrate that the siting engineer defined Critical Areas that are consistent with and traceable to the equipment manufacturer's continuity and integrity allocations and inflation factors

f. RRA Multipath

Multipath is the phenomena whereby signals arrive at the receiver via different paths due to reflections and diffraction. It is the characteristics of these reflected / diffracted signals, relative to the direct signal, that determines the characteristics of the multipath incident at the receiver. A DGPS system, such as the GBAS, corrects for pseudorange errors that are common between the reference station and the user platform. Any residual errors that are not common between the reference station and user platform that are not eliminated by the GBAS Ground Facility using other techniques will result in errors in the aircraft position solution. Multipath is not common between the two stations and therefore cannot be corrected for using differential techniques. The GBAS Ground Facility relies on the design of the RR's, RRA's, and siting to mitigate unacceptable multipath effects. Multipath is generally accepted to be the largest pseudorange correction error source. The minimization of RRA multipath is a primary goal of RRA siting. RRA multipath can be classified as either ground multipath or non-ground multipath.

(1) RRA Ground Multipath. RRA Ground multipath is defined as multipath that is incident at negative elevation angles relative to the RRA phase center. Ground multipath is typically caused by the local terrain (e.g., ground, surface water, or rooftop). The impact of the ground multipath on the pseudorange measurement will depend on the reflective medium's dielectric properties and the RRA pattern. Figure 5-5 Ground and Non-Ground Multipath, shows an example of a simplified ground reflection multipath. Ground multipath can cause significant low frequency pseudorange errors that are difficult to mitigate through siting and / or signal processing. The most effective mitigation technique is to employ an RRA design that attenuates the ground multipath signal relative to the direct signal. The siting engineer will make decisions for mitigating ground multipath based on the type of RRA. The engineer can mitigate ground multipath by choosing the optimum phase center height for the particular antenna and by avoiding sites in proximity to mediums with high reflection coefficients (e.g., bodies of water) where possible.

(2) RRA Non-Ground Multipath. RRA Non-ground multipath is defined as multipath that is incident at positive elevation angles relative to the RRA phase center. Non-ground multipath is typically caused by objects (e.g., equipment shelters, antenna towers) that are within the RRA LOCA, but can also be caused by up-sloping terrain. The impact of these objects on the multipath error seen at the RRA will depend on the objects' reflection coefficients and their relative position to the antenna/satellite line-of-site. Figure 5-5 Ground and Non-Ground Multipath shows an example of a simplified non-ground reflection multipath.

NOTE – All of the signals are from the same Space Vehicle (SV)

Signal path	Description
1	Direct signal from SV to antenna
2	Ground reflection
3	Object Reflection + Ground Reflection
4	Object Edge Reflection / Diffraction + Ground Reflection
5	Object Reflection
6	Object Edge Reflection / Diffraction

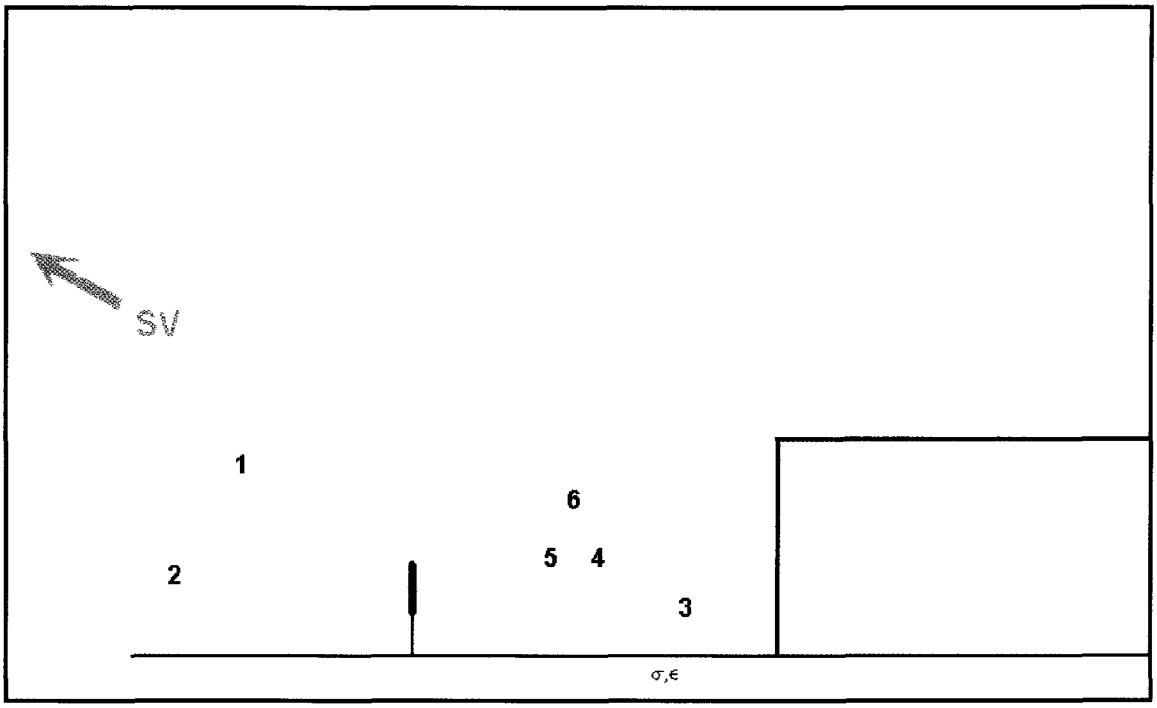

Figure 5-5 Ground and Non-Ground Multipath

Since non-ground multipath enters the antenna at positive elevation angles, there is usually no inherent attenuation of the reflected signal due to the antenna gain pattern. This makes the elimination of sources of non-ground multipath a primary goal in the siting of RRA's.

The siting engineer will make decisions for mitigating non-ground multipath based on the LOCA for the RRA. The engineer should also study the local topography to evaluate the potential for non-ground multipath caused by up-sloping terrain.

g. RRA Shadowing. Shadowing is defined as the blockage of either the reception or transmission of signals. Terrain and objects in the local environment may cause signal shadowing. The shadowing of the GPS SPS signal-in-space within the GBAS reception mask may cause a degradation of system availability. Permanent scatterers such as terrain, trees, and man-made structures and transient scatterers such as aircraft and vehicles typically cause RRA shadowing. An availability analysis should be performed to determine the extent of the availability degradation caused by permanent scatterers. Controlling surface movement in the critical areas during CAT I operations can be used to preserve the GBAS availability in the presence of transient scatterers. The siting engineer will use the GBAS RRS model and/or horizon profiles to determine the presence and sources of shadowing of the GPS constellation. Mitigation techniques include increasing antenna height or removal of the shadowing source. The incorporation of additional RRA's may also reduce the impact of shadowing on system availability.

3. VDB Antenna Siting

a. VDB Antenna Siting Environment Evaluation. The VDB Antenna siting environment evaluation is similar to the RRA siting environment evaluation described in Chapter 5, Paragraph2.a RRA Siting Environment Evaluation. The VDB site should also be evaluated with respect to permanent and transient scatterers. There are corresponding VDB Antenna LOCA criteria and VDB Antenna critical areas, which must be defined analogous to the RRA case. The primary difference is the impact that objects within these areas have on the GBAS performance. In the VDB Antenna siting evaluation, the impact is primarily on the VDB coverage volume.

b. Safety Area. Safety area is defined as the area around the VDB antenna that indicates an area that personnel should not enter. This area is to protect personnel from the VDB antenna emissions. See Figure 5-2 VDB Safety Area and LOCA.

c. VDB Antenna Installation Considerations. During GBAS precision approach operations, parked vehicles or aircraft are prohibited from being in the critical area. At a minimum, the movement of surface traffic through the critical area is controlled, and it may be prohibited entirely depending on the location of the road/taxiway relative to the VDB antenna locations. Accordingly, the selection of VDB antenna locations takes into consideration the impact of critical area requirements on surface operations. The objective is to find VDB antenna locations that provide an acceptable multipath/shadowing environment and critical areas that do not impact surface operations. The GBAS performance can be adversely affected by the presence of strong multipath and/or shadowing at the VDB antenna location. The presence of strong multipath and/or shadowing sources at the VDB antenna location can cause nulls in the VDB coverage volume. The selection of the appropriate equipment configuration and proper equipment siting are essential in avoiding unacceptable multipath signal levels and shadowing at the VDB antenna location. In general, the VDB antenna-scatterer geometry, as well as the scatterer size, orientation, and composition are all factors that influence the magnitude, duration, and scalloping characteristics of the multipath. These geometries form the basis for the VDB LOCA criteria used for evaluation the multipath environment about the VDB antenna location.

(1) VDB Antenna LOCA. The VDB LOCA's are defined volumes about the VDB antenna(s) within which stationary objects have a high potential to cause unacceptable degradation of system performance. Objects located within the VDB Antenna LOCA may either block the VDB signal or generate reflections that cause nulls in the VDB signal in operationally significant regions of its coverage volume. The siting engineer provides the dimensions of the VDB Antenna LOCA. The siting engineer shall provide simulation results, analysis, and test data to demonstrate that the defined LOCA's are consistent with, and traceable to the equipment manufacturer's continuity allocations.

