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November 28, 2008

Mr. Glenn Bissonnette, AJW-331
Manager, Flight Inspection Policy, Practices & Training
Federal Aviation Administration
PO Box 25082
Oklahoma City, OK 73125

Dear Mr. Bissonnette:

Please find enclosed two copies of our report, "Review of Local Area Augmentation System (LAAS) Flight Inspection Requirements, Methodologies, and Procedures for Precision Approach, Terminal Area Path, and Airport Surface Guidance Operations." The submission of this report is intended to fulfill the requirement for the delivery of final project report under Task Order 0002, Contract DTFAAC-03-A-15689.

Please contact us if there are any questions.

Sincerely,

Michael F. DiBenedetto

Michael F. DiBenedetto, Ph.D.
Senior Research Program Engineer

Encl: OU/AEC 07-01TM15689/0002-1; (1 bound copy 1 loose copy)

TECHNICAL MEMORANDUM
OU/AEC 07-01TM15689/2-1

REVIEW OF LOCAL AREA AUGMENTATION SYSTEM (LAAS) FLIGHT INSPECTION REQUIREMENTS, METHODOLOGIES, AND PROCEDURES FOR PRECISION APPROACH, TERMINAL AREA PATH, AND AIRPORT SURFACE GUIDANCE OPERATIONS

The Local Area Augmentation System (LAAS) is a safety-critical ground-based augmentation system based on differential GPS concepts. LAAS is capable of supporting precision approach, terminal area, and airport surface guidance procedures. In order to implement LAAS within the United States National Airspace System (NAS), flight inspection criteria must be developed for these LAAS applications. This paper provides: background material on LAAS; the rationale used for developing the initial flight inspection criteria; an overview of initial FAA flight inspection requirements, procedures, and analysis methodologies for the evaluation of precision instrument approach procedures supported by LAAS; discussion of efficiencies that may be gained during the inspection of an LAAS Ground Facilities servicing multiple runways; draft flight inspection criteria for terminal and airport surface procedures; and, conclusions and recommendations.

by

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October 2008

FAA Aeronautical Center
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Contract DTFAAC-03-A-15689
Task Order 0002 – Final Project Report

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I. INTRODUCTION

The Office of Aviation Systems Standards (AVN) is preparing to conduct flight inspections for Local Area Augmentation System (LAAS) Ground Facilities (LGFs), including the facilities that will be installed in both Guam and Memphis [1]. The certification of an equipment design is in progress and installation of approved equipment is expected to occur early during the year 2009 with commissioning flight inspection to occur shortly thereafter. The initial operational goal for both of these facilities is to provide non-precision as well as precision approach procedures at Guam and Memphis.

In order to facilitate the integration of satellite-based navigation systems into the NAS, standards must be developed based on specific operational requirements and system architectures [2]-[7]. The objective of these standards is to detail, in terms of system-architecture-specific parameters, the minimum performance required to support a given procedure. The standards development process includes the generation of flight inspection criteria [8]. These criteria address the specific system parameters to be assessed and the assessment methodology required to ensure that the installed-system performance is suitable for supporting the intended procedure(s). Such flight inspection criteria must be developed and verified to enable the implementation of the Local Area Augmentation System (LAAS).

Avionics has been involved with FAA flight inspection and flight test work for navigation and landing aids since its inception in 1963. Avionics personnel have conducted many studies for the FAA, including ones for the Office of Aviation System Standards (AVN) specifically related to the development, implementation, and modernization of flight inspection concepts, criteria and procedures. Efforts during this past decade include six separate substantive studies focusing on the development and revision of flight inspection criteria for satellite-based systems [9]-[14]. Avionics personnel have significant experience with the LAAS that includes the development, implementation and assessment of both prototype LAAS receiver and LGF architectures. Avionics currently operates a prototype LFG at the Ohio University Airport (KUNI) and has provided experimental systems to support FAA and NASA flight test activities [15]-[18]. Based on this experience, AVN tasked Ohio in 1999 to conduct a study with the purpose of developing provisional flight inspection concepts for LAAS [10]. The results of this initial study included a recommendation for continued assessment of the concepts as experience is gained. As documented in this report, the current study has two primary objectives. Given nearly a decade has passed since the initial study, the first objective is to provide an independent review of the flight inspection requirements, methodologies and procedures that will be used for the evaluation of LAAS precision approach procedures with Decision Altitudes (DA) of not less than 200 feet Above Ground Level (AGL). The second objective is to develop draft criteria for the evaluation of Terminal Area Path (TAP) procedures and airport surface operations.

Accordingly, this report provides background material on LAAS; the rationale used for developing the initial flight inspection criteria; and the revew of initial FAA flight inspection procedures, evaluation criteria and tolerances. Also, it addresses efficiencies that may be gained during the inspection of an LGF servicing parallel runways, documents a comment received on the related draft criteria, and presents two initial case studies used to investigate that comment.

In the way of new material, this report provides draft criteria for the evaluation of TAP procedures and airport surface operations. This report closes with conclusions and recommendations for follow-on activities.

II. BACKGROUND INFORMATION ON LAAS

This section provides a high-level discussion of the major GPS components and how LAAS is used to augment GPS performance to meet requirements for navigation and landing operations. The key LAAS subsystems are introduced with discussions then focusing on the ground subsystem.

GPS is an integrated system comprised of the following three components: the satellite constellation or space segment; the ground control and monitoring network also knows as the operational control segment; and, the user segment commonly referred to as the GPS receiver [19]. The space segment nominally consists of a 24-satellite constellation with each satellite providing ranging signals and data to the GPS receiver. The operational control segment maintains the satellites in terms of orbital location and functionality, as well as monitoring the health and status of each satellite. Although the satellites are monitored by the control segment, the requisite user alarm or warning functionality typical of navigation, approach, and landing systems is not provided. Further, enhancement of the GPS SPS is normally required to meet the accuracy, integrity, availability and continuity performance requirements for instrument operations.

Enhancement of the GPS SPS can be accomplished by using airborne based augmentation systems (ABAS), satellite based augmentation systems (SBAS), and/or ground-based augmentation systems (GBAS). As referred to herein, LAAS is the specific realization of the GBAS architecture adopted by the United States of America. LAAS is intended to be an all-weather navigation service meeting ICAO Standards and Recommended Practices (SARPS) in terms of performance and interoperability. As illustrated in Figure 1, it consists of the following three primary subsystems: 1) the satellite subsystem; 2) the ground subsystem; and, 3) the airborne subsystem [2]. For LAAS, the satellite subsystem is GPS, which was discussed previously. It provides ranging signals to both the airborne subsystem and the ground subsystem.

As previously stated, the ground subsystem for LAAS is referred to as the LGF [2]. The LGF produces ground-monitored differential corrections for each satellite in view, integrity-related information, and definition of the final approach segment, missed approach, or Terminal Area Path (TAP) based on path point data stored within its local navigation database. These data are transmitted throughout the entire service volume by the VHF Data Broadcast (VDB) transmitter to the aircraft avionics comprising the airborne subsystem. Thus, LAAS is capable of providing service simultaneously to all aircraft in the service volume. Also, the LGF provides for both local and remote status, control, and maintenance interfaces.

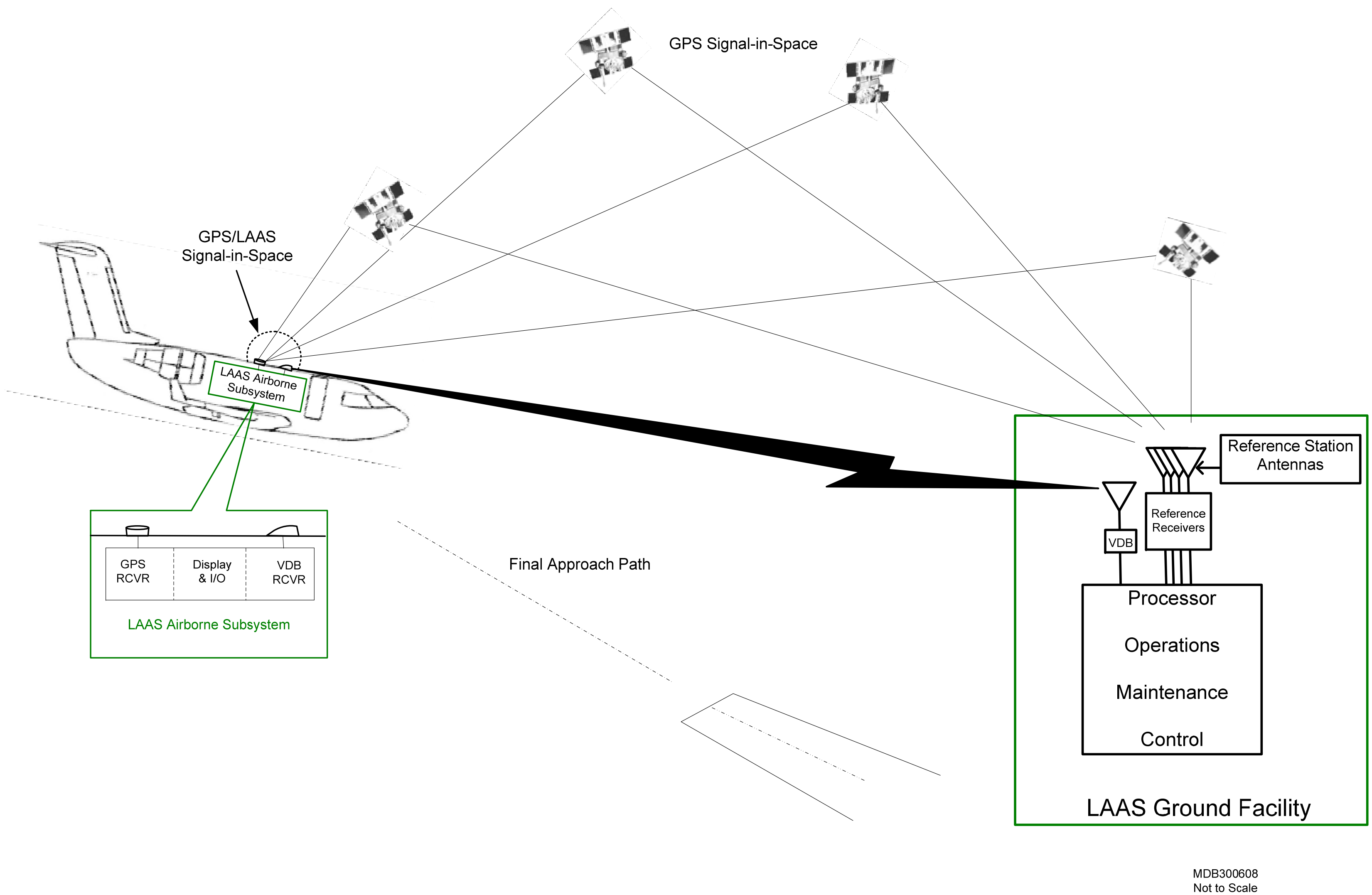

Figure 1. Illustration of LAAS subsystems.

The airborne subsystem applies the LGF-generated differential corrections to the GPS ranging signals to obtain a differentially-corrected position solution with the required accuracy, integrity, continuity, and availability. In addition to the integrity information broadcast by the VDB, the airborne subsystem also employs Receiver Autonomous Integrity Monitoring (RAIM) as a means of GPS ranging signal fault detection on the airborne side [20]. The more-precise position solution and the path point data transmitted by the VDB are used to calculate lateral and vertical guidance with respect to the final approach path (precision approach), TAP or other supported instrument procedures. Proportional guidance deviation outputs, in “ILS look-alike” fashion, are provided to aircraft displays and navigation systems. The airborne subsystem also provides appropriate annunciations of system performance to the user, e.g., alerts and flags. In addition to deviation outputs, a position-velocity-time (PVT) output with integrity is provided to support enhanced navigation and surveillance operations.

In general, LAAS provides a flexible positioning service capable of supporting precision approach, TAP, departure procedures, airport surface operations, and enhanced area navigation (RNAV). It enables “precision RNAV” in the terminal area that provides the level of navigation serviced required for supporting curved arrival, approach, and departure procedures. The position accuracy is well suited for supporting airport surface operations by enabling both enhanced situational awareness and electronic guidance. The PVT output can be used to support surveillance applications within local and terminal areas; it can be used as a source of position information for Automatic Dependent Surveillance-Broadcast (ADS-B) equipment.

The objective of a commissioning LAAS flight inspection is the evaluation of a particular LGF and all of the instrument flight procedures to be supported by that facility [8][21][22]. The rationale for this objective is discussed further in the following section. Since the inspection activity is “LGF-based”, the LGF and related matters will be discussed in more detail at this point.

LAAS is intended to provide radio navigation vertical and lateral guidance for instrument precision approach and landing from 20 nm from the runway threshold through touchdown and rollout. It will nominally require only one LGF at an airport to provide service to all runways and aircraft in the service volume. The ground subsystem will be modular and will have appropriate redundancy to support all runway ends, and it is capable of being installed entirely on the airport. An LGF generally consists of the following four main equipment groups: reference receiver; VDB equipment; processor; and operations and maintenance.

The reference receiver group usually consists of four reference receiver stations, each station containing a GPS reference receiver, a reference receiver antenna, associated cables, equipment racks, and antenna mounts. The reference receivers may be located in an environmentally controlled shelter or individual equipment enclosures located in proximity to the reference receiver antenna. Although there are limitations on the location of the reference receiver antennas relative to the runways being serviced, they are not constrained to be in close proximity (i.e., 1,000 feet) to those runways. The reference receiver antennas should be sited in protected, low-multipath (GPS signal reflection) locations with an unobstructed view of the sky.

The VDB equipment group consists of the VDB transmitter, antenna, monitor, associated cables, equipment racks, and antenna mounts. Although it may be preferable from a logistic view point to site the reference receiver antennas and VDB antenna in the same location, the VDB antenna may be independently sited to provide adequate signal coverage. If required, two or more VDB equipment groups can be used to satisfy coverage requirements at complex airports or airports having coverage-related siting issues. The use of multiple VDB groups is one method for satisfying both airborne and airport surface coverage requirements, since antenna installation requirements differ in the case of airborne versus surface coverage.

The processor group consists of dedicated micro-processors, operationally pertinent data, software that performs the differential correction computations and integrity processes, and VDB message generation functions, as well as human interfaces (display), associated communication cables, and equipment racks. Operationally pertinent data includes the navigation database containing the all procedure data that is broadcast to users within the LAAS service volume. This group is housed in the primary LGF equipment shelter, which may also contain the reference receivers.

The operations and maintenance group includes equipment to perform those control and status functions normally required for a landing aid. This group includes items such as a local status and control panel, maintenance data terminal/terminal interface, remote status panel/interface, and an air traffic control unit/interface.

It is important to realize that LAAS uses an earth-centered, earth-fixed (ECEF) reference system based on the WGS-84 datum instead of being source-referenced like conventional radio navigation systems. Because of this, reference receiver antenna locations, runway threshold coordinates, obstacle locations, and all path point data must be accurately surveyed relative to each other. Further, if the coordinates for these items are surveyed separately by different entities and/or accomplished over an extended period of time, then accuracy of the absolute coordinates becomes important.

III. LAAS INSPECTION CRITERIA DEVELOPMENT

This section discusses the impetus for developing flight inspection criteria for LAAS. Next, the design and site qualification activities that are assumed to be accomplished prior to flight inspection are overviewed, as well as the rationale employed when developing the initial FAA LAAS flight inspection criteria. This section concludes with an overview of when flight inspection should be conducted and discussion of system accuracy assessment during flight inspection.

In order to facilitate the integration of LAAS into the NAS, standards must be developed based on specific operational requirements and system architectures. These standards provide, in terms of system-architecture-specific parameters, the minimum performance required to support a given operation. The standards development process includes the generation of flight inspection criteria. These criteria address the specific system parameters to be assessed and the assessment methodology employed to ensure that the installed-system performance is suitable for supporting the intended instrument flight procedures (IFPs). Such flight inspection criteria must be developed and verified to enable implementation of LAAS.

The FAA effort to develop LAAS flight inspection criteria was initiated nearly a decade ago with the identification of four distinct activities to be accomplished [21]. The first activity involved identifying those system-specific parameters that should be recorded during flight inspection of LAAS IFPs. Once the identification of parameters was completed, the next activity was to develop candidate methodologies for assessing the data collected for these parameters, as well as specifying other evaluations to be performed (e.g., obstacle evaluation). This activity includes determining tolerances and other conditions that must be satisfied for a facility or procedure to be put in service. The third activity is the development of flight inspection criteria and procedures that ensure a thorough yet efficient inspection of the service volume and IFPs. That is, how to accomplish effective, meaningful sampling of the service volume. The final activity is verification of the inspection criteria and procedures. This activity is accomplished through implementation of the criteria and procedures, which provides the opportunity to assess the technical merit of the specific parameters considered, data collection and assessment methodologies utilized, and any implementation issues that may arise during the actual application of the criteria. Additionally, revision of the criteria and procedures to improve effectiveness and efficiency may occur as operational experience is gained with a given system.

Developing effective LAAS flight inspection criteria requires understanding what other test and qualification activities will be accomplished and the objectives of those activities. Thus, an overview of the activities that are assumed to be accomplished prior to flight inspection will be discussed at this point.

LAAS receiver standards specify performance requirements, the manner in which data transmitted by the VDB is to be used, and that receivers shall not provide hazardously misleading information in the presence of Radio Frequency Interference (RFI) [22]. Thus, it is assumed the receiver design approval process and installation qualification procedures ensure compliance with the receiver standards in the operational environment.

Similar standards and guidance material exist for the LGF [2][22]. Specifically, it is assumed the aggregate of the system design approval, site qualification activities, and installation qualification procedures successfully accomplish the following:

- Verifying suitable GPS signal level and signal quality exist at each reference receiver antenna site;

- Ensuring installation and systematic errors are addressed such as accurate determination of each reference receiver antenna phase center or that the maximum use distance parameter (D_{max}) is set appropriately;

- Addressing/monitoring long term variation in range error due to environmental changes; and,

- Ensuring data sampling intervals, techniques and spatial correlation between reference receiver antennas are addressed as required to ensure compliance with accuracy and integrity requirements.

Based on the system design approval and installation qualification procedures discussed above, it should be realized that LAAS flight inspection criteria are not intended to, nor required to, provide an assessment of either LGF or LAAS receiver equipment performance. Once design approval and installing qualification procedures are completed, one relies on the monitoring and built-in tests inherent to the equipment to detect and announce faults.

Thus, the development of FAA LAAS flight inspection criteria is based on the need to assess the site-specific elements of a LAAS instrument approach procedure and to confirm service availability. Specifically, flight inspection is used to confirm procedure design, final segment alignments, obstacle clearance, GPS signal reception, and VDB signal reception within the coverage volume. Flight inspection should be performed for the following situations [21][22]:

- Prior to commissioning on each runway served for each procedure;

- Periodically to ensure there has been no notable degradation of GPS signal reception and VDB coverage in operationally utilized airspace;

- When interference is reported or suspected and elimination of the interference cannot be verified by ground-based testing;

- Existing procedures are revised or new procedures are introduced at an operational facility;

- Whenever changes to the LGF configuration are made such as hardware/software changes having the potential to affect the internal navigation database or coding/construction of the VDB messages, changes in reference receiver and/or VDB antenna phase center locations, or change in VDB antenna type; and,

- Whenever physical changes occur at the site having the potential to effect GPS signal reception and VDB coverage, such as new obstructions or construction.

Requirements for commissioning, periodic and special inspections for approach procedures are already contained in the FAA draft LAAS Order, which is discussed in the next section. Thus, discussion of these requirements is not repeated here.

Although the FAA LAAS flight inspection criteria specifies which parameters are measured and under which conditions, this section will close with a short discussion of assessing system accuracy as it pertains to flight inspection. Traditionally, system accuracy is measured and assessed during the flight inspection of ground-based navigation aids. However, LAAS system accuracy is time varying on a sub-hourly basis due to variation in satellite geometry. Thus, LGF accuracy tests must be accomplished continuously, which is only feasible by conducting ground-based assessments. Further, the LGF accuracy performance is specified in the range domain, thus testing and monitoring in the range domain is required to ensure compliance with the accuracy requirement. Although a flight inspection recording showing in-tolerance accuracy performance is not a sufficient condition for verifying system performance, it is a necessary condition. Thus, position domain accuracy measurements performed during flight inspection can provided a meaningful functional check.

IV. OVERVIEW OF FAA DRAFT ORDER 8200.LAAS

This section provides an overview of FAA draft Order 8200.LAAS [8]. This draft order contains initial FAA flight inspection procedures, requirements, and analysis for the evaluation of LAAS precision instrument approach procedures. The current version of the order is applicable to the evaluation of procedures with DAs of not less than 200 feet AGL. Since the development of preliminary criteria for TAP procedures and airport surface procedures supporting enhanced situational awareness was planned at the time this version of the draft Order was produced, sections in the order have been reserved for inclusion of this material when available. Similarly, as Category II/III LAAS equipment becomes available or as additional operational experience is gained, this order is expected to be reviewed and revised as appropriate.

In addition to the cover letter, FAA draft Order 8200.LAAS consists of the following four appendices: Appendix 1 - Background Material for LAAS; Appendix 2 - Flight Inspection Evaluation of LAAS Instrument Approach Procedures; Appendix 3 - Records and Reports Required for LAAS Flight Inspection; and Appendix 4 - Acronyms and Definitions. The introduction section of this paper is based heavily on the material contained in Appendix 1. The material for Appendix 3 is under development, and draft material for this appendix is not available in the current version of the order. Thus, the focus of this section is to provide an overview of Appendix 2, which addresses pre-flight requirements; flight inspection procedures for commissioning, periodic and special inspections; data analyses and evaluations to be performed; and tolerances.

A. Pre-flight Requirements

The material contained in Order 8200.LAAS on pre-flight requirements focuses on those items specifically related to preparing for a LAAS flight inspection and captures general preparation requirements by reference to FAA Order 8200.1 [7]. Requirements for calibration of the flight inspection system draws attention to the fact the VDB antenna may radiate both horizontally and vertically polarized signals, thus calibration of both antennas on the flight inspection aircraft are to be performed. The next item addressed is determining the LGF maximum use distance (D_{max}) since this parameter influences the distance at which orbit maneuvers are performed. The LAAS Final Approach Segment (FAS) data blocks, which have been developed and coded into binary data files by the procedure designer, are to be downloaded to removable disk media. Flight inspection system access to each FAS data block is confirmed before mission departure, including confirmation that the Cyclic Redundancy Check (CRC) remainder is correct to ensure no errors occurred during data transfer.

Additional pre-flight requirements exist for the inspection of an LGF supporting parallel runways, and these requirements center on defining approach sectors. An approach sector bounds the area of airspace common to all the approach procedures having the same approach and landing direction. Thus, a set of parallel runways will have two approach sectors associated with them, one for each landing direction. The methodology for evaluation of the approach sector, as opposed to assessing each runway end individually, permits sufficient assessment of each approach procedure while improving the efficiency of the inspection by eliminating redundant VDB coverage assessments.

The first step in defining an approach sector is determining the coordinates of the Fictitious Approach Sector Alignment Point (FASAP) and Fictitious Approach Sector Landing Threshold Point (FASLTP) for each approach sector. The approach sector centerline runs parallel to the runway centerlines and is located midway between the centerlines of the two outer-most runways (see Figure 2). The FASAP and FASLTP are located abeam the furthest most runway stop end and threshold, respectively, and on the approach sector centerline as illustrated in Figure 2.

The second step is to determine the four coordinates for the left and right limit boundaries of the approach sectors for each set of parallel runways. The right limit boundary is defined by a radial rotated 10˚counterclockwise from the controlling runway centerline. The left limit boundary is defined by a radial rotated 10˚clockwise from the other controlling runway centerline. The final step is to determine the Right Boundary Alignment Point #1 (RBAP1), Right Boundary Alignment Point #2 (RBAP2), Left Boundary Alignment Point #1 (LBAP1), and Left Boundary Alignment Point #2 (LBAP2) as indicated by Figure 3.

B. Flight Inspection Procedures

This portion of Appendix 2 provides the flight inspection procedures for commissioning, periodic, and special inspections. The check list for initial or commissioning inspections includes material addressing the evaluation of VDB coverage and the LAAS instrument approach procedures to be supported. This material will be discussed first, followed by discussion of requirements for periodic and special flight inspections.