(2) VDB Antenna Phase Height Considerations. The VDB Antenna Phase Center Height (PCH) shall be chosen to ensure at least the minimum field strength is met in the operational coverage volumes. The selection of the antenna phase center height may involve trade-offs between coverage to the approach and coverage on the surface. The siting engineer shall provide an optimum VDB antenna PCH range. The siting engineer performs a sensitivity analysis to determine the effect of PCH height on approach coverage and surface coverage. The siting engineer shall provide simulation results, analysis, and test data to validate the height range and the trade-off analysis. Figure 5-2, VDB Safety Area and LOCA shows the safety area and LOCA for the GBAS VDB antenna.

(3) VDB Critical Area Dimensions. VDB Antenna Critical Areas are defined volumes about the VDB antenna(s) within which transient objects have a high potential to cause unacceptable degradation of system performance. These areas should be protected from the unlimited movement of surface and air traffic to ensure GBAS Ground Facility continuity. The critical area criteria are determined by those airport surface movement areas where an object of specified size penetrates a surface of the LOCA. The critical area criteria shall consider a stationary worst-case user with respect to size, in the airport surface movement areas. The airport surface movement areas include runways, taxiways, and any roadways. In addition to surface movement areas, areas where hovering rotorcraft are present shall be considered. The siting engineer uses the system manufacturer's information (as defined in the Commercial Instruction Book (CIB)) in establishing the methodology for defining the VDB Antenna Safety and Critical Areas. The siting engineer provides simulation results, analysis, and test data to demonstrate that the critical areas are consistent with, and traceable to the equipment manufacturer's continuity allocations.

(4) VDB Physical Antenna Installation Consideration Considerations. The candidate sites for installing the VDB antennas should be chosen with the following considerations:

- Provide a safety area around the VDB antenna as specified by the equipment manufacturer. For the Honeywell SLS-4000 system refer to Appendix D Appendix D HONEYWELL SLS-4000 SPECIFIC PARAMETERS
- A fence or non-reflective barrier/ marking may be placed around the antenna to mark the area.
- The ground in the enclosed area should be prepared to eliminate the growth of vegetation.
- The ground in the enclosed area should be prepared to eliminate standing water and provide the proper drainage away from the foundation of the antenna pedestal. Properly graded gravel can be used to satisfy this requirement.
- Any lease or installation agreements should contain provisions to control vegetation growth.
- Growth of crops of any type must not be permitted.
- Airport management shall provide proper signage indicating that personnel should not enter the area when the GBAS is in operation.

(5) Maintenance of the VDB LOCA. The following maintenance actions should be performed for the VDB antenna (s) installed as part of the LGF facility: Monitors within the system will detect out-of tolerance GBAS operation. If the planned maintenance activities are expected to degrade system performance to unacceptable levels, the system should be NOTAM'ed out of service. Vegetation should not be permitted to exceed 3.3 feet (1 meter) in height in an area with a radius of 6 meters around the VDB antenna. Action must be initiated when observed vegetation growth exceeds 3.3 feet (1 meter). A fence using non-reflective material may be placed around the antenna to mark this area. Mowing operations should be coordinated for a time to coincide with scheduled facility maintenance.

d. VDB Antenna Site Survey. The VDB antenna site survey shall consist of the precise horizon profile described in Chapter 3, Paragraph 4.a (6), Precise Horizon Profile. The precise horizon profile will be used as an input to the VDB math model, which is a major part of the final VDB antenna site selection process. The site survey flight test will verify the coverage attained at the selected site. It is anticipated that this additional data collection will be required for early GBAS installations. For later installations, the mature VDB math model will be used predominantly while the site survey flight test will be used to assess the coverage volume impact of obstructions and terrain in difficult siting environments.

e. Requirement for an Additional VDB Antenna. There will be one VDB antenna required for typical GBAS installations. It may be determined during the site survey that an additional VDB may need to be installed to meet the coverage requirements at the site. The criteria for selecting the location for the additional VDB antenna shall be the same as that of the primary VDB antenna.

f. VDB Field Strength Considerations

(1) Minimum Field Strength. The VDB shall be sited to meet, at a minimum, the minimum field strength requirements throughout the CAT I Approach Coverage Volume described in Appendix A GBAS PARAMETERS CRITICAL TO ATC OPERATIONS, for each runway end designated for a CAT I approach. If required, the VDB will also be sited to meet the minimum field strength requirements in the CAT I Missed Approach Coverage Volume and the Appendix A GBAS PARAMETERS CRITICAL TO ATC OPERATIONS. The GBAS Ground Facility is designed with an allowance of not meeting the field strength directly above the antenna. This region is defined as a 5° cone, which is an upper bound of the coverage volume. The actual upper bound must be verified during the flight inspection. This cone must be considered when siting the VDB antenna to ensure that it does not impact the required coverage volume. The minimum VDB RF field strength is defined in 3.2.4 VDB RF Field Strength of DO-245A, the Minimum Aviation System Performance Standards for Local Area Augmentation System (LAAS) [MASPS]

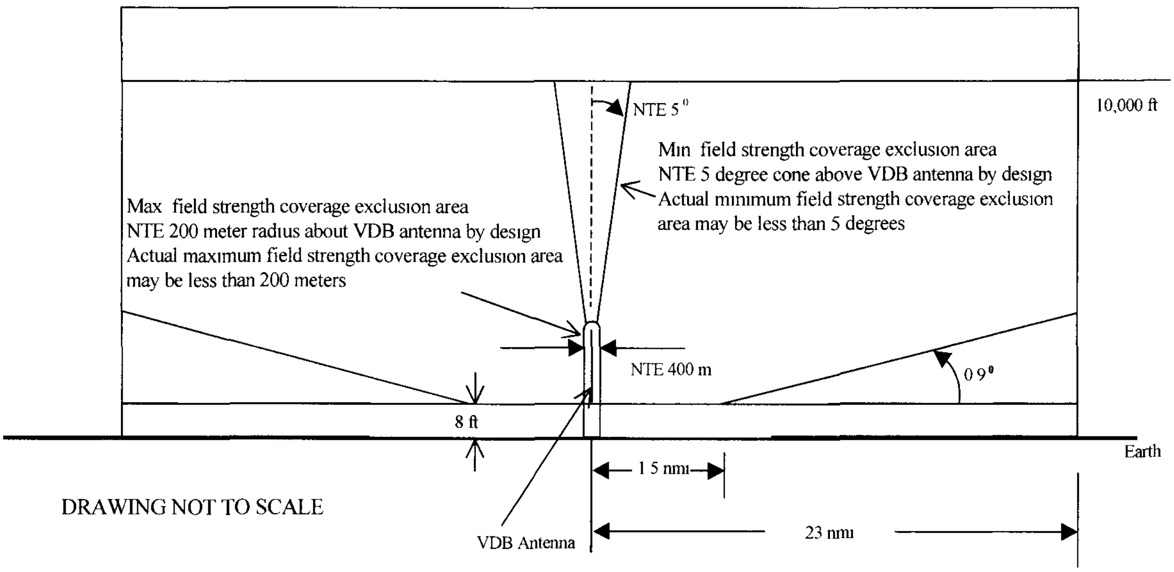

Figure 5-6 VDB Coverage Volume

(2) Maximum Field Strength. The antenna shall be installed so that no users that are employing the GBAS signal for navigation are in an area where the signal exceeds the maximum permitted signal level. The maximum VDB RF field strength is defined in 3.2.4 VDB RF Field Strength of DO-245A, the Minimum Aviation System Performance

Standards for Local Area Augmentation System (LAAS) [MASPS] The GBAS Ground Facility is designed with an upper bound specification on the maximum field strength that the avionics receiver can be subjected to at a distance of 656 feet (200 meters) from the VDB antenna. The actual upper bound on the maximum field strength distance is based on the VDB hardware and nominal GBAS VDB power range, both of which are design specific and shall be less than 656 feet (200 meters).

(3) VDB Antenna Volume Exclusion Volume. There are two allowed exclusion volumes in the VDB coverage volume. The first exclusion volume allows for field strengths below the minimum requirements directly above the VDB antenna. This volume is defined as a cone with a cone angle not to exceed (NTE) 5° by design. The second exclusion volume allows for field strengths greater than the maximum field strength requirements in proximity to the VDB antenna. This exclusion volume is defined as a cylinder (with a semi sphere at the top) about the VDB antenna with radius NTE 656 feet (200 meters) by design. The siting engineer provides the dimensions of the coverage exclusion volume above the VDB antenna. The analysis should include a sensitivity analysis of exclusion volume dimensions versus VDB site-specific power budget variables (e.g., RF cable loss, transmitter output power). The siting engineer provides simulation results, analysis, and test data to validate the criteria. The siting engineer provides the volume about the antenna where the maximum field strength is exceeded. The volume should be defined below the antenna to aid in siting when the antenna is mounted at upper heights. The analysis should include a sensitivity analysis of maximum field strength volume versus VDB site-specific power budget variables (e.g., RF cable loss, transmitter output power). The siting engineer provides simulation results, analysis, and test data to validate the criteria. The VDB Coverage Exclusion Volume Criteria described above shall be verified during site survey. This testing shall include flight testing and/or ground testing depending on whether the exclusion volumes at the prospective site are anticipated to intersect any operational areas. The siting engineer provides the VDB Coverage Exclusion Volume Verification methodology in this section. The test description includes test setup, data collection, and test duration.