VDB Coverage Assessments: The service volume for LAAS is constrained by both the Radio Frequency (RF) signal coverage provided by the VDB antenna(s) and the maximum use range (D_{max}) from the LGF for which the broadcast differential corrections are applicable. Thus, the RF signal coverage of the VDB must encompass the area of intended terminal and approach operations. Since the outer limit of the service volume is defined by D_{max}, D_{max} must also be set appropriately for each facility. Facility-based coverage assessments are specified to evaluate both the VDB RF signal coverage and the suitability of the value used for D_{max}. In addition, procedure-based coverage assessments are specified for evaluating RF signal coverage within the service volume for procedurally significant airspace. Coverage assessments are performed with the VDB power output at the alarm limit and coverage is validated for both horizontally and vertically polarized signals. The coverage evaluation is based on loss of signal and data continuity alerts, and this evaluation methodology is based on current inspection equipment capabilities. The implementation of this methodology will require the development and validation of a procedure for calibration of flight inspection equipment to ensure that VDB data

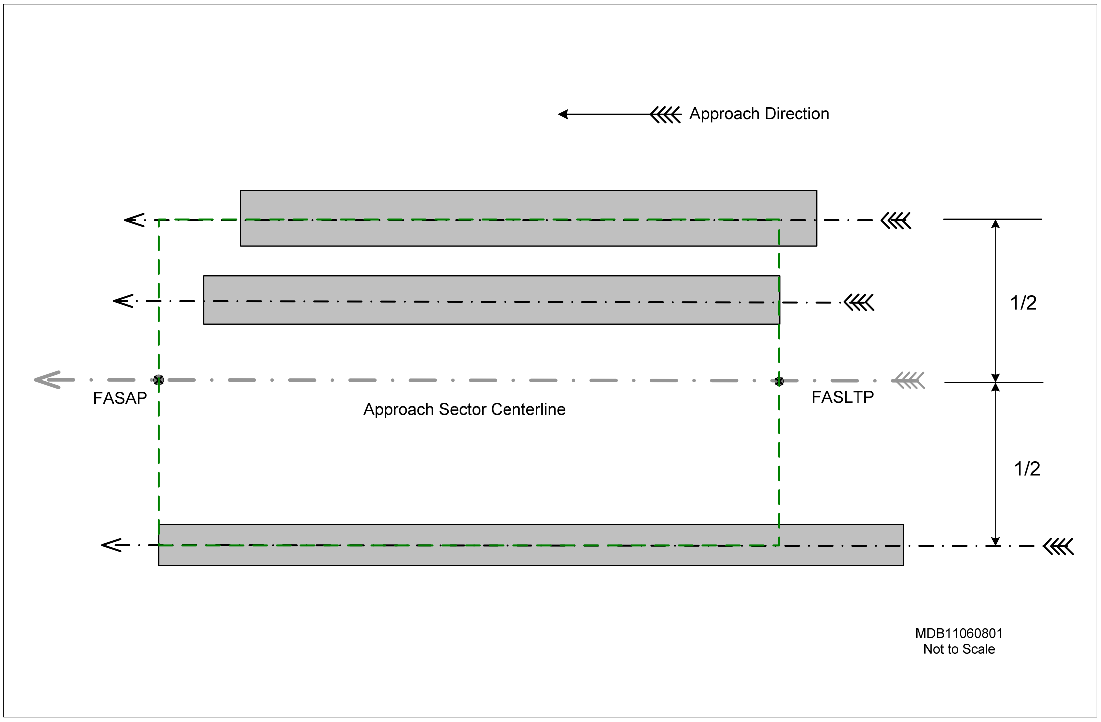

Figure 2. Determining Approach Sector Centerline, FASAP, and FASLTP.

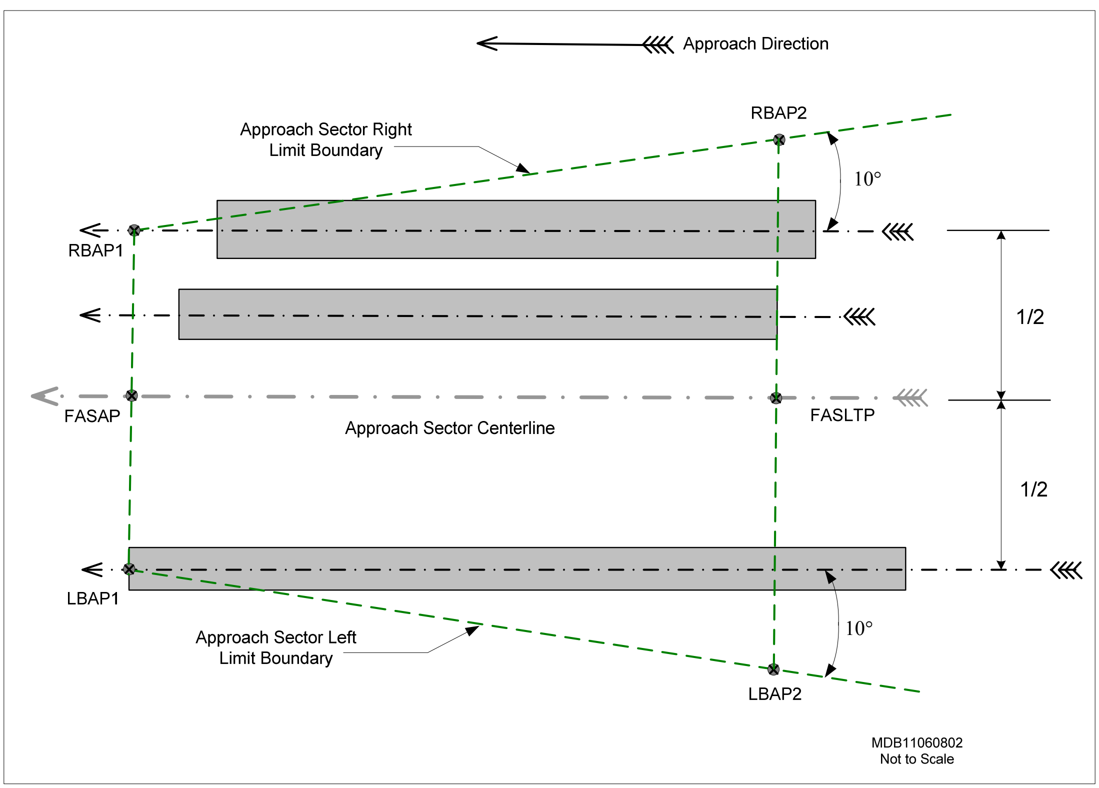

Figure 3. Determining Right/Left Boundary and Boundary Alignment Points.

continuity alerts occur whenever the VDB signal strength is not assured to meet or exceed ICAO requirements. Since this methodology will have to accommodate the variations in the gain of the VDB antenna pattern on the flight inspection aircraft, this methodology may provide an overly conservative assessment of signal strength; thus, fully compliant facilities may inadvertently end up with restrictions on occasion.

As the previous paragraph states, coverage assessments are currently based on loss of signal and data continuity alerts, and this evaluation methodology is based on current inspection equipment capabilities. This method does not provide a direct assessment of signal strength against power density requirements. This situation results in the dilemma of what should be done to properly assess coverage requirements and temporarily settling for what can be done due to current equipment limitations. During the course of this study, the author has discussed this dilemma on several occasions with FAA flight inspection personnel. These discussions indicate they have realized for some time that there is a need to transition to a capability that allows for measurement of signal strength so power density requirements can be thoroughly assessed. VDB receivers that have an Automatic Gain Control (AGC) or signal strength output have been available for some time, but the author's experience back in the year 2000 time frame was these units were all 19" rack mount prototype units [15]-[18]. Since the technical capability to make such measurements exists, developing the required capability from a technical perspective hinges on the FAA allocating sufficient funding to cover the cost of identifying a receiver suitable for flight inspection applications (quality, size, weight, power, I/O), procurement of equipment, installation and calibration of the system, the development and validation of calibration procedures, et cetera. Additionally, the results of the associated cost-benefit analysis will influence what path is taken forward.

Facility-based coverage assessments consist of orbits flown at the extremes of the LGF service volume (D_{max}). Two orbits are required for initial coverage evaluations. One orbit is flown at the lower coverage limit as computed using the criteria provided. Since the typical value for D_{max} is 23 nm, this orbit will normally be flown at 2,300 feet above site level. A second orbit is flown at 10,000 ft above site level. Clear line-of-sight (LOS) from the VDB transmit antenna to the lower extreme coverage limit may not exist for the entire 360 degrees of azimuth. Such situations may cause unavoidable outages of the VDB signal during inspection of the lower coverage limit. In this case, an additional orbit, partial or whole as required, is performed at the lowest altitude where clear LOS from the VDB transmit antenna to the lower extreme coverage limit exists for the entire 360 degrees of azimuth.

Procedure-based coverage assessments are intended to verify coverage along TAP procedures, initial and intermediate approach segments, final approach segments, missed approach segments, and on the airport surface. These VDB coverage assessments are performed with the power output at the RF power alarm point. Detailed evaluations are performed to assess coverage for each instrument approach procedure. Table 1 provides the requirements for assessing VDB coverage for each approach procedure and is based primarily on recommendations from Reference [3]. The maneuvers listed in Table 1 are intended to provide assessment of the coverage requirements illustrated in Figure 4. For LGFs servicing multiple runways, each approach procedure shall be evaluated in accordance with Table 1, except for the case of parallel runways.

When the LGF to be evaluated supports approach procedures to parallel runways, approach sectors are defined, one for each landing direction. Table 2 provides modified requirements for assessing parallel runway configurations, and the measured values are the same as those specified in Table 1.

Instrument Approach Procedures Assessments. All instrument procedures are required to be evaluated to ensure flyability and safety. The evaluation and analysis for the Standard Instrument Approach Procedures (SIAPs) are included by reference to FAA Order 8200.1 [7]. In addition, the following requirements are set forth in draft Order 8200.LAAS:

- Initial and Intermediate Approach Segments: The procedure is flown from the Initial Approach Fix (IAF) to the Final Approach Fix (FAF), maintaining procedural altitudes. The evaluations performed include obstructions, procedure design, supporting navigation systems, and VDB coverage where required.

- Final Approach Segment: The final segment is flown at procedural altitudes until intercepting the glidepath, and then the aircraft descends on the glidepath to the Landing Threshold Point (LTP) and Fictitious Threshold Point (FTP). Evaluations performed include obstructions, procedural design, horizontal alignment, glidepath alignment, and VDB coverage. Procedures that support azimuth only approaches shall be evaluated to the Missed Approach Point (MAP).

- Missed Approach Segment: The missed approach procedure is flown from the MAP using the procedural waypoints or associated navigation systems. Evaluations performed include obstructions, procedural design, transition to the missed approach, and VDB coverage.

Periodic Inspections. In general, the need for periodic flight inspection stems from the fact that as time passes system performance can degrade from that measured during the commissioning inspection or the obstacle environment may change. The typical causes for system degradation and methods for mitigating those causes are discussed in references [23] and [24]. Those causes mitigated by periodic flight inspection include a change in the environment and Radio Frequency Interference (RFI).

For LAAS, the purpose of periodic inspection is to ensure that there has not been any degradation of VDB coverage due to environmental changes and to ensure that new sources of RFI have not come into existence. Draft Order 8200.LAAS states that commissioned facilities are initially required to be inspected on a 360-day interval. The interval used for subsequent periodic inspections may be increased based on both performance of the individual facility and as NAS-wide experience with LAAS is gained. Since the primary concern is degradation of VDB coverage due to environmental changes (e.g., signal blockage by a new obstacle), it is anticipated that the basic interval will migrate towards 540 days, which is consistent with the interval used for approach obstacle verification [7]. VDB coverage is evaluated at the altitude established for the lower orbit during commissioning, and the evaluation is based on loss of signal and data continuity alerts. For each SIAP, the LGF broadcast FAS data block CRC will be checked to ensure there has been no change or corruption.

Table 1. VDB Approach Coverage Assessment – Single Runway (See Note 3).

Requirement	Evaluation Area	Method	Evaluation Criteria
Normal Approach	From 20 NM to LTP	Fly on path, on course	1) LAAS Receiver maintains "GBAS" Integrity 2) No CDI Flags
Lower-Limit of Approach	From 20 NM to LTP	From 21 NM and 5000 above LGF, fly on course, intercept and fly glide path within 1 dot of full scale below path	Same as above Note 1 Note 2
Upper-Limit of Approach	From 20 NM to LTP	From 21 NM and 8000 above LGF, fly on course, intercept and fly glide path within 1 dot of full scale above path	Same as above Note 1 Note 2
Left-Limit of Approach [Note 4]	From 20 NM to LTP	From 21 NM, fly on path and offset course to within 1 dot of full scale of "fly right"	1) LAAS Receiver maintains "GBAS" Integrity 2) No CDI Flags Note 2
Right-Limit of Approach [Note 4]	From 20 NM to LTP	From 21 NM, fly on path and offset course to within 1 dot of full scale of "fly left"	1) LAAS Receiver maintains "GBAS" Integrity 2) No CDI Flags Note 2
Coverage from the Minimum Vectoring Altitude (MVA) [Note 4]	From 20 NM to 7° glide path	From 21 nm, on course and the MVA or 2,300 feet above LTP, which ever is higher, fly at level altitude until 7-degree path	1) LAAS Receiver maintains "GBAS" Integrity 2) No CDI Flags Note 2
Coverage from Upper Service Volume [Note 4]	From 20 NM to 7° glide path	From 21 nm, on course and 10,000 feet above LTP fly at level altitude until 7 degree path	1) LAAS Receiver maintains "GBAS" Integrity 2) No CDI Flags Note 2
Missed Approach	From Runway Stop End to 4 NM	Fly runway course, climb at 200 feet per NM	1) LAAS Receiver maintains "GBAS" Integrity 2) No CDI Flags
Roll Out	From Runway End to Runway End	Taxi along runway	1) LAAS Receiver maintains "GBAS" Integrity 2) No Lateral CDI Flags

Note 1: Determine that guidance is available and the CDI is active at the upper and lower vertical procedure extremities.
Note 2: Determine that guidance is available and the CDI is active at the lateral procedure extremities.
Note 3: VDB transmitter power set at the lower limit of the VDB monitor.
Note 4: See Table 2 for requirements when evaluating parallel runway configurations.

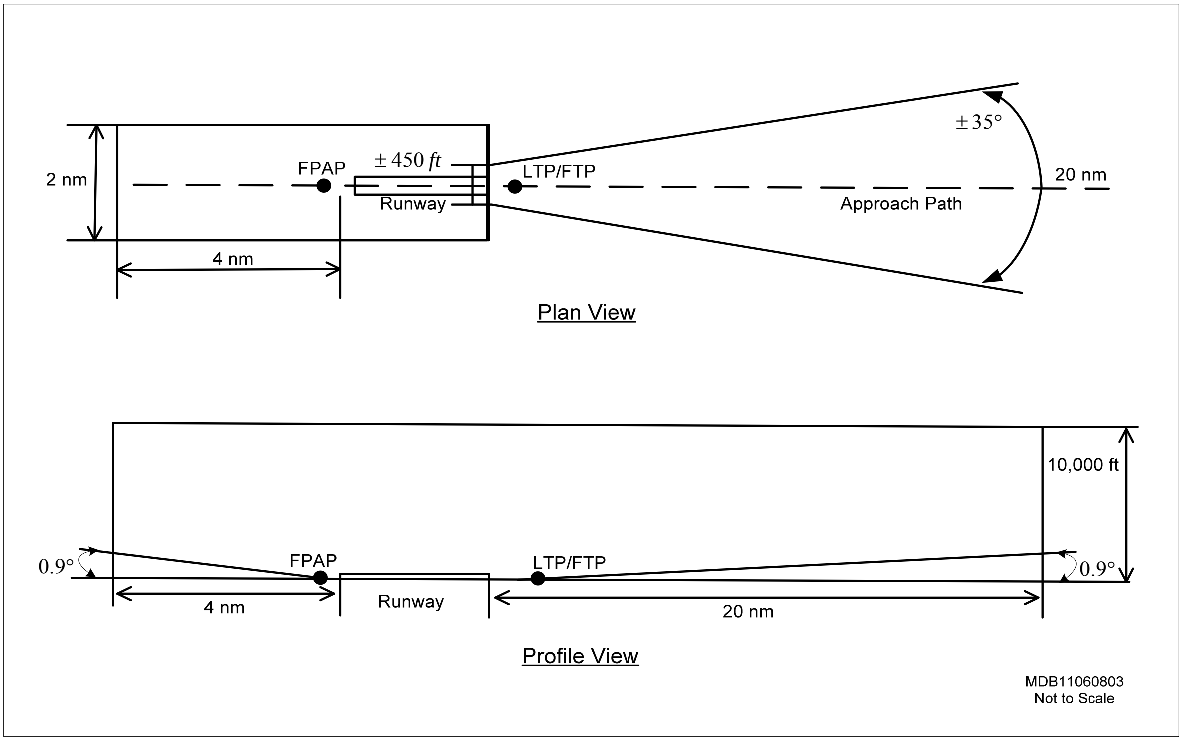

Figure 4. LAAS Approach Coverage Requirements.

Table 2. VDB Approach Coverage Assessment – Parallel Runways.

Requirement	Evaluation Area	Modified Method	Performed For
Normal Approach	From 20 NM to LTP	No change	Each approach procedure
Lower-Limit of Approach	From 20 NM to LTP	No change	Each approach procedure
Upper-Limit of Approach	From 20 NM to LTP	No change	Each approach procedure
Left-Limit of Approach	From 20 NM to LBAP2 (Figure 3)	From 21 NM, on path and fly along left limit of approach sector boundary	For left limit of each approach sector
Right-Limit of Approach	From 20 NM to RBAP2 (Figure 3)	From 21 NM, on path and fly along right limit of approach sector boundary	For right limit of each approach sector
Coverage from MVA	From 20 NM to 7° glide path	From 21 nm, on approach sector centerline and the MVA or 2,300 feet above FASLTP, which ever is higher, fly at level altitude until 7-degree path relative to FASLTP.	For each approach sector centerline
Coverage from Upper Service Volume	From 20 NM to 7° glide path	From 21 nm, on course and 10,000 feet above FASLTP fly at level altitude until 7 degree path relative to FASLTP.	For each approach sector centerline
Missed Approach	From Runway Stop End to 4 NM	No change	For each approach procedure
Roll Out	From Runway End to Runway End	No change	Once for each runway

Special Inspections. Special inspections are performed when there has been a modification of the instrument approach procedure or a new procedure has been added to a commissioned facility. Similarly, a special inspection is required whenever changes to the LGF configuration are made such as hardware/software changes having the potential to affect the internal navigation database or coding/construction of the VDB messages; when there is a change in VDB antenna, antenna type or antenna phase center location; whenever physical changes occur at the site having the potential to effect GPS signal reception and VDB coverage (e.gs., new obstructions or construction); or in response to multiple user complaints. As predicated by the reason for the special, VDB coverage is evaluated at the altitude established for the lower orbit during commissioning, and in operationally utilized areas where coverage is predicted or known to be affected. For each modified or new SIAP, the LGF broadcast FAS data block CRC should be checked to ensure there has been no change or corruption. A normal approach should be flown for modified instrument approach procedures (see Table 1). A normal approach, as well as upper, lower, left, and right limit profiles should be flown for new procedures (see Table 1). The evaluations performed should include procedure design, segment alignments, obstacle clearance, GPS signal reception, and VDB signal reception within the coverage volume.

C. Flight Inspection Analysis and Tolerances

This section of Appendix 2 provides a high-level discussion of the need for paper records and electronic collection of data. An overview of what data are collected during each stage of the flight inspection and how the data are analyzed to confirm proper operation of the service is presented. As examples, the horizontal alignment and glidepath angle are evaluated to confirm the aircraft is delivered to the designed LTP/FTP, or how to assess the electromagnetic spectrum if RFI is suspected. Table 3 lists the parameters that must be documented at the time anomalies are found. Table 4 lists the tolerances used for evaluation of collected data. The material in these sections of draft Order 8200.LAAS is expected to become more detailed as operational experience is gained.

Table 3. GPS Satellite Parameters Recorded.

Parameter	**Expected Values**
Horizontal Protection Level (HPL_{GBAS})	≤ 10m
Vertical Protection Level (VPL_{GBAS})	≤ 10m
Horizontal Dilution of Precision (HDOP)	≤ 4.0
Vertical Dilution of Precision (VDOP)	≤ 4.0
Horizontal Integrity Limit (HIL)	≤ 0.3nm
Figure of Merit (FOM)	≤ 22meters
Satellites Tracked	5 Minimum
Signal-to-Noise Ratio (SNR)	30 dB/ Hz minimum

Table 4. Tolerances for LAAS Flight Inspection.

Parameter	**Tolerances**
Terminal Area Path	TBD
Airport Surface Operations	TBD
Initial/Intermediate Approach Segment	FAA Order 8200.1
Final Approach Segment FAS data: Bearing to LTP Glidepath Angle FAS Data CRC Threshold Crossing Height Course Alignment w/runway C/L	 ± 0.1° true course ± 0.05^0 No Corruption ±2 m Centerline
Missed Approach Segment	FAA Order 8200.1
Broadcast VDB messages Coverage VDB, minimum field strength, horizontal polarization Coverage VDB, minimum field strength, vertical polarization	Required message types -99 dBW/m^2/215 µV/m -103 dBW/m^2/136 µV/m
Horizontal Protection Level Vertical Protection Level	40m 10m
Co-channel / adjacent channels (VOR or ILS) Annex 10, V1, Attach D Para 7.2	No misleading information
RFI	No misleading information
Maximum Usable Distance (D_{max})	As defined by LGF site

V. REQUIREMENTS FOR TERMINAL AREA PATH PROCEDURES

According to the FAA, "*A TAP is a curved path procedure that can begin at the fringes of the terminal area and end in a Category I LAAS approach, while maintaining the most stringent RNP equivalent values*"[25]. The FAA is assessing the feasibility of TAP as a potential implementation of RNP/RNAV, including flight testing at the FAA Technical Center and in Memphis to validate performance. The author's understanding of procedure design criteria and near-term applications for TAP is limited and the scope of this task did not permit performing a detailed literature search and review effort in this regard. However, this subject has been discussed on several occasions with FAA Flight Inspection Policy personnel, and the general impression is that experience in this area is limited. The author can envision TAP procedures being used to increase ATC efficiency by defining a TAP procedure that encompasses several segments of a commonly used terminal route, and/or to provide positive navigation around an obstruction, or having containment requirements that mandate the use of a system fully meeting LAAS-level RNP/RNAV performance requirements. Such a TAP procedure is shown in Figure 5.

As was the case for approach procedures, the development of FAA LAAS flight inspection criteria for TAP procedures is based on the need to assess the site-specific elements of a LAAS instrument procedure and to confirm service availability. Flight inspection of TAP procedures should be used to confirm procedure design, segment alignments, obstacle clearance, GPS signal reception, and VDB signal reception within the coverage volume. Flight inspection should be performed for the following situations:

- Prior to commissioning a TAP procedure;

- Periodically to ensure there has been no notable degradation of GPS signal reception and VDB coverage in operationally utilized airspace;

- When interference is reported or suspected along the TAP procedure and elimination of the interference cannot be verified by ground-based testing;

- Existing procedures are revised or new procedures are introduced at an operational facility;

- Whenever physical changes occur at the site having the potential to effect GPS signal reception and VDB coverage, such as new obstructions or construction.

In addition to the above listed items, requirements for approach procedures indicate that flight inspection should be performed whenever changes to the LGF configuration are made, such as hardware/software changes having the potential to affect the internal navigation database or coding/construction of the VDB messages, and changes in reference receiver antenna phase center locations. The effect of these types of changes is common across approach, TAP and surface operations or most likely to affect only the approach procedures. Thus, it is not necessary to replicate this requirement for TAP procedures since the assessments required for approach procedures will also suffice in this case.

As discussed previously at the end of section III, flight inspection recordings showing in-tolerance accuracy performance is not a sufficient condition for LGF performance, but it is a necessary condition. As with precision approach procedures, position domain accuracy measurements performed during flight inspection of TAP procedures can provide a meaningful functional check.

Commissioning Inspection: The TAP procedure should be flown from the initial waypoint to the final waypoint, flying on course and on path. The evaluations performed should include procedure design, segment alignments, obstacle clearance, supporting navigation systems, GPS signal reception, and VDB signal reception within the coverage volume. If the TAP procedure is

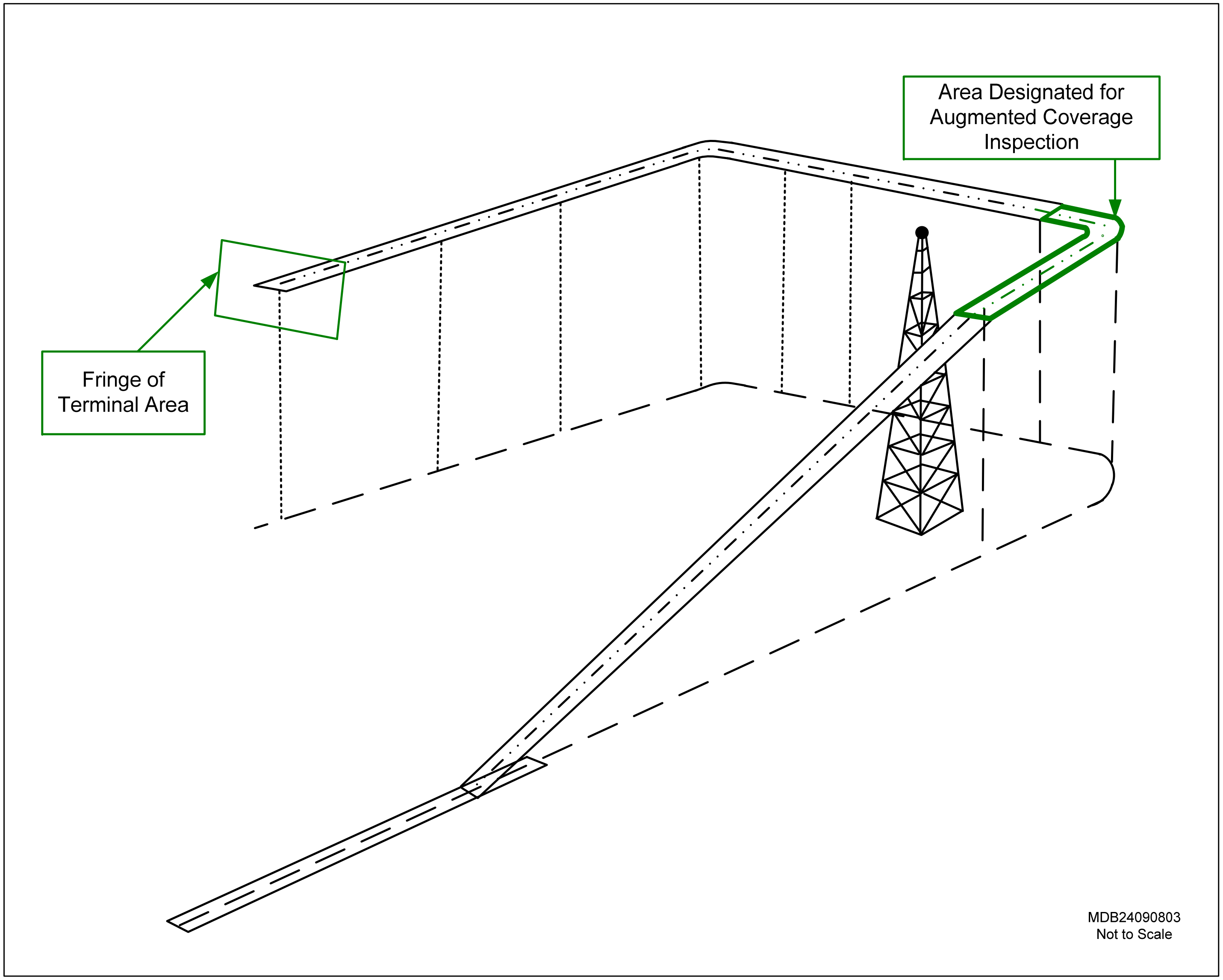

Figure 5. Illustration of TAP procedure with Containment Requirements.

used to provide positive navigation around an obstruction, an augmented GPS/VDB coverage assessment should be performed for the pertinent segment of the procedure (see Figure 5). Its recommended that the following profiles be flown:

- Full deflection below path, full deflection towards obstacle;

- On path, full deflection towards obstacle; and,

- Full deflection above path, full deflection towards obstacle.