g. VDB Coverage Volume Assurance. The siting engineer assures that VDB coverage is provided to defined approaches. Approach coverage area extends to at least 20 NM out from the runway threshold. GBAS VDB equipment is designed to provide acceptable field strength up to 23 NM from the VDB transmitting antenna. Airport Layout Plans and associated paper maps / charts will assist the siting engineer in this analysis. The siting engineer will identify areas on the composite map that are potential VDB sites. These areas however could be eliminated from further consideration because of line-of-sight obstructions due to buildings. If a single VDB cannot provide the required coverage an additional VDB will be required.

h. VDB Location with Respect to Runway Threshold. The VDB antenna should be sited within 3 NM of the runway threshold to be serviced. The VDB Coverage Assurance Zone can be determined by drawing 3

NM radius circles centered at each runway threshold. The area common to all circles is the area where a single VDB can provide the required approach coverage to aid in selecting areas where the VDB primary antenna could be sited. The siting engineer will create a composite map of the AOA showing the keep-out areas and the 3-NM VDB Coverage Assurance Zone.

i. VDB line of Sight Study. Line-of-Sight (LOS) studies are used to determine whether obstructions lie between the VDB antenna and the required operational reception points. Using building height and topographical information, sight lines may be drawn from the VDB antenna site to each covered runway threshold or decision height location. Line-of-sight blockages due to buildings, parking ramps, etc. will be evaluated. Re-positioning the VDB antenna slightly left or right could eliminate the obstruction or minimize these blockages. Height of the VDB antenna may also be increased to eliminate line of sight blockages. The siting engineer recognizes that VHF signals can diffract around structures and reflect off structures, creating complete coverage when it appears that an obstruction exists. When working to prioritize and qualify potential VDB sites, the following priority will be used to evaluate:

(1) Unobstructed view to CAT I glidepath decision height location.

(2) Unobstructed view to runway threshold.

(3) Unobstructed view of surface coverage areas.

The siting engineer should consult with local Airport Operations on whether there is a possibility of periodic temporary obstructions such as a ship, plane, or crane that may affect the VDB line-of-sight study.

j. Line-of-Sight Glidepath Decision Height. It is expected that the location selected for the VDB will meet the requirement of providing an unobstructed view at the glidepath decision height. However, the area where the 200-feet (61 meters) decision height intercepts the 3-deg glidepath to each runway (typically 3,000 feet (914 meters) from the runway threshold on centerline) shall be evaluated to ensure that the location for the VDB selected has an unobstructed view of the glidepath decision height. The current method relies on line-of-sight (LOS) analysis. LOS analysis is done by drawing a line on the area map from the decision height point through any obstruction taller than 100 feet (30 meters). The area along the line that extends on the other side of the obstruction may have signal blockage to the decision height. Any structures that block more than 5 degrees of azimuth when viewed from the VDB antenna will be identified as criteria for rejection. Narrow structures like the Air Traffic Control Tower or radar towers do not impact the analysis because the VDB signal will diffract around these narrow structures and any potential outage they might create would be short enough for the airborne receive to not lose the signal.

k. Line of Sight to Runway Threshold. Next, the siting engineer will perform a line-of-sight evaluation of the VDB antenna to each runway threshold. This is achieved by drawing lines on the area map from the proposed VDB antenna to each runway threshold. If a line crosses any buildings or obstructions, the siting engineer will determine the height of the imposing obstruction along the sight line and its distance to the runway threshold.

l. Line-of-Sight Surface Coverage Area. The siting engineer shall confirm VDB coverage for surface coverage areas. Using the same methodology as discussed for runway thresholds, if an obstruction occurs, the siting engineer will calculate the amount of blockage (if any). Blockage in excess of 5 degrees of azimuth shall be identified as criteria for rejection.

m. VDB Height Determination. During this analysis, the siting engineer should look for optimal mounting height(s) of the VDB antenna. There are two opposing criteria in selecting optimal height(s). To ensure signal coverage at runway thresholds, the line-of-sight angle of incidence from the VDB antenna is often maximized. However, to ensure signal coverage and the far-out edge of volume coverage area, the VDB antenna should be as low as practical to reduce multipath fading. The maximum height is defined in the manufacturer's commercial instruction book. In determining line-of-sight obstructions during the Initial Site Assessment, The siting engineer should assume that the VDB antenna is at the maximum height. If all runway thresholds are visible from the VDB antenna, then the height will be adjusted downward to ensure coverage at the farthest runway. Also considered at this time will be antenna heights that penetrate Title 14 CFR Part 77 **[3]** requirements. If no single VDB antenna site can meet all the above requirements, then the siting engineer will look for a combination of options that achieve full coverage including additional GBAS sites, or work with the customer to revise operational requirements for available VDB locations.

n. VDB Multipath. The VDB transmission is also susceptible to the effects of multipath. Reflections and diffraction effects resulting from objects that may be either near or far from the direct path can cause considerable path loss in the VDB transmission. The minimization of VDB multipath is a primary goal of VDB siting. VDB multipath can be classified as either ground multipath or non-ground multipath.

(1) VDB Ground Multipath

VDB ground multipath is defined as multipath that emanates from negative elevation angles relative to the VDB antenna phase center. The local terrain (e.g., ground, surface water, or rooftop) typically causes ground multipath. The amount of fading will depend on the properties of the VDB antenna, the reflecting surface and the angle of incidence of the direct wave on the reflector.
Figure 5-5 Ground and Non-Ground Multipath

shows an example of a simplified VDB ground reflection multipath. VDB ground multipath can cause significant nulls in the transmitted radiation pattern that may be difficult to mitigate. VDB ground multipath poses a significant challenge to the siting engineer since the reflective surface may be located at a significant distance from the VDB antenna site. The siting engineer can mitigate VDB ground multipath by selecting the optimum antenna height for the particular VDB antenna and by avoiding sites where the reflection points in the area of primary interest occur on mediums with high reflection coefficients (e.g., bodies of water) where possible. Another ground multipath mitigation method is to site antennas where the indirect path is blocked or attenuated by natural obstacles.

(2) VDB Non-ground Multipath

VDB non-ground multipath is defined as multipath that emanates from positive elevation angles relative to the VDB antenna phase center. Non-ground multipath is typically caused by objects (e.g., equipment shelters, buildings, antenna towers) that are within the VDB antenna LOCA. The impact of these objects on the radiation pattern will depend on the objects' reflection coefficients and the angle of incidence of the direct wave on the diffractor. Figure 5-6 Ground and Non-Ground Multipath shows an example of a simplified non-ground reflection multipath. Non-ground reflections can combine with the direct signal and cause nulls in the VDB radiation pattern. The siting engineer will make decisions for mitigating non-ground multipath based on the LOCA of the VDB antenna.

o. VDB Shadowing

The shadowing of the VDB transmission may cause areas in the GBAS coverage volume to be below the minimum field strength requirement. Permanent scatterers such as terrain, trees, and man-made structures and transient scatterers such as aircraft and vehicles typically cause VDB shadowing. Field strength measurements should be taken in the required coverage area to determine the impact of shadowing on VDB field strength. The siting engineer will use the VDB model and/or horizon profiles to make decisions for mitigation of shadowing of the VDB signals. Mitigation techniques include increasing antenna height or removal of the shadowing source. Changing the antenna height may have an impact on VDB multipath. The incorporation of Additional VDB Subsystems may also mitigate the effects of shadowing on system coverage. Controlling surface movement in the critical areas during CAT I operations can be used to reduce the impact of transient scatterers on the VDB coverage area.

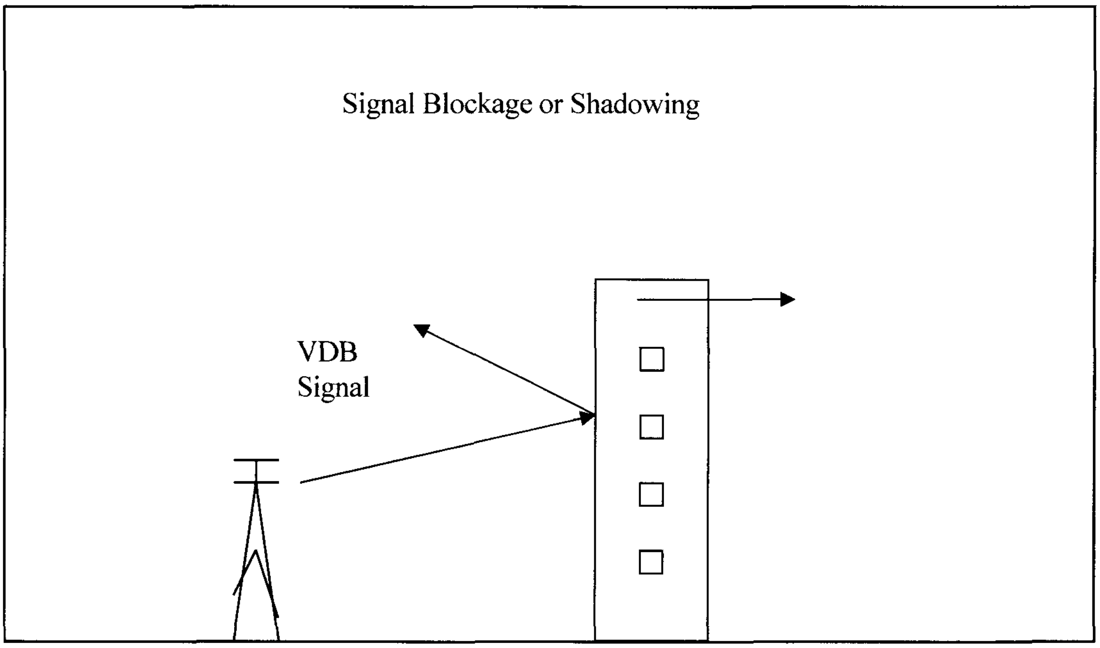

Figure 5-7 VDB non - Ground Reflection and Shadowing

4. Obstruction Zones.

Around each runway there are imaginary safety / obstruction surfaces. These surfaces are defined in FAA AC 150/5300-13, Airport Design and FAR Part 77 Subpart C, Obstruction Standards **[4]**. The size of these surfaces is based on the type of approaches available or planned for the runway. Generally, a runway with precision approach capability will have larger safety / obstruction surfaces than a runway designed for visual approach. GBAS Ground Facility equipment must be sited to avoid penetrating these surfaces.

5. Communication, NAVAID Protection Areas.

Many communication systems exist on the airport with protection areas associated with their function. Examples include:

a. VHF Omni-Directional Radio-Range (VOR).
b. Instrument Landing System (ILS).
c. Airport Surveillance Radar (ASR).
d. Airport Surface Detection Equipment (ASDE).
e. Remote Transmit – Receive Facilities (RTR).

The initial site assessment will identify these areas and assess whether the GBAS Ground Facility will potentially impact other NAVAID's. Should a potential site lie within an existing system keep out area, performance of the existing system and GBAS Ground Facility will be evaluated to the extent necessary to determine and mitigate the effects.

6. Airport Development Plans

Knowledge of an airport's development plans is critical to the siting process as it will identify future operational requirements; as well as potential future sources of multipath or Very High Frequency (VHF) Data Broadcast (VDB) interference. The siting team will identify areas where a high probability of future development exists and work with airport officials to either include or preclude these areas as candidate sites for initial site identification and subsequent formal surveys. The safety/obstruction areas, existing system keep out areas, and future development areas are places to be avoided if possible. Should the initial site assessment reveal that all acceptable sites lie within safety/ obstruction areas, then the site team will undertake exercises to evaluate the impact on existing systems while meeting RR reception and VDB volume coverage requirements. See Chapter 3, Paragraph 2. A, Initial Data Acquisition for additional information.

7. Implementation.

Effective implementation of the critical area restrictions requires the coordinated effort of regional offices,, field offices and airport management. Advise airport
management authorities must be advised of these criteria and request they provide and maintain the necessary signs, holding lines, and other markings delineating the critical areas. In addition, when planning for new installations, on the airport, the plan should include the avoidance of critical area encroachment to existing runways and taxiways. (See latest edition of Advisory Circular 150/5340-1, Standards for Airport Marking, Marking of Paved Areas on Airports, for marking information.) Refer to 2.e, RRA LOCA's, Selective Masking vs. Critical Areas on page 5-10 for information on identifying areas that should be selectively masked or designated as critical. Preference should be given to identifying the area using selective AZ / EL masking.
As a minimum, the airport authority should be advised of the following:

a. Areas that are to be clear of vegetation.
b. The height limitations on where vegetation is permitted and the need for coordinating cutting with the facility operations.
c. Areas and height limitations when snow removal is required.
d. Traffic restrictions/advisories on access roads.
e. The RRA LOCA (dissection) Figure 5-1 RRA LOCA should be reviewed and understood prior to defining selective masking or identifying an area as critical. Individual RRA LOCA's will be assigned as deemed appropriate and/or dictated by anticipated Airport Operations Area (AOA) activity.
f. The GBAS system has monitors to detect excessive movement in the LOCA, and persistent transients. The impact of these protections would be on availability.

Chapter 6 Acronym

ACRONYM	TERM
AC	Advisory Circular
ADO	Airport District Office
AF	Airway Facilities
AGL	Above Ground Level
ALP	Airport Layout Plan
AOA	Airport Operations Area
ASDE	Airport Surface Detection Equipment
ASR	Airport Surveillance Radar
ATC	Air Traffic Control
ATCU	Air Traffic Control Unit
ATSU	Air Traffic Status Unit
AVS	Additional VDB Subsystem
AZ/EL	Azimuth/Elevation
CAT	Category
CEQ	Council of Environmental Quality
CFR	Code of Federal Regulation
CIB	Commercial Instruction Book
CM or cm	Centimeter
CNS	Communications, Navigation and Surveillance
DCP	Differential Corrections Processor
DH	Decision Height
DGPS	Differential Global Positioning System

ACRONYM	TERM
DOT	Department of Transportation
EDDA	Environmental Due Diligence Audit
FAA	Federal Aviation Administration
FAF	Final Approach Fix
FCC	Federal Communications Commission
Fed	Federal
FPO	Flight Procedures Office
FPAP	Flight Path Alignment Point
FTP	Fictitious Threshold Point
GAD	Ground Accuracy Designator
GBAS	Ground Based Augmentation System
GNAS	General National Airspace System
GPS	Global Positioning System
IAP	Instrument Approach Procedure
ICMS	Integrated Control and Monitor System
ILS	Instrument Landing System
LAAS	Local Area Augmentation System
LAL	Lateral Alert Limit
LGF	LAAS Ground Facility
LOS	Line of Sight
LOCA	Local Object Consideration Area
LPL	Lateral Protection Limit

ACRONYM	TERM
LPL_E	Lateral Protection Limit – Ephemeris
LPL_{H0}	Lateral Protection Limit – Fault Free
LPL_{H1}	Lateral Protection Limit – Single Reference Fault
LPL_{H0}	Lateral Protection Limit – Fault Free
LSP	Local Status Panel
LTP	Landing Threshold Point
MASPS	Minimum Aviation System Performance Standards
MDE	Minimum Detectable Error
MDT	Maintenance Data Terminal
MHz	MegaHertz
MI	Misleading Information
MLA	Multipath Limiting Antenna
MOPS	Minimum Operational Performance Standards
MOU	Memorandum of Understanding
NAS	National Airspace System
NAVAID	Navigation Aid
NGS	National Geodetic Survey
NM or nm	Nautical Mile
NSE	Navigation Sensor Error
NTE	Not to Exceed
OFA	Object Free Areas
OFZ	Obstacle Free Zones
OT&E	Operational Test & Evaluation

ACRONYM	TERM
PACS	Primary Airport Control Stations
PC	Phase Center
PCH	Phase Center Height
PVS	Primary VDB Subsystem
R	Radius
RF	Radio Frequency
RFI	Radio Frequency Interference
RNAV	Area Navigation
RR	Reference Receiver
RRA	Reference Receiver Antenna
RRS	Reference Receiver Station
RSA	Runway Safety Area
RTCA	Radio Technical Commission for Aeronautics
RTR	Remote Transmit – Receive Facilities
SACS	Secondary Airport Control Stations
SBAS	Satellite Based Augmentation System
SCAP	Security Certification and Authorization Package
SCAT	Special Category Differential GPS Landing System
SMO	System Maintenance Office
SPS	Standard Positioning Service
SSC	System Support Center
SV	Space Vehicle

ACRONYM	TERM
TERPS	United States Standard for Terminal Instrument Procedures
VAL	Vertical Alert Limit
VDB	Very High Frequency Data Broadcast
VDBA	Very High Frequency Data Broadcast Antenna
VFR	Visual Flight Rules
VHF	Very High Frequency
VOR	VHF Omni-Directional Radio-Range
VPL	Vertical Protection Limit
VPL_E	Vertical Protection Limit – Ephemeris
VPL_{H0}	Vertical Protection Limit – Fault Free
VPL_{H1}	Vertical Protection Limit – Single Reference Fault

Appendix A GBAS PARAMETERS CRITICAL TO ATC OPERATIONS

1. GBAS Integration

Integrity of a system is its ability to detect occurrence of any failure and notify the user within a specified time-to-alarm. The GBAS Ground Facility is designed to ensure the probability of misleading information (MI) is within specification. This is accomplished through allocation of integrity to the GBAS subsystems.

MI is defined as the probability the navigation sensor error (NSE) exceeds the alert limits without an integrity alarm within the required time-to-alarm. NSE is the difference between the user position as determined by the GBAS and the actual user position. The GBAS estimates lateral and vertical NSE through the use of statistical equations. The NSE estimates are termed Lateral Protection Levels (LPL) and Vertical Protection Levels (VPL). There are three LPL's and VPL's computed each epoch:[1]

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[1] **Epoch** - A specific instant in time. GPS carrier phase measurements are made at a given frequency (e.g. every 30 seconds) or epoch rate.

1. Fault-free (LPL_{H0}, VPL_{H0})
2. Single Reference Receiver (RR) Fault (LPL_{H1}, VPL_{H1})
3. Ephemeris (LPL_E, VPL_E)

The maximum value of the three estimates is compared to the Lateral Alert Limit (LAL) and Vertical Alert Limit (VAL) each epoch.

Minimum Aviation System Performance Standards (MASPS) for LAAS RTCA-DO 245 **[6]** provides details on the LPL/VPL.