GPS signal availability and VDB coverage should be assessed when conducting these augmented coverage profiles.

Periodic Inspections: As is the case for approach procedures, the purpose of periodic inspection for TAP procedures is to ensure that there has not been any degradation of VDB signal coverage due to environmental changes, to ensure that new sources of RFI have not come into existence, and to ensure there has not been a change in, or corruption of, the TAP procedure data. It is recommended that periodic inspections be performed initially on a 360-day interval. As discussed for approach procedures, the interval used for subsequent periodic inspections may be increased based on both performance of the individual facility and as NAS-wide experience with LAAS is gained, with the migration to a 540-day interval anticipated. The TAP procedure should be flown from the initial waypoint to the final waypoint, flying on course and on path and the evaluations performed should include obstacle clearance, GPS signal reception, VDB signal reception, and a check to ensure the TAP procedure data have not changed or been corrupted. Augmented VDB coverage assessments should be performed when degradation of the VDB signal or a change in the VDB signal characteristics in a containment region is observed during the on-path evaluation.

Special Inspections: Special inspections should be performed when there has been a modification of the TAP procedure or a new procedure has been added to a commissioned facility. Similarly, a special inspection should be required subsequent to select maintenance actions; when there is a change in VDB antenna, antenna type or antenna phase center location; whenever physical changes occur at the site having the potential to effect GPS signal reception and VDB coverage; or in response to multiple user complaints. As predicated by the reason for the special, VDB coverage should be evaluated in operationally utilized areas where coverage is predicted or known to be affected. Each modified or new TAP procedure should be flown from the initial waypoint to the final waypoint, flying on course and on path and the evaluations performed should include obstacle clearance, GPS signal reception, and VDB signal reception within the service volume. The evaluation of procedure design and segment alignments should be performed when an existing procedure has been modified or a new procedure has been added. Augmented VDB coverage assessments should be performed when degradation of, or a change in, the signal characteristics in a containment region is observed during the on-path evaluation.

This section addresses draft flight inspection requirements for TAP procedures. These requirements should be revisited as experience is gained to improve both effectiveness and efficiency. Tolerances for the flight inspection of LAAS TAP procedures (Table 4) will need to be developed, particularly for assessing segment alignments.

VI. REQUIREMENTS FOR AIRPORT SURFACE GUIDANCE PROCEDURES

As was the case for approach procedures, the development of FAA LAAS flight inspection criteria for airport surface operations is based on the need to assess the site-specific elements of a LAAS instrument procedure and to confirm service availability. Potential LAAS airport surface applications include the use of LAAS as the source of PVT information for ADS-B in support of airport surface surveillance applications [15]-[18][26]. This application supports both ATC and the electronic enhancement of "see-and-avoid" capabilities during low visibility conditions. LAAS used in conjunction with an electronic airport map (database) and a suitable display can provide pilots and vehicle drivers enhanced situational awareness at the low-end and electronic guidance during low-visibility conditions on the high-end (i.e., addition of INS/IRU, head-up display, etc). The author's expectation is the near-term application for LGFs capable of supporting precision approach procedures to a decision altitude of not less than 200 feet AGL is that of providing enhanced situational awareness. That is, the pilot or vehicle driver has sufficient visibility to steer and avoid other aircraft/obstacles based on visual observation. Similarly, the author is not aware at this writing of any intent to implement airport surface procedures; that is, the use of waypoints to define specific pre-determined surface routes.

Accordingly, flight inspection should be used to confirm physical alignment/agreement of the electronic airport map with runway and major taxiway surfaces (minimum), GPS signal reception, and VDB signal reception within the coverage volume intended to be serviced. Flight inspection should be performed for the following situations:

- Prior to authorization of LAAS-supported airport surface operations at an airport;

- Periodically to ensure there has been no notable degradation of GPS signal reception and VDB coverage in operationally utilized surface areas;

- When interference is reported or suspected;

- Whenever physical changes occur at the site having the potential to effect GPS signal reception and, particularly, VDB coverage on the airport surface, such as new obstructions or construction; and,

- Whenever changes are made to the VDB antenna phase center location(s), or for a change in VDB antenna, or antenna type.

In addition to the above listed items, requirements for approach procedures indicate that flight inspection should be performed whenever changes to the LGF configuration are made, such as hardware/software changes having the potential to affect the internal navigation database or coding/construction of the VDB messages, and changes in reference receiver antenna phase center locations. The effect of these types of changes is common across approach, surface and TAP procedures or most likely to affect only approach procedure. Thus, it is not necessary to replicate this requirement for surface operations since the assessments required for approach procedures will also suffice for surface operations.

As previously discussed for approach procedures, flight inspection recordings showing in-tolerance accuracy performance is not a sufficient condition for verifying LGF performance, but it is a necessary condition. This is a valid statement for approach procedures with decision altitudes of not less then 200 feet AGL since range errors caused by multipath will be negligible for the airborne receiver [27]. However, this is not the case for a user operating on the airport surface, since significant multipath can be encountered when operating on the airport surface. Since multipath effects are not common to the LGF and aircraft or surface vehicle antenna locations in general, these effects cannot be mitigated using differential GPS techniques such as LAAS. Although position domain accuracy measurements performed during inspections for airport surface operations can provide a meaningful functional check, the observation of an out-of-tolerance condition does not necessarily indicate a problem with the LGF. Range errors caused by multipath at the aircraft or surface vehicle location may be responsible for the out-of-tolerance condition. Actually, this is most likely the case assuming one has carefully selected the LGF reference receiver antenna locations, properly configured the ground station, and given the inter-comparison of range information across reference stations (i.e., B-values).

Commissioning Inspection: Commissioning inspection should include taxing along all runway centerlines and major taxiway centerlines within the airport surface area to be serviced. The evaluations to be performed should include assessing alignment/agreement of the electronic airport map with runway and major taxiway surfaces, GPS signal reception, and VDB signal reception within the coverage volume intended to be serviced.

Periodic Inspections: As is the case for approach procedures, the purpose of periodic inspection for airport surface operations is to ensure that there has not been any degradation of VDB coverage due to environmental changes, to ensure that new sources of RFI have not come into existence, and to ensure there has not been a change in, or corruption of, the airport map data. For operations limited to visibility conditions where the pilot or vehicle driver has sufficient visibility to steer and avoid other aircraft/obstacles based on visual observations (advisory only), no periodic inspection is suggested For operations authorized in visibility conditions where the pilot or vehicle driver may have some level of reliance on LAAS to steer, avoid other aircraft/obstacles, and detect upcoming runway and taxiway intersections, it is recommended that periodic inspection be performed initially on a 360-day interval. The interval used for subsequent periodic inspections may be increased based on both performance of the individual facility and as NAS-wide experience with LAAS is gained, with the migration to a 540-day interval anticipated. In this case, the evaluations to be performed should include assessing alignment/agreement of the electronic airport map with runway and major taxiway surfaces, GPS signal reception, VDB signal reception within the coverage volume intended to be serviced, and a check to ensure the airport map data have not changed or been corrupted.

Special Inspections: This paragraph applies when operations are authorized in visibility conditions where the pilot or vehicle driver may have some level of reliance on LAAS to steer, avoid other aircraft/obstacles, and detect upcoming runway and taxiway intersections. One may elect to conduct special inspection when LAAS guidance is used in an advisory only capacity. Special inspections should be conducted when the airport map for a facility has been revised; when there is a change in VDB antenna, antenna type or antenna phase center location; whenever physical changes occur at the site having the potential to effect GPS signal reception and VDB coverage, such as new obstructions or construction; or in response to multiple user complaints. As predicated by the reason for the special, VDB coverage should be evaluated in operationally utilized areas where coverage is predicted or known to be affected. The evaluations to be performed should include assessing alignment/agreement of the electronic airport map with runway and major taxiway surfaces, GPS signal reception, and VDB signal reception within the coverage volume intended to be serviced.

This section addresses draft flight inspection requirements for airport surface operations. Although the phrase “flight inspection” is used throughout this section, such inspections may be performed with a suitably equipped vehicle [18]. Further, these requirements should be revisited as experience is gained to improve both effectiveness and efficiency. Tolerances for the flight inspection of airport surface procedures (Table 4) will need to be developed, particularly for assessing the agreement/alignments between airport physical surfaces and electronic map/database information.

VII. PARALLEL RUNWAYS CASE STUDY

An overview of the material contained in the FAA draft Order 8200.LAAS [8] was presented by the author during the June 2008 International Flight Inspection Symposium [14]. This included the material for the inspection of an LGF supporting parallel runways, and this material was drafted by the author. Recall that, in part, the pre-flight requirements contain criteria that are used to define two approach corridors for each group of parallel runways, one for each approach direction. The boundaries of these corridors are flown to assess VDB coverage towards the outside of the outer-most approach procedures, see Figure 3 and section IV.A. During the symposium, a participant from the audience asked a question regarding the applicability of these criteria to widely spaced parallel runways. In light of this question, further consideration of the criteria for the case of parallel runways has occurred since the symposium, as well as determining the need for further development, or at least some clarification of the current criteria.

It was intended that these criteria to be applicable to the case of “tightly spaced” parallel runways not the “all encompassing” case of any group of parallel runways, although this thought is not conveyed in the current criteria. Certainly runway separation is an important factor and the term “tightly spaced” is used herein in the notional sense and is not associated in any way with the formal FAA definition for closely spaced runways. For any given group of parallel runways, is there a maximum separation between the outer most runways that would determine if a group of runways is suitable for the approach corridor concept? In addition to the physical separation between the outermost runways of a group, what objects or terrain lies between the runways, and the location of the VDB antenna relative to the runways are also factors in determining if the approach corridor concept is applicable to a particular group of runways.

A case study was conducted with the intend of gaining some insight into answering this question The Dallas-Forth Worth International Airport (DFW) was used as an example to bring to light some thoughts on this subject. DFW has five runways that could be considered as a group of parallel runways, which are runways 35R, 35C, 35L and 36L, 36R. The first case study is to consider all five runways as one group of parallels. The criteria in the draft LAAS Order were applied and the results are illustrated in Figure 6. According to Table 2 herein, which are the same criteria as contained in Table 2 from the Order, normal approach, lower-limit approach and upper-limit approach maneuvers are flown, represented by the red dashed lines in Figure 6. A coverage run at the Minimum Vectoring Altitude (MVA) along the approach sector centerline is flown, and the approach sector right and left boundaries are flown, all shown as blue dashed lines in Figure 6. There are three ellipses in Figure 6, denoted as A, B, and C, each showing a region where the VDB signal could be blocked (a coverage gap) and potentially go undetected during flight inspection since there are no maneuvers flown through these regions. These blockage regions would be caused by the buildings or other physical structures between the runways. The boxes denoted by A', B' and C' indicate areas where the VDB antenna would have to be located and installed improperly to create these signal blockage regions. In assessing the likelihood for this situation to occur, it is the author's understanding at this writing that a formal, validated FAA LAAS siting manual or order does not exist. Such a document would normally contain criteria used to select suitable antenna locations, thus reducing the likelihood of an improper location being selected. Even should such blockage regions exist, one also would need to discuss the operational significance or insignificance of these regions, but this discussion will not be taken at this time. This case study brings the question: Is the 10-degree rotation for the left/right sector boundary too large?

Similarly, DFW was considered for a second case study. In this case, two groups of parallel runways were considered, one group comprised of runways 35R, 35C, 35L and a second group comprised of runways 36L, 36R. The criteria from the draft LAAS Order were applied and the results are shown in Figure 7. This result shows less potential for an undetected coverage gap, but would require more flight time.