2. GBAS Integrity Parameters

The airborne system utilizes parameters that are transmitted from the GBAS Ground Facility to compute the values of LPL and VPL. This section describes these integrity parameters and addresses some of the siting considerations relative to these parameters.

a. Sigma pr-gnd (σpr-gnd)

$\sigma_{pr\text{-}gnd}$ is defined as the standard deviation of a normal distribution associated with the signal-in-space contribution of the pseudorange error due to conditions on the ground. The $\sigma_{pr\text{-}gnd}$ quantities provide a statistical measure of ground-based error sources (e.g., multipath, noise) not including errors caused by equipment failures, rare satellite signal anomalies, and ephemeris errors. $\sigma_{pr\text{-}gnd}$ values are utilized directly in the computation of the LPL_{H0} and VPL_{H0} in the Airborne Unit.

The establishment of $\sigma_{pr\text{-}gnd}$ values is a function of the GBAS Ground Facility and will be performed during installation/commissioning. Although the values for $\sigma_{pr\text{-}gnd}$ are not established during siting, they will be estimated during the site survey to minimize risk in the site selection process.

The GBAS Ground Facility is designed so that $\sigma_{pr\text{-}gnd}$ meets the ground accuracy designator (GAD) C-curves shown in Figure A-1 Ground Accuracy Designator (GAD) B and C curves. However, an installed system that does not meet the curve but meets the availability requirements at the site will be acceptable.

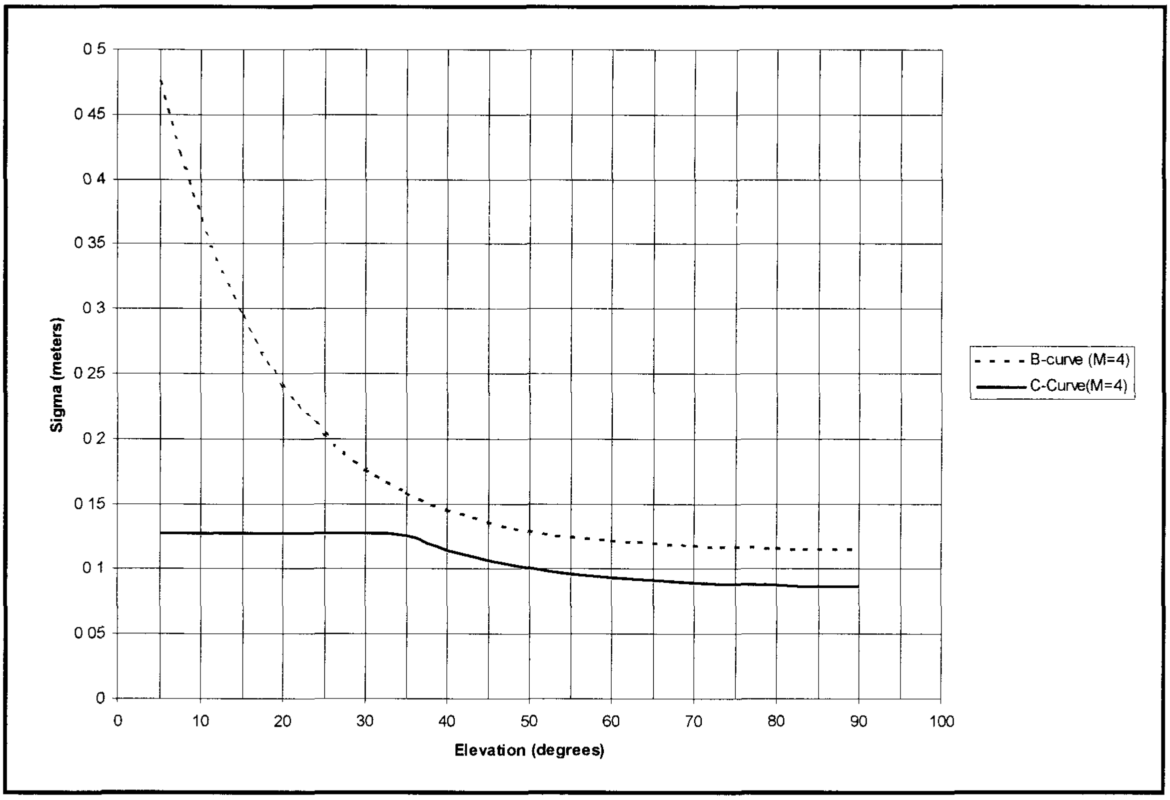

Figure A-1 Ground Accuracy Designator (GAD) B and C Curves

b. B-Values

B-values are the estimate of the instantaneous, vice statistical, error contribution from a single RR on the average pseudorange correction error. B-values are defined as the difference between the broadcast pseudorange corrections and the corrections obtained excluding the specific reference receiver measurements. B-values are utilized directly in the computation of the LPL_{H1} and VPL_{H1} in the Airborne Subsystem.

B-values indicate several ground station error sources. Specifically, the errors that are uncorrelated between Reference Receivers (RR's) are detected and isolated using the B-values. These errors include RR failures and multipath. Those errors that are correlated between RR's cannot be detected by the B-values. The correlation of errors between RR's is related to the separation distance between the Reference Receiver Antennas (RRA's).

c. Ephemeris Decorrelation Parameter (P-Value)

P-values characterize the impact of residual ephemeris errors due to spatial decorrelation for each satellite. P-values are computed by dividing the minimum detectable ephemeris error by the minimum distance to the satellite. P-values are utilized directly in the computation of the LPL_E and VPL_E in the Airborne Subsystem.

d. Distance between RRA Centroid and Decision Height

The estimates of LPL_E and VPL_E are impacted by the distance between the RRA centroid, defined as the geometrical center of the four (4) RRA's, and the Decision Height (DH) for the intended operation. This distance may be a siting constraint at some airports.

3. GBAS Continuity

GBAS Ground Facility continuity is defined as the ability of the system to provide fault-free signal to the aircraft during the period of use, providing that the signal was available to the aircraft at the start of the service.

Continuity requirements for the GBAS are sub-allocated to the continuity of the VDB transmission, and to the continuity of the reference receivers and ground integrity monitors. The GBAS continuity requirements are expressed as a probability that:

The VDB fails to transmit for a period greater than or equal to 3 seconds or,
The number of valid B-values is reduced below three (3) for any valid ranging source.

The GBAS is designed to meet specific sub-allocated continuity requirements in the FAA-E-3017 Non-Federal Specification Category I Local Area Augmentation System Ground Facility. It can be interpreted that the GBAS Ground Facility is designed to meet these continuity requirements in a 'fault-free' siting environment. In an operational siting environment, there are many siting considerations that have an impact on system continuity.

4. GBAS Availability

The broadcast $\sigma_{pr\text{-}gnd}$ shall be such that the GBAS service availability, as defined in Section 2.3.3.2 of RTCA/DO-245A, for a nominal 24-satellite constellation described in the GPS Standard Positioning Service

The following requirement is defined in the 3.2.1.2.8.7 of the Non-Federal Speciation Category I Local Area Augmentation System Ground Facility
"The broadcast $\sigma_{pr\text{-}gnd}$ shall be such that the GBAS service availability, as defined in Section 2.3.3.2 of RTCA/DO-245A, for a nominal 24 satellite constellation described in the GPS Standard Positioning Service Performance Standards, must be at least 0.99."

The availability requirements at a specific airport will be determined by the airport based on the service level required.

The availability attained at the site will be dependent on the satellite constellation visible to the ground facility, the installed RRA performance, potential ephemeris decorrelation effects, and equipment reliability. The satellite visibility is dependent on the geographic location of the airport and obstructions, which can potentially block the satellite signals. The RRA performance is analogous to the parameter $\sigma_{pr\text{-}gnd}$, which will be estimated during the site survey.

5. GPS Reception Capabilities

The GBAS Ground Facility is designed to provide corrections for all ranging sources above 5° elevation. A finite amount of time of continuous tracking is required for initialization and convergence of the smoothing filters before the corrections are approved for broadcast. This initialization time results in a GBAS Ground Facility ranging source reception and continuous tracking capability at an elevation less than 5 degrees for rising satellites.

In the airport siting environment, obstructions and terrain may degrade the GBAS Ground Facility ranging source reception capabilities through blockage of the satellite signals. Further, the GBAS has the capability to mask out sectors of the reception volume to exclude measurements with significant multipath from the correction computation. This technique may be used to reduce the value of $\sigma_{pr\text{-}gnd}$ or to ensure the B-value checks are not rejecting the measurements thereby potentially excluding multiple ranging source measurements and causing a continuity fault.

Any masking introduced will cause a degradation of system availability.

6. Nominal Radio Frequency Interference (RFI) Environment

The GBAS Ground Facility is designed to operate in the nominal interference environment. This is defined in DO-245A Minimum Aviation System Performance Standard for the Local Area

Augmentation System (LAAS). Figure H-1 in this reference defines the Interference Levels at the Antenna Port and Figure H-2 Defines the In-Band and Near-Band Interference Environments.

The siting engineer shall evaluate the interference environment at prospective sites and compare the site results with the RFI mask. RFI characterization and localization should be performed prior to site selection if interference levels above the interference mask are detected.

This means the GBAS Ground Facility will not have a significant degradation of ranging source reception or introduce significant RR measurement errors in the presence of interference that is within the defined interference mask.

Interference with other communications, navigation and surveillance (CNS) systems must be avoided. Sufficient spacing from existing antennas should be maintained to avoid antenna pattern distortion and intermodulation product generation. The transmitted VDB signal must not cause the desensitization of any nearby receivers.

a. Radio Frequency Interference (RFI)

RFI is defined as electromagnetic energy that causes a significant degradation of signal quality.

b. GPS Interference

RFI may cause a degradation of signal quality resulting in a loss-of-lock of the satellite signal and hence has an impact on continuity and availability. FAA-E-3017 **[1]** Non-Federal Specification Category I Local Area Augmentation System Ground Facility specifies the nominal operating GPS interference environment for the GBAS Ground Facility. The GBAS Ground Facility is required to meet all accuracy, integrity, and continuity requirements when installed at a site that meets the RFI requirement.

The siting engineer will ensure the local interference environment meets the requirements in FAA-E-3017 **[1]** Non-Federal Specification Category I Local Area Augmentation System. RFI characterization and localization should be performed prior to site selection if interference levels above the interference mask are detected.

7. Data Broadcast Capabilities

The GBAS Ground Facility is designed to provide the service level necessary to support CAT I operations to applicable runways at a given airport. The VDB is also designed to provide a coverage volume that can encompass the CAT I approach coverage at multiple runway ends. If the VDB design includes the capability to provide coverage for missed approach procedures, practice autolands, and terminal and surface navigation, this should be factored into the coverage volume evaluation.

VDB coverage volume is the volume of airspace where the VDB signal meets the minimum field strength requirements and does not exceed the maximum field strength threshold specified in RTCA/DO-246D, **[10]**. The coverage volume definition assumes that there is no blockage of line-of-sight due to obstructions, and a flat ground plane around the VDB antenna.

Figure 5-6 VDB Coverage Volume illustrates the VDB coverage volume. The region is defined laterally 360° about the antenna out to 23 nautical miles (NM) from the antenna. The region is defined vertically between 10,000 feet (3,048 meters) Above Ground Level (AGL) and a lower surface defined by two intersecting planes:

- The horizontal plane 8 feet above the ground (at the antenna site),
- The plane inclined at 0.9° originating at the 274 feet (83.5 meters) below the ground (at the antenna site).

There are two allowed exclusion zones in the coverage volume. The first exclusion zone allows for field strengths below the minimum requirements directly above the VDB antenna. This zone is defined as a cone with a cone angle not to exceed (NTE) 5° by design. The second exclusion zone allows for field strengths greater than the maximum field strength requirements in proximity to the VDB antenna. This exclusion volume is defined as a cylinder (with a semi-sphere at the top) about the VDB antenna with radius NTE 656 feet (200 meters) by design.

In the airport siting environment, obstructions and terrain may degrade the VDB broadcast and cause nulls in the coverage volume. This Order establishes object clearance areas and critical areas to minimize VDB multipath and shadowing and also establishes coverage priorities to assist the siting engineer in choosing locations for the VDB equipment.

8. Operational Coverage Volumes

a. CAT 1 Coverage Volumes

The GBAS Ground Facility is required to provide at least the minimum field strength throughout the CAT I approach coverage volume for all applicable runway ends. The minimum coverage volume is shown in Figure A-2 CAT I Approach Coverage Volume, and extends:

- Laterally beginning at 450 ft each side of the Landing Threshold Point (LTP) or Fictitious Threshold Point (FTP) and projecting out ± 35° either side of the final approach path to a distance of 20 NM from the LTP/FTP.

- Vertically, within the lateral region (between 10,000 feet [3,048 meters] AGL and a lower surface defined by two intersecting planes: 1) the horizontal plane 50 feet (17.4 meters) above the LTP/FTP, and 2) the plane inclined at 0.9° originating at the LTP/FTP). Obstacle clearance requirements shall also be met in accordance with the United States Standard for Terminal Area Procedures (TERPS).

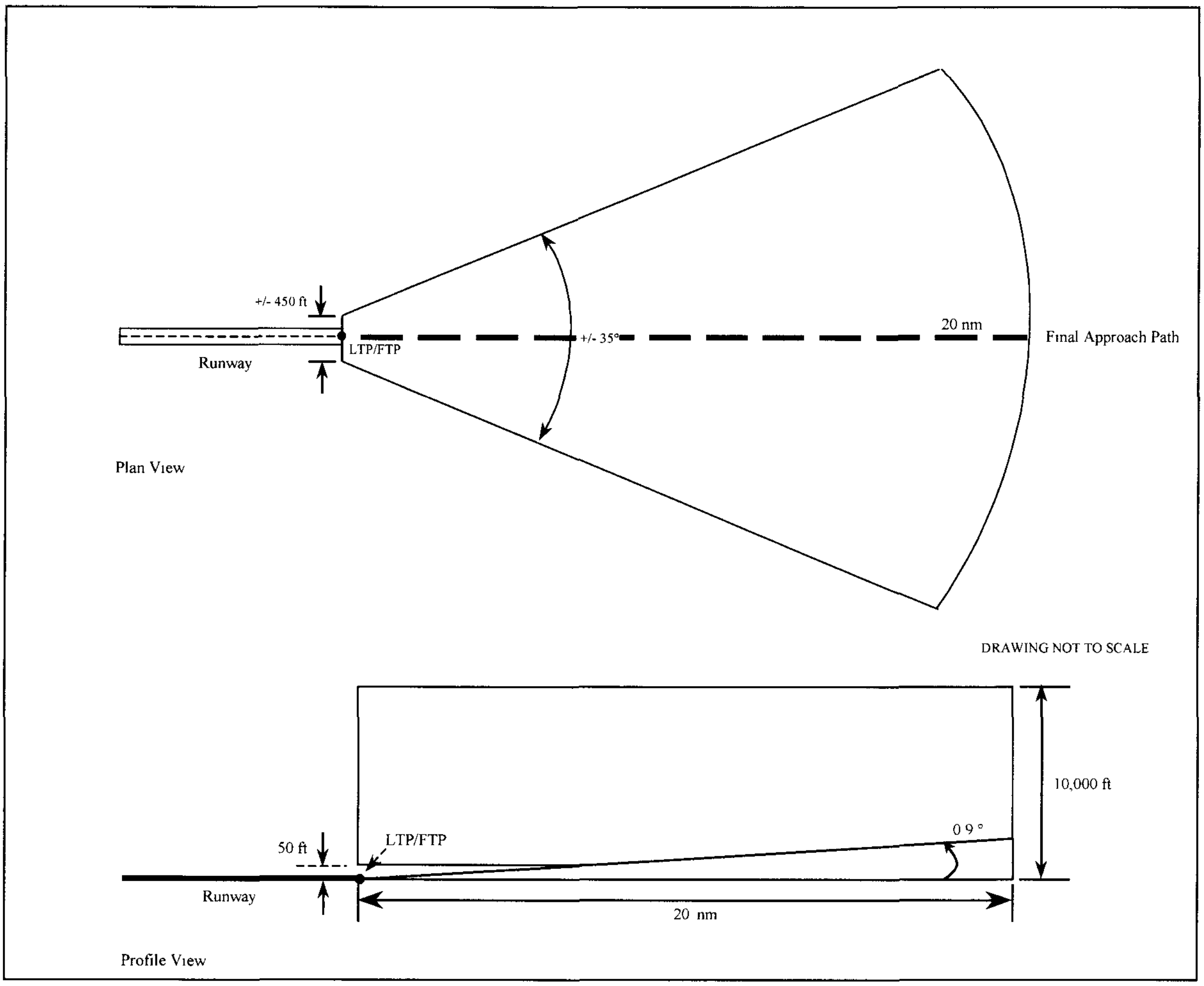

Figure A-2 CAT I Approach Coverage Volume

b. CAT 1 Missed Approach Coverage Volume

Although there is no requirement for positive guidance to be provided by the GBAS Ground Facility in the CAT I missed approach coverage volume, there may be cases where the GBAS Ground Facility can be sited to provide the minimum field strength throughout the CAT I approach coverage volume and the missed approach coverage volume. The minimum CAT I missed approach coverage volume is shown in Figure A-3 CAT I Missed Approach Coverage Volume Vertically, within the lateral region, between 10,000 feet (3,048 meters) AGL and a lower surface defined by two intersecting planes: 1) the horizontal plane 50 feet (17.4 meters) above the LTP/FTP, and 2) the plane inclined at 0.9° originating at the Flight Path Alignment Point (FPAP).