Based on the discussion above, it would be beneficial to perform a limited number of case studies for select airports as a means of better assessing and vetting the current criteria. Such a study should include assessing the suitability of the 10-degrees rotation angle used to define approach sector corridor boundaries as well as investing the suitability of using an angle more inline with the close-in course width (i.e., somewhere between 3-6 degrees).

VIII. CONCLUSIONS AND RECOMMENDATIONS

As stated in the introduction, the study undertaken and documented by this report had two primary objectives. The first objective was to provide an independent review of the flight inspection requirements, methodologies and procedures that will be used for the evaluation of LAAS precision approach procedures with DAs of not less than 200 feet AGL. The second objective was to develop draft criteria for the evaluation of TAP procedures and airport surface operations.

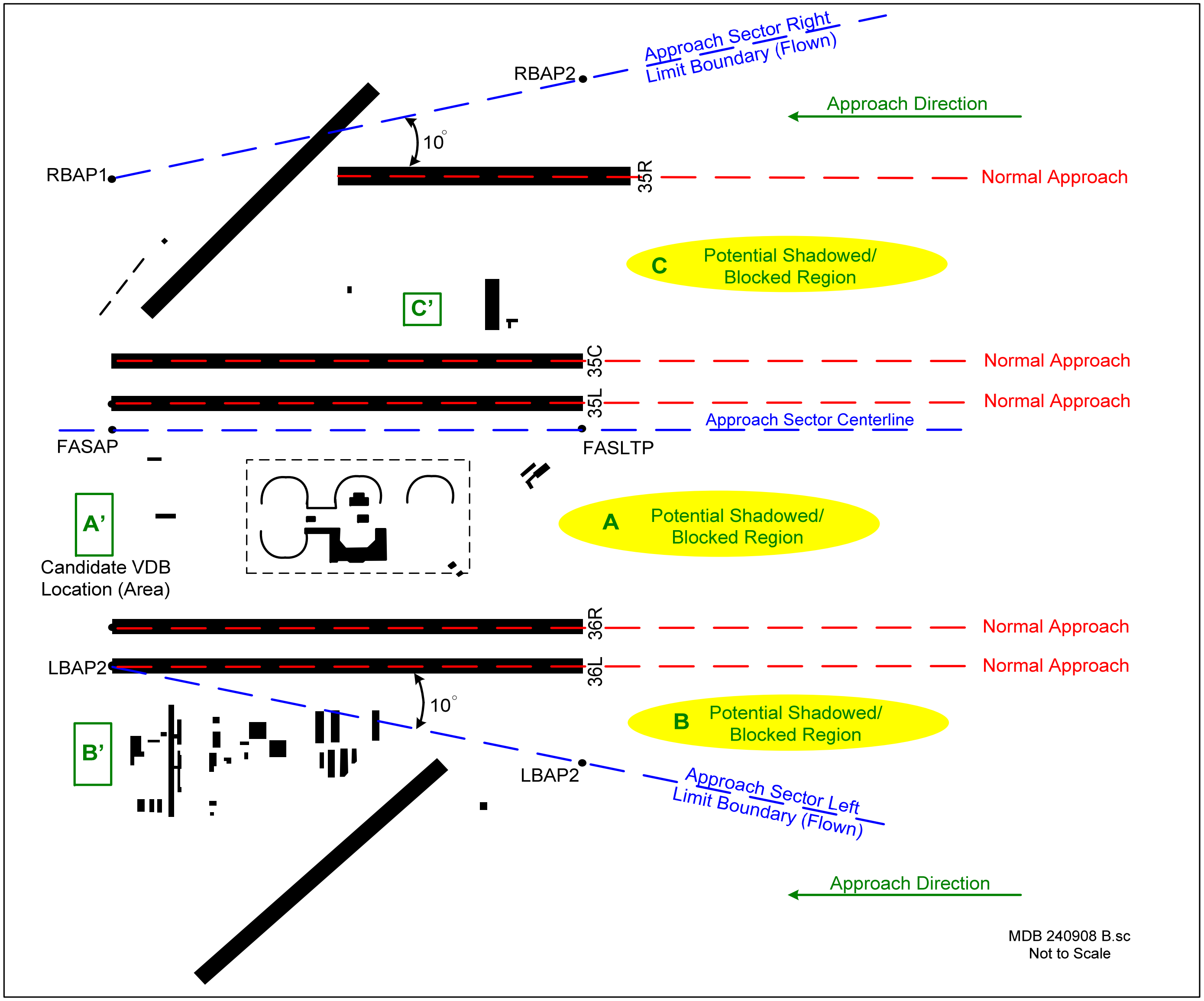

Figure 6. DFW Case Study 1, One Parallel Runway Group.

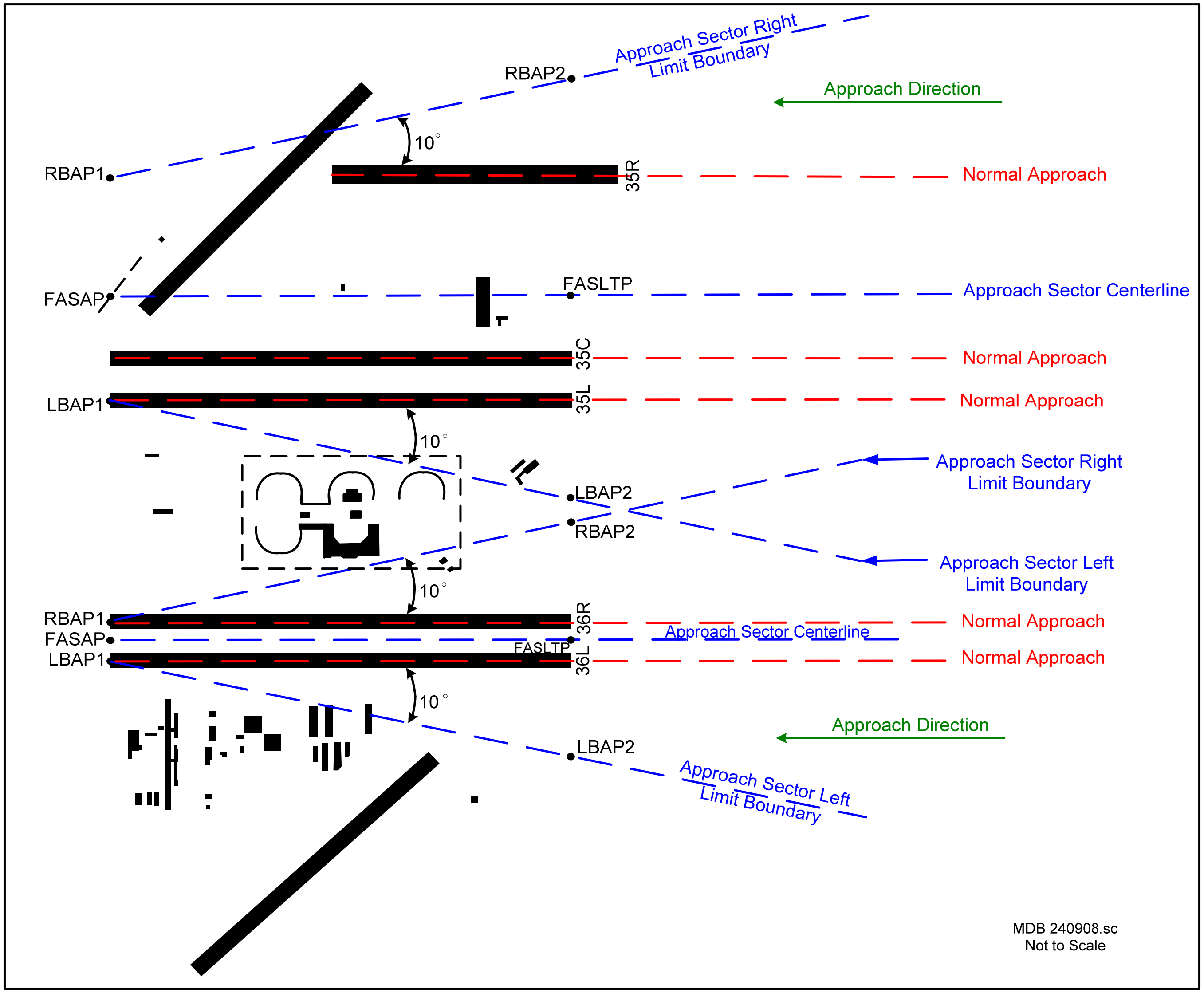

Figure 7. DFW Case Study 2, Two Parallel Runway Groups.

Accordingly, this report provided background material on LAAS; the rationale used for developing flight inspection criteria; and the review of initial FAA flight inspection procedures, evaluation criteria and tolerances (Order 8200.LAAS). Also, it addressed efficiencies that may be gained during the inspection of an LGF servicing parallel runways, documented a comment received on the related draft criteria, and presented two initial case studies performed to investigate that comment. In the way of new material, this report provided draft criteria for the evaluation of TAP procedures and airport surface operations.

The following has been concluded based on the results of this study:

1) LAAS flight inspection criteria are not intended to, nor required to, provide an assessment of either LGF or LAAS receiver equipment performance as such assessments are assumed to be performed during equipment design and installation procedures approvals;

2) LAAS flight inspection criteria are needed to evaluate the site-specific elements of a LAAS instrument approach procedure and to confirm service availability. Specifically, the objective of flight inspection is to confirm procedure design, final segment alignments, obstacle clearance, GPS signal reception, and VDB signal reception within the coverage volume defined by $D_{max;}$

3) Based on available experience and information, the flight inspection criteria contained in FAA Order 8200.LAAS (June 2007) are applicable to and suitable for the evaluation of procedures with DAs of not less then 200 feet AGL when supported by properly approved ground and airborne equipment; and,

4) FAA Order 8200.LAAS is expected to be reviewed and revised as operational experience is obtained.

The following recommendations are offered for consideration:

1) The effectiveness and efficiency of the current criteria should be evaluated periodically as operational experience is gained and as Category II/III LAAS equipment becomes available;

2) The development of Appendix 3, Records and Reports Required for LAAS Flight Inspection, of FAA Order 8200.LAAS should be progressed;

3) The feasibility of developing and validating a procedure for calibration of the current LAAS flight inspection equipment suite to ensure that VDB data continuity alerts occur whenever the VDB signal strength is not assured to meet or exceed ICAO requirements should be assessed;

4) The transition to a capability that enables the direct measurement of signal strength so that facility signal strength can be more effectively assessed against FAA/ICAO power density requirements should be progressed;

5) A limited number of case studies for select airports should be performed as a means of better vetting/assessing the current criteria for the evaluation of facilities with parallel runways, with the study focusing on GPS/VDB signal sampling within the approach corridors and the angle used to define approach sector corridor boundaries;

6) Flight inspection tolerances (i.e., Table 4 material) for TAP and airport surface operations should be developed;

7) Criteria for defining the region for augmented coverage assessments for TAP procedures used to provide positive navigation around an obstruction, or having containment requirements that mandate the use of a system fully meeting LAAS-level RNP/RNAV performance requirements should be developed;

8) A review of the draft flight inspection criteria for TAP procedures and airport surface operations supporting enhanced situational awareness should be facilitated;

9) Re-assessment of TAP and airport surface operations criteria should be performed once a better understanding of their application and design procedures are gained; and,

10) The viability of migrating to a 540-day interval for periodic inspections should continue to be evaluated.

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X. APPENDIX: Draft LAAS Flight Inspection Order, 28 November 2008

This appendix contains an updated draft LAAS Flight Inspection Order (8200.LAAS), which is based on the draft version produced in June 2007. Updates to the attached version include the incorporation of a new appendix 1, the inclusion of draft TAP criteria based on recommendation made herein, and the inclusion of draft airport surface criteria based on recommendations made herein.

ORDER

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

8200.LAAS

DRAFT

SUBJ: FLIGHT INSPECTION OF GLOBAL POSITIONING SYSTEM (GPS) LOCAL AREA AUGMENTATION SYSTEM (LAAS) PRECISION INSTRUMENT APPROACH PROCEDURES

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1. PURPOSE. This order details the flight inspection procedures, requirements and analysis for the evaluation of LAAS precision instrument approach procedures. This version of the order is applicable to the evaluation of procedures with Decision Altitudes (DA) of not less then 200 feet above ground level (AGL), terminal area path (TAP) procedures, and airport surface procedures that provide enhanced situational awareness. As LAAS equipment certified for supporting Category II/III operation becomes available and as additional operational experience is gained, this order will be reviewed and revised as appropriate.

2. DISTRIBUTION. This order is distributed to the division level in Airway Facilities and Air Traffic, and to the branch level in Aviation System Standards, Washington headquarters; to the Regulatory Standards and Compliance Division, FAA Academy; to the branch level in the regional Airway Facilities, Air Traffic, and Flight Standards Divisions; to the Flight Inspection Offices and International Flight Inspection Office; and to Special Military Addressees.