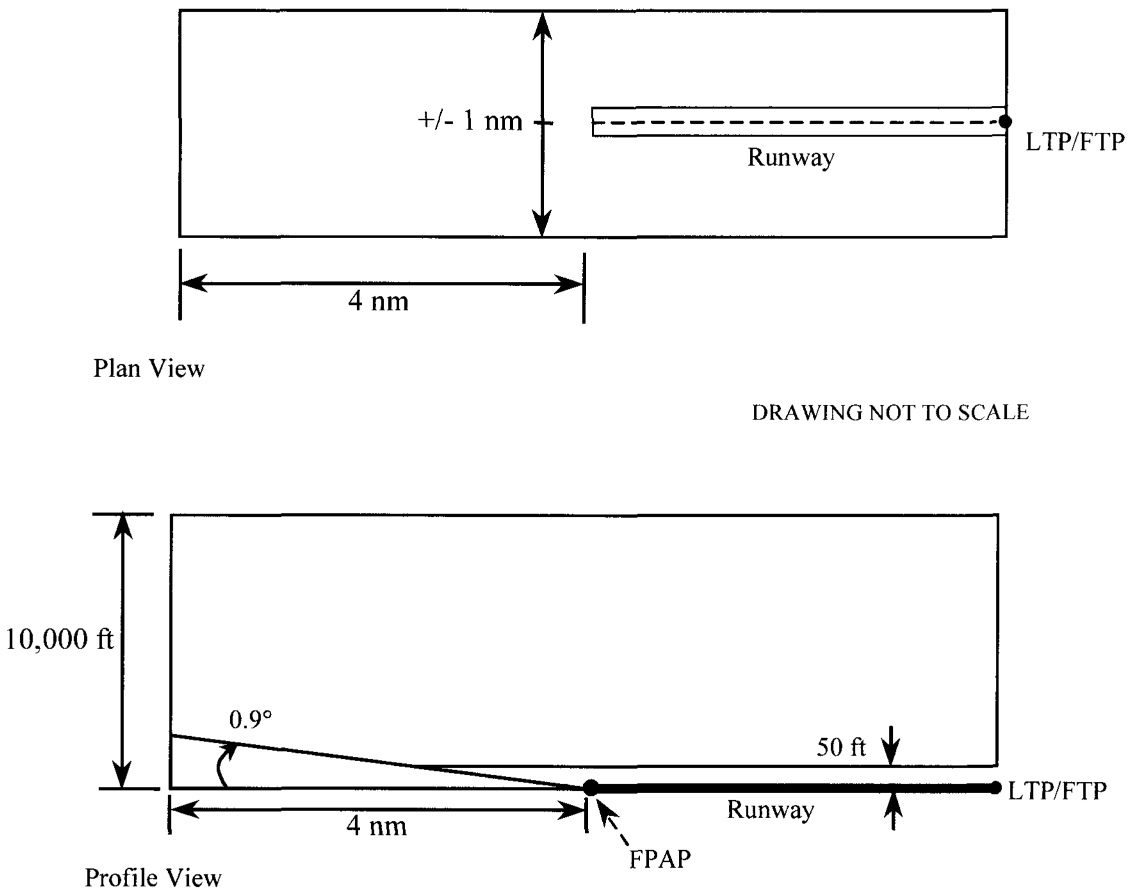

Figure A-3 CAT I Missed Approach Coverage Volume

Appendix B VDB SUBSYSTEM CONFIGURATION OPTIONS

This appendix contains a detailed description of the various VBD subsystem configurations possible in siting the GBAS. The configuration options are presented in order of anticipated prevalence in the field.

1. Standard VDB Subsystem Configuration

The standard Primary VDB Subsystem (PVS) equipment configuration, shown in Figure B-1 Standard PVS Equipment Configuration consists of the VDB electronic equipment housed in the GBAS equipment rack. The VDB antenna is mounted on an antenna platform in proximity to the shelter. The maximum distance from the shelter to the antenna will be dictated by the maximum allowable loss in the cable run.

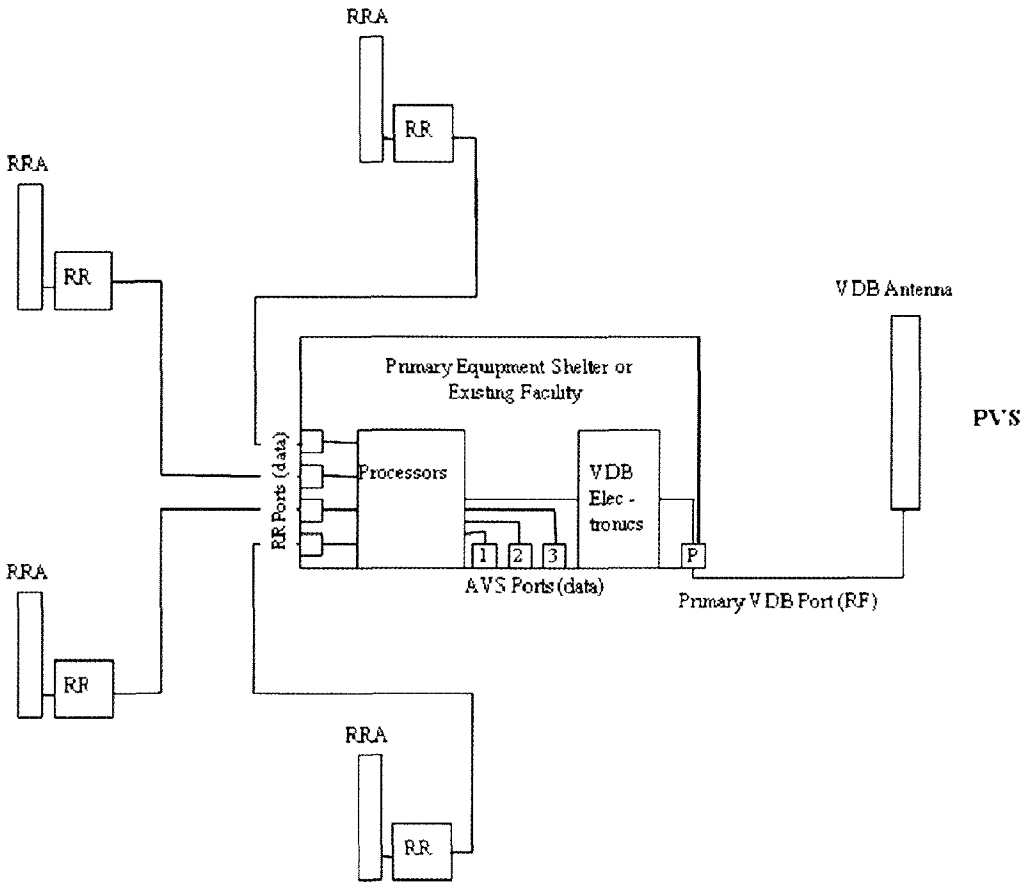

Figure B-1 Standard PVS Equipment Configuration

2. Option 1 - Standard Primary VDB Subsystem with Additional VDB Subsystem

Option 1 consists of the Standard PVS configuration with a one to three AVS's. The AVS electronic equipment is housed in dedicated Secondary Equipment Shelters, or existing facilities and the AVS VDB antennas are mounted on antenna platforms in proximity to the secondary shelters. The AVS's are connected to the GBAS processors located in the Primary Equipment Shelter via data cable. Figure B-2 Option 1: PVS Configuration with two AVS's shows the Option 1 configuration with two AVS's.

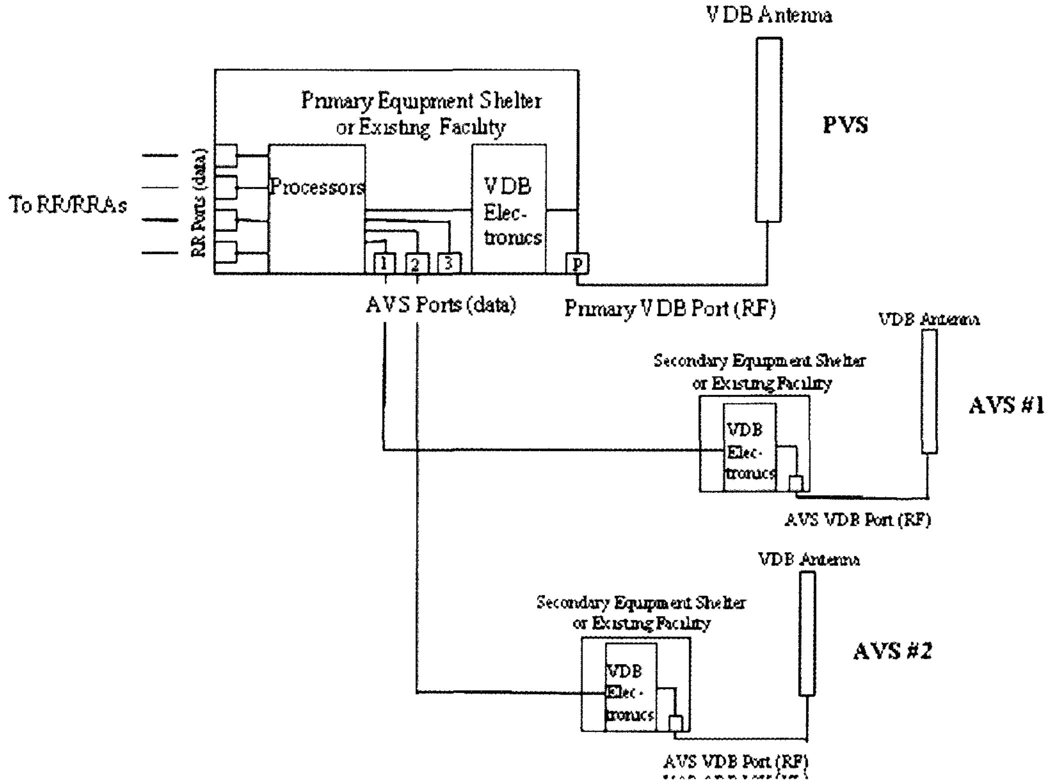

Figure B-2 Option 1: PVS Configuration with two AVS's

3. Option 2 – Non-Standard Primary VDB Subsystem without Additional VDB Subsystem

Option 2 consists of the PVS electronic equipment housed in a dedicated Secondary Equipment Shelter, or existing facility, in proximity to the antenna. The PVS electronic equipment is connected to the GBAS Ground Facility processors located in the Primary Equipment Shelter via data cable. Figure B-3 Option 2: Non-standard Primary VDB Subsystem without AVS depicts this configuration.