3. BACKGROUND. The GPS is a world-wide position, velocity, and time determination system operated by the Department of Defense that includes a satellite constellation and a ground control segment. The GPS has been accepted by the International Civil Aviation Organization (ICAO) as an integral part of the Global Navigation Satellite System (GNSS). Civil use of GPS for oceanic, enroute, terminal, non-precision, and special precision approach flight has been authorized in the National Airspace System (NAS).

LAAS is a safety-critical system consisting of the hardware and software that augments the GPS Standard Positioning Service (SPS) to provide for precision approach and landing capability. The standard positioning service provided by GPS is insufficient to meet the integrity, continuity, accuracy, and availability demands of precision approach and landing navigation. The LAAS Ground Facility (LGF) augments the GPS SPS in order to meet these requirements. These augmentations are based on differential GPS concepts.

4. RELATED MATERIAL.

a. Specification FAA-E-2937, April 17, 2002, “Performance Type One Local Area Augmentation System Ground Facility”.

b. RTCA DO-245A, December 9, 2004, “Minimum Aviation System Performance Standards for the Local Area Augmentation System.”

c. RTCA DO-246C, April 7, 2005, “GNSS Based Precision Approach Local Area Augmentation System (LAAS) –Signal-In-Space Interface Control Document (ICD).”

d. RTCA DO-253A, November 28, 2001, “Minimum Operational Performance Standards for GPS Local Area Augmentation System Airborne Equipment.”

e. RTCA DO-247, January 7, 1999, "The Role of the Global Navigation Satellite System (GNSS) in Supporting Airport Surface Operations."

f. ICAO AN-WP/7556, Addendum No. 1, "Draft Standards and Recommended Practices for Global Navigation Satellite Systems," October 27, 2000.

g. FAA Order 8200.1C, October 2005, "United States Standard Flight Inspection Manual (USSFIM)."

h. Technical Memorandum OU/AEC 00-09TM00078/2-4, May 2000, "Development of Provisional Flight Inspection concepts for Local Area Augmentation System (LAAS) Approach Procedures", Avionics Engineering Center, Ohio University.

i. Technical Memorandum OU/AEC 07-01TM15689/2-1, October 2008, "Review of Local Area Augmentation System (LAAS) Flight Inspection Requirements, Methodologies, and Procedures for Precision Approach, Terminal Area Path, and Airport Surface Guidance Operations", Avionics Engineering Center, Ohio University.

5. FLIGHT INSPECTION PROCEDURES, ANALYSIS, AND TOLERANCES. Appendix 1 contains background material concerning the LAAS. Appendix 2 contains the flight inspection procedures, requirements, and analysis for LAAS approaches. Appendix 3 contains the records and reports required for LAAS flight inspection. Appendix 4 contains Acronyms and Definitions.

6. INFORMATION UPDATE. Any deficiencies found, clarifications needed, or suggested improvements regarding the contents of this order should be noted on FAA Form 1320-19, Directive Feedback Information. If an interpretation is needed, call the originating office for guidance; however, you should also use FAA Form 1320-19 as a follow-up to the verbal conversation.

Thomas C. Accardi
Program Director of Aviation
System Standards

APPENDIX 1. BACKGROUND MATERIAL FOR LAAS

This appendix provides a high-level discussion of the major GPS components and how LAAS is used to augment GPS performance to meet requirements for navigation and landing operations. The key LAAS subsystems are introduced with discussions then focusing on the ground subsystem.

GPS is an integrated system comprised of the following three components: the satellite constellation or space segment; the ground control and monitoring network also knows as the operational control segment; and, the user segment commonly referred to as the GPS receiver. The space segment nominally consists of a 24-satellite constellation with each satellite providing ranging signals and data to the GPS receiver. The operational control segment maintains the satellites in terms of orbital location and functionality, as well as monitoring the health and status of each satellite. Although the satellites are monitored by the control segment, the requisite user alarm or warning functionality typical of navigation, approach, and landing systems is not provided. Further, enhancement of the GPS SPS is normally required to meet the accuracy, integrity, availability and continuity performance requirements for instrument operations.

Enhancement of the GPS SPS can be accomplished by using airborne based augmentation systems (ABAS), satellite based augmentation systems (SBAS), and/or ground-based augmentation systems (GBAS). As referred to herein, LAAS is the specific realization of the GBAS architecture adopted by the United States of America. LAAS is intended to be an all-weather navigation service meeting ICAO Standards and Recommended Practices (SARPS) in terms of performance and interoperability. As illustrated in Figure 1, it consists of the following three primary subsystems: 1) the satellite subsystem; 2) the ground subsystem; and, 3) the airborne subsystem. For LAAS, the satellite subsystem is GPS, which was discussed previously. It provides ranging signals to both the airborne subsystem and the ground subsystem.

As previously stated, the ground subsystem for LAAS is referred to as the LGF. The LGF produces ground-monitored differential corrections for each satellite in view, integrity-related information, and definition of the final approach segment, missed approach, or Terminal Area Path (TAP) based on path point data stored within its local navigation database. These data are transmitted throughout the entire service volume by the VHF Data Broadcast (VDB) transmitter to the aircraft avionics comprising the airborne subsystem. Thus, LAAS is capable of providing service simultaneously to all aircraft in the service volume. Also, the LGF provides for both local and remote status, control, and maintenance interfaces.

The airborne subsystem applies the LGF-generated differential corrections to the GPS ranging signals to obtain a differentially-corrected position solution with the required accuracy, integrity, continuity, and availability. In addition to the integrity information broadcast by the VDB, the airborne subsystem also employs Receiver Autonomous Integrity Monitoring (RAIM) as a means of GPS ranging signal fault detection on the airborne side. The more-precise position solution and the path point data transmitted by the VDB are used to calculate lateral and vertical guidance with respect to the final approach path (precision approach), TAP or other supported instrument procedures. Proportional guidance deviation outputs, in “ILS look-alike” fashion, are provided to aircraft displays and navigation systems. The airborne subsystem also provides

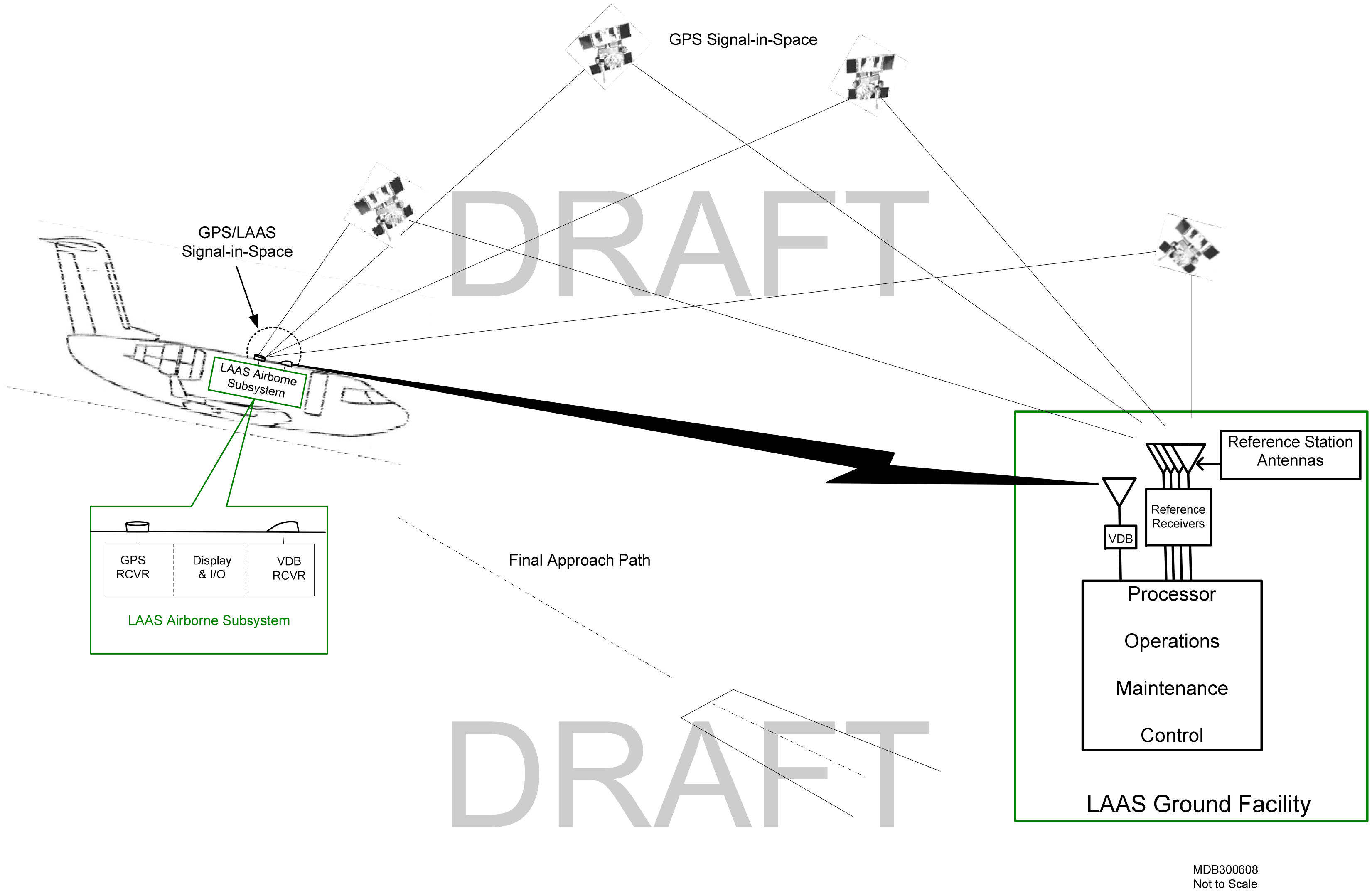

Figure 1. Illustration of LAAS subsystems.

appropriate annunciations of system performance to the user, e.g., alerts and flags. In addition to deviation outputs, a position-velocity-time (PVT) output with integrity is provided to support enhanced navigation and surveillance operations.

In general, LAAS provides a flexible positioning service capable of supporting precision approach, TAP, departure procedures, airport surface operations, and enhanced area navigation (RNAV). It enables "precision RNAV" in the terminal area that provides the level of navigation serviced required for supporting curved arrival, approach, and departure procedures. The position accuracy is well suited for supporting airport surface operations by enabling both enhanced situational awareness and electronic guidance. The PVT output can be used to support surveillance applications within local and terminal areas; it can be used as a source of position information for Automatic Dependent Surveillance-Broadcast (ADS-B) equipment.

The objective of a commissioning LAAS flight inspection is the evaluation of a particular LGF and all of the instrument flight procedures to be supported by that facility. The rationale for this objective is discussed further in the following section. Since the inspection activity is "LGF-based", the LGF and related matters will be discussed in more detail at this point.

LAAS is intended to provide radio navigation vertical and lateral guidance for instrument precision approach and landing from 20 nm from the runway threshold through touchdown and rollout. It will nominally require only one LGF at an airport to provide service to all runways and aircraft in the service volume. The ground subsystem will be modular and will have appropriate redundancy to support all runway ends, and it is capable of being installed entirely on the airport. An LGF generally consists of the following four main equipment groups: reference receiver; VDB equipment; processor; and operations and maintenance.

The reference receiver group usually consists of four reference receiver stations, each station containing a GPS reference receiver, a reference receiver antenna, associated cables, equipment racks, and antenna mounts. The reference receivers may be located in an environmentally controlled shelter or individual equipment enclosures located in proximity to the reference receiver antenna. Although there are limitations on the location of the reference receiver antennas relative to the runways being serviced, they are not constrained to be in close proximity (i.e., 1,000 feet) to those runways. The reference receiver antennas should be sited in protected, low-multipath (GPS signal reflection) locations with an unobstructed view of the sky.

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The VDB equipment group consists of the VDB transmitter, antenna, monitor, associated cables, equipment racks, and antenna mounts. Although it may be preferable from a logistic view point to site the reference receiver antennas and VDB antenna in the same location, the VDB antenna may be independently sited to provide adequate signal coverage. If required, two or more VDB equipment groups can be used to satisfy coverage requirements at complex airports or airports having coverage-related siting issues. The use of multiple VDB groups is one method for satisfying both airborne and airport surface coverage requirements, since antenna installation requirements differ in the case of airborne versus surface coverage.

The processor group consists of dedicated micro-processors, operationally pertinent data, software that performs the differential correction computations and integrity processes, and VDB message generation functions, as well as human interfaces (display), associated communication cables, and equipment racks. Operationally pertinent data includes the navigation database containing the all procedure data that is broadcast to users within the LAAS service volume. This group is housed in the primary LGF equipment shelter, which may also contain the reference receivers.

The operations and maintenance group includes equipment to perform those control and status functions normally required for a landing aid. This group includes items such as a local status and control panel, maintenance data terminal/terminal interface, remote status panel/interface, and an air traffic control unit/interface.

It is important to realize that LAAS uses an earth-centered, earth-fixed (ECEF) reference system based on the WGS-84 datum instead of being source-referenced like conventional radio navigation systems. Because of this, reference receiver antenna locations, runway threshold coordinates, obstacle locations, and all path point data must be accurately surveyed relative to each other. Further, if the coordinates for these items are surveyed separately by different entities and/or accomplished over an extended period of time, then accuracy of the absolute coordinates becomes important.

APPENDIX 2. FLIGHT INSPECTION EVALUATION OF LAAS INSTRUMENT APPROACH PROCEDURES

1. Introduction. This appendix provides flight inspection requirements for LAAS precision approaches. This policy is preliminary and will be revised as more experience with system performance is acquired.

2. Preflight Requirements. The Flight Inspector shall prepare for the flight inspection in accordance with FAA Order 8200.1 (USSFIM). For each LGF to be evaluated, the inspector shall determine the type and number of approach procedures to be support, if approach procedures to parallel runway groups will be provided, if TAP procedures will be provided, and if airport surface operations are to be supported. For each TAP procedure, determine if augmented VDB coverage assessments are required.

2.1 Inspection System Calibration. Since the VDB antenna may radiate both horizontally and vertically polarized signals, the flight inspection system will be calibrated for both horizontal and vertical polarized signals. This will include data for the airborne antenna pattern and cable loss.

2.2 Dmax Determination. Determine LGF maximum use distance (Dmax) for approach coverage evaluation.

2.3 LAAS FAS Data Block Verification. The LAAS FAS data (data specified on FAA Form 8260-10) is developed and coded into binary files by the procedure developer. The FAS data files are saved into a network file for flight inspection access. Download the FAS data blocks files required for the scheduled itinerary onto removable disk media.

Prior to mission departure, confirm Automated Flight Inspection System (AFIS) access to the removable disk media. Access each individual FAS data file and confirm the cyclic redundancy check (CRC) remainder matches the FAA Form 8260-10 data, or equivalent This ensures no errors occurred during data transfer (data file integrity). Any corruption must be resolved prior to conducting the inspection. AFIS uses the FAS data to calculate course alignment and glide path angle.

2.4 LGF Supporting Parallel Runways. When the LGF to be evaluated supports approach procedures to parallel runways, approach sectors are defined. An approach sector bounds the area of airspace common to all the approach procedures having the same approach and landing direction. Thus, a set of parallel runways will have two approach sectors associated with them, one for each landing direction. The methodology for evaluation of the approach sector, as opposed to assessing each runway end individually, permits sufficient assessment of each approach procedure while improving the efficiency of the inspection by eliminating redundant VDB coverage assessments.

2.4.1 Determine FASAP and FASLTP. Determine the coordinates of the fictitious approach sector alignment point (FASAP) and fictitious approach sector landing threshold point (FASLTP) for each approach sector. The approach sector centerline runs parallel to the runway centerlines and is located midway between the centerlines of the outer-most runways (see figure 2-1). The FASAP and FASLTP are located abeam the furthest most runway stop end and threshold, respectively, and on the approach sector centerline as illustrated in figure 2-1.

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2.4.2 Determine Left/Right Sector Limits. Determine the four coordinates for the left and right limit boundary of the approach sectors for each set of parallel runways. The right limit boundary is defined by a radial rotated 10˚counterclockwise from the controlling runway centerline. The left limit boundary is defined by a radial rotated 10˚clockwise from the controlling runway centerline. Determine right boundary alignment point #1 (RBAP1), right boundary alignment point #2 (RBAP2), left boundary alignment point #1 (LBAP1), and left boundary alignment point #2 (LBAP2) as indicated by figure 2-2.

2.5 LGF Supporting TAP Procedures. The TAP procedure data (data specified on FAA Form TBD is developed and coded into binary files by the procedure developer. The TAP procedure data files are saved into a network file for flight inspection access. Download the data files required for the scheduled itinerary onto removable disk media.

If augmented VDB coverage assessments are to be performed, determine the segment(s) of each procedure that requires an augmented assessment (criteria TBD). For each segment, the waypoint/navigation data need to fly the required profiles is developed and coded into data files. The required profiles are: 1) Full deflection below path, full deflection towards obstacle; 2) On path, full deflection towards obstacle; and, 3) Full deflection above path, full deflection towards obstacle. The augmented coverage profile data files are saved into a network file for flight inspection access. Download the data files required for the scheduled itinerary onto removable disk media.

Prior to mission departure, confirm AFIS access to the removable disk media. Access each individual TAP procedure data file and confirm the cyclic redundancy check (CRC) remainder matches the FAA Form TBD data, or equivalent Access each individual augmented coverage profile data file and confirm the cyclic redundancy check (CRC) remainder matches the FAA Form TBD data, or equivalent. This ensures no errors occurred during data transfer (data file integrity). Any corruption must be resolved prior to conducting the inspection. AFIS uses the TAP to calculate course alignment, and path vertical angle/decent profile or altitude and the augmented VDB coverage flight profiles, if required.

2.6 LFG Supporting Airport Surface Operations. The airport map data (data specified on FAA Form TBD) is developed and coded into binary files by the map developer. The map data files are saved into a network file for flight inspection access. Download the map data files required for the scheduled itinerary onto removable disk media.

Prior to mission departure, confirm AFIS access to the removable disk media. Access each individual airport map data file and confirm the cyclic redundancy check (CRC) remainder matches the FAA Form TBD data, or equivalent This ensures no errors occurred during data transfer (data file integrity). Any corruption must be resolved prior to conducting the inspection. AFIS uses the airport map data display the location of runways, taxiways, and other pertinent airport features.

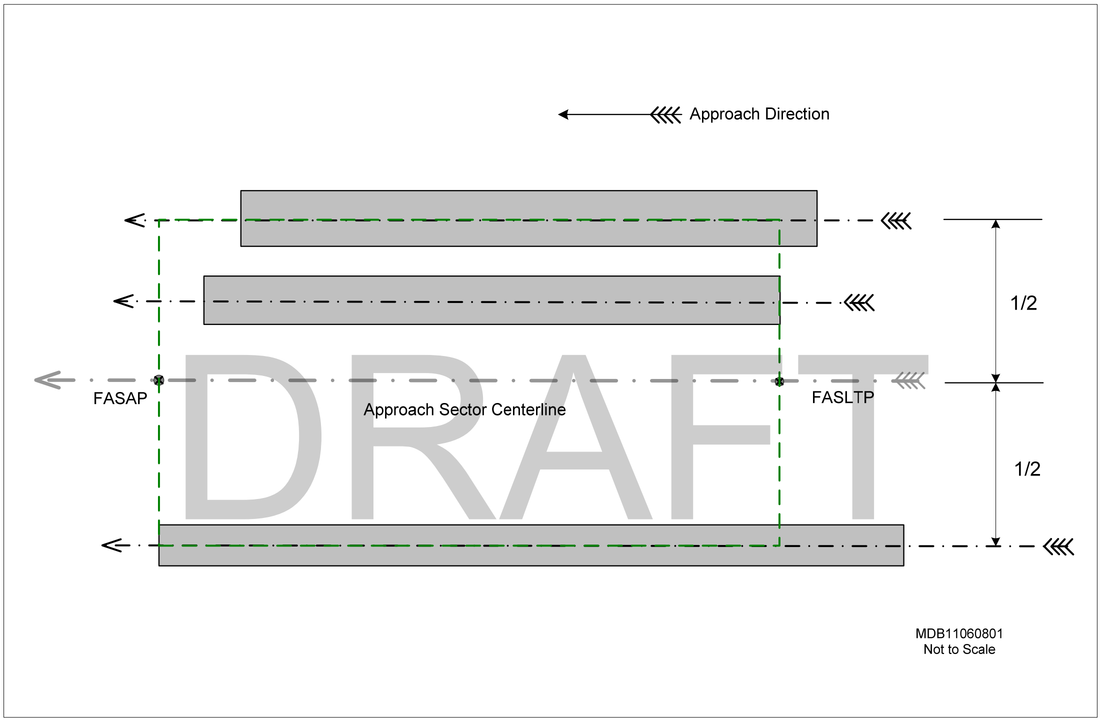

Figure 2-1. Determining Approach Sector Centerline, FASAP, and FASLTP.

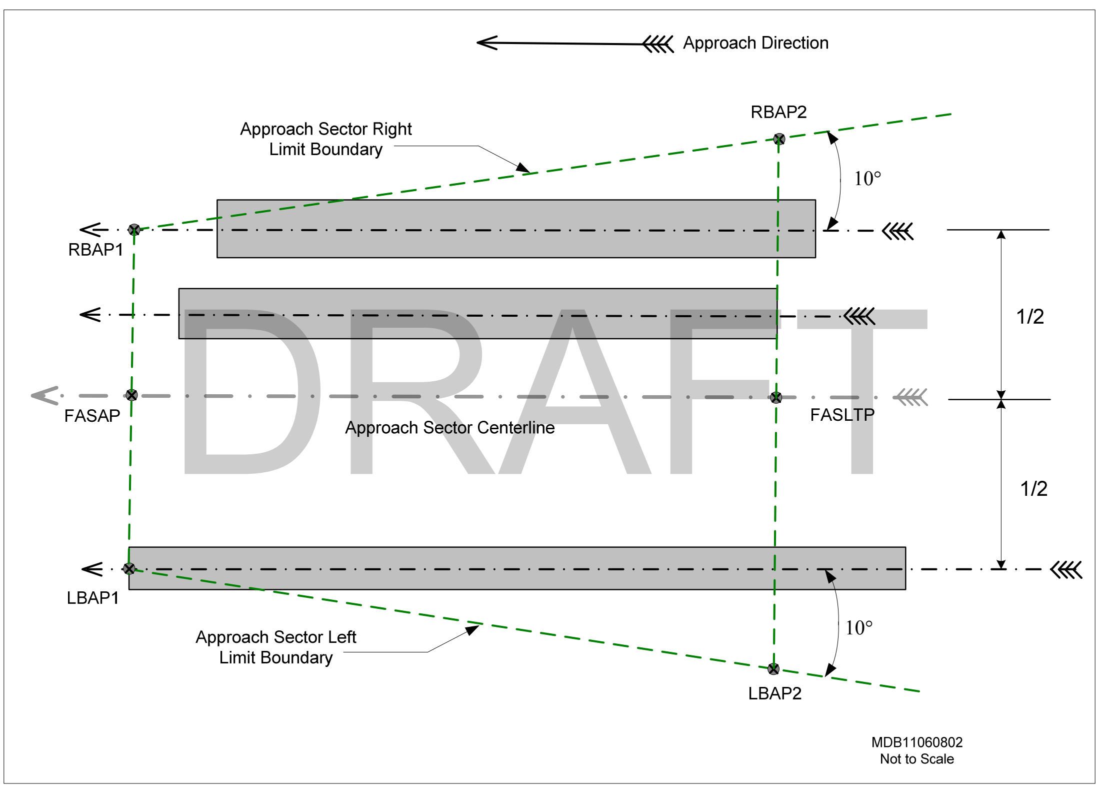

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Figure 2-2. Determining right/left boundary and boundary alignment points.

3. Flight Inspection Procedures.

3.1 Checklist.

Check	Reference
Initial Evaluation/Commissioning	
VHF Data Broadcast (VDB)	3.2.1
Terminal Area Path (TAP)	3.2.1.2.2a, 3.2.2
Initial and Intermediate Approach Segment	3.2.3
Final Approach Segment	3.2.1, 3.2.4
Missed Approach Segment	3.2.1, 3.2.5
Instrument Approach Procedure	3.2.6
Airport Surface	3.2.1.2.2b, 3.2.7
VDB Equipment or Frequency Change	
VHF Data Broadcast (VDB)	3.2.1
Final Approach Segment	3.2.4
Periodic Evaluation	3.3
Facility-based Coverage	3.3.1
Approach Procedures	3.3.2
Terminal Area Path (TAP)	3.3.3
Airport Surface	3.3.4
Special Evaluations	3.4
Approach Procedures	3.4.1
Terminal Area Path (TAP)	3.4.1
Airport Surface	3.4.1

3.1.1 Maintenance Procedures That Require a Confirming Flight Evaluation. A confirming flight inspection evaluation shall be required whenever the data link transmit antenna location or type is changed, or the system database has been changed or corrupted. The extent of the evaluation shall depend on the changes made.

3.1.2 Flight Inspection Evaluation.

Commissioning: The LAAS instrument approach procedures and VHF Data Broadcast (VDB) coverage shall be evaluated during initial flight inspection. If provided, each TAP procedure shall be evaluated during initial inspection. If airport surface operations are supported, the applicable electronic map and VDB signal coverage shall be evaluated during initial inspections.

Periodic: VDB coverage along the lower orbit will be evaluated based on loss of signal and data continuity alerts. The altitude established for the lower orbit during commissioning shall be used. The LGF broadcast FAS data block CRC will be checked for each Standard Instrument Approach Procedure (SIAP) to ensure there has been no change or corruption. VDB signal coverage and obstructions shall be evaluated for each commissioned TAP procedures, and the TAP data CRC will be checked to ensure there has been no change or corruption. VDB signal coverage