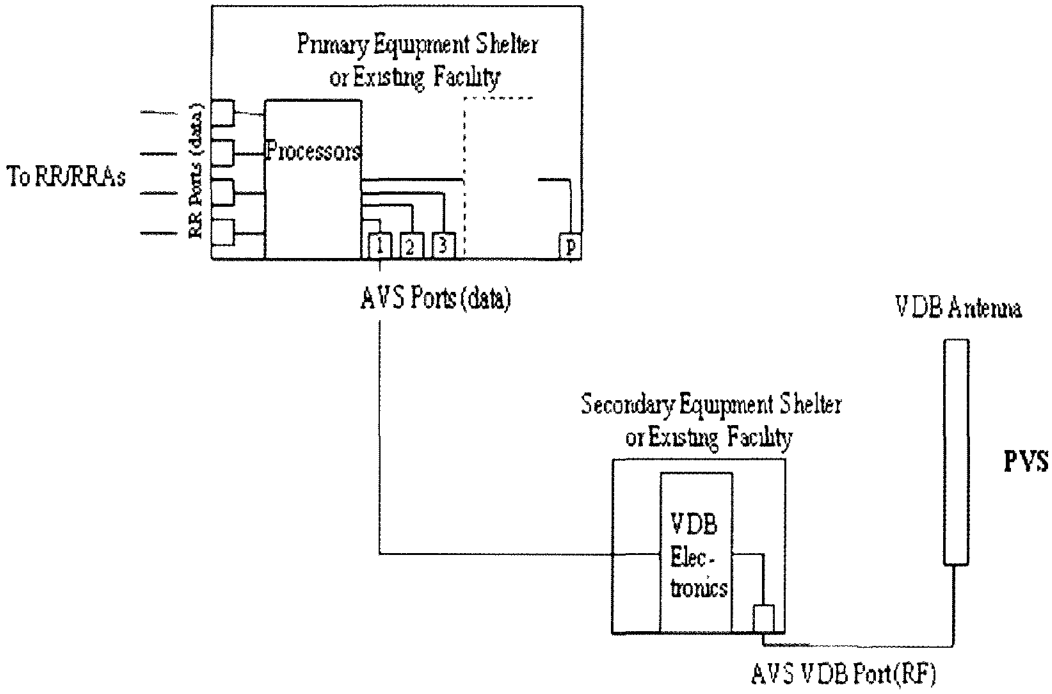

Figure B-3 Option 2: Non-standard Primary VDB Subsystem without AVS

4. Option 3 – Non-Standard Primary VDB Subsystem with Additional VDB Subsystem(s)

Option 3 consists of the Non-standard PVS configuration with one or two AVS's. In this case, there are potentially three shelters, one primary and two secondary, if no existing facilities are used. Figure B-4 Option 3: Non-standard Primary VDB Subsystem with AVS below depicts this configuration with a single AVS.

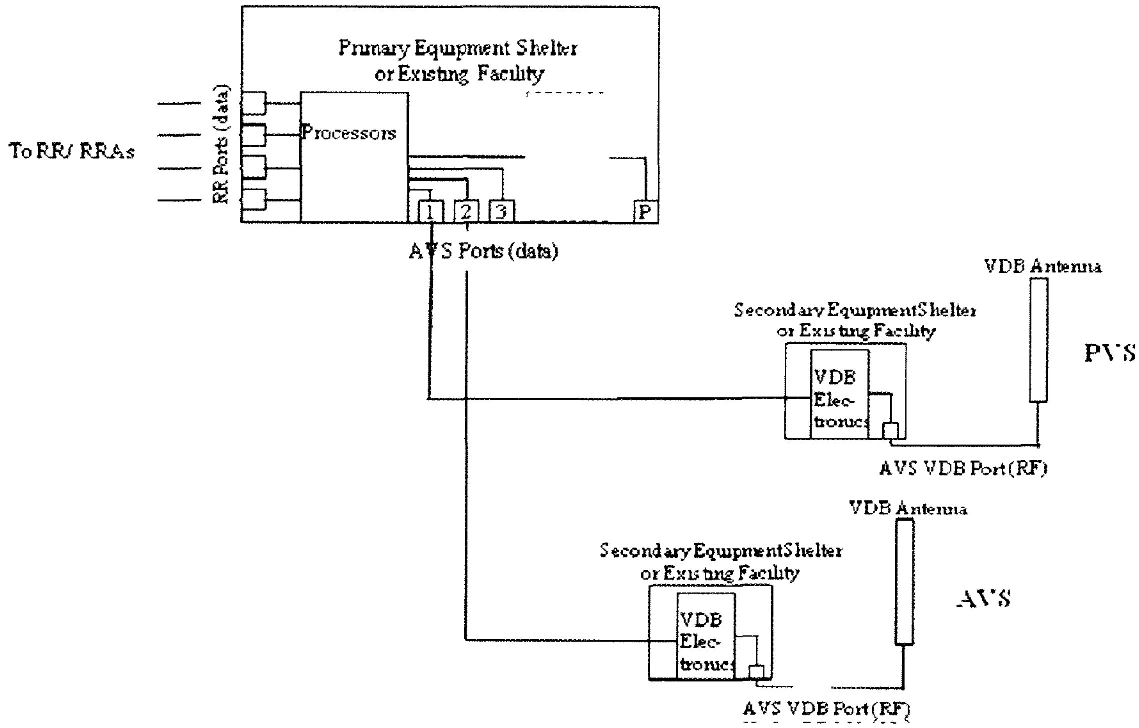

Figure B-4 Option 3: Non-standard Primary VDB Subsystem with AVS

Appendix C DATA ANALYSIS AND MATH MODELING

1. Overview of Data Analysis

Data analysis will be required to support the site selection process. The amount of data analysis required will depend on the nature of the issues at the site. Data analysis activities may include:

(1) Availability Assessment
(2) Pseudorange Correction Error Estimation
(3) Pseudorange Error Correlation Analysis
(4) RFI Analysis
(5) Coverage Volume Field Strength Analysis

2. Math Modeling

Math models are used to predict performance of GBAS subsystems based on transmitter/receiver design, antenna design, electromagnetic properties of the signal, and the propagation environment. The siting engineer shall employ math modeling developed by the equipment manufacturer to develop LGF siting criteria, and to aid in site identification. The equipment specific models should be capable of estimating system performance in the presence of terrain and obstacles. The siting engineer shall validate models with field data. The equipment specific model should include the Reference Receiver Subsystem, the VDB Subsystem, applicable GBAS processing, and the Global Positioning System (GPS) / Satellite Based Augmentation System (SBAS) constellation. The siting engineer should utilize these models to predict performance at prospective sites.

a. GBAS Reference Receiver Station (RRS) Model

The RRS model should have the ability to estimate RRS performance (e.g., smoothed pseudorange accuracy) in the presence of objects and terrain. The model should be able to simulate specular and diffuse reflections and diffraction. The model should be able to take into account the characteristics of the scattering medium, e.g., conductivity and permittivity. The model should also incorporate any receiver-specific multipath mitigation technology as well as any other applicable details of the signal processing used in the receiver. The model should have the capability to vary antenna height to aid in antenna height determination at prospective sites.
The model description should include all model assumptions and provide a listing of all model inputs with associated values, where applicable, used for the simulations.

b. VDB Subsystem Model

The VDB subsystem model should have the ability to estimate VDB performance in the presence of objects and terrain. The model should be able to simulate specular and diffuse reflections and diffraction. The model should be able to take into account the characteristics of the reflecting medium, e.g., conductivity and permittivity. The model should also consider applicable processing techniques used by the VDB receiver that may mitigate the risk from multipath interference, e.g., forward error correction and redundancy checks. The model should have the capability to vary antenna height to aid in antenna height determination at prospective sites.

The model description should include all model assumptions and should also provide a listing of all model inputs with associated values, where applicable, used for the simulations.

c. Availability Model

The availability model should have the ability to compute service availability based on:

(1) GPS/SBAS Constellation

(2) Antenna location(s)

(3) Ranging Source Broadcast Mask

(4) As-installed σ_{pr_gnd} curve

(5) RRA Centroid to Decision Height Distance

(6) All potential airborne equipage (Airborne Accuracy Designator)

The equipment manufacturer's model should use the worst-case subset of three RR's to compute availability. The model should be capable of predicting the duration and frequency of service availability outages.

The equipment manufacturer should describe all model assumptions, including, but not limited to, aircraft equipage (Airborne Accuracy Designator), and constellation assumptions. The equipment manufacturer should also provide a listing of all model inputs with associated values, where applicable, used for the simulations.

Appendix D HONEYWELL SLS-4000 SPECIFIC PARAMETERS

1. RRA to Centroid DH Distance

For the Honeywell SLS-4000 system, the RRA Centroid to DH Distance as defined in c, RRA Centroid to DH Distance on page 3-7 shall be a radius is 3.24 NM (6 kilometers).

2. RRA Placement Parameters

For the Honeywell SLS-4000, the Phase Center height as defined in b(5), RRA Placement Considerations on page 5-6 shall be limited to 13 feet (4 meters).

3. VDB Antenna Safety Area

For the Honeywell SLS-4000, the Radius defining the VDB safety area in c(4), VDB Physical Antenna Installation Consideration Considerations on page 5-16 is 10.feet (3.1 meters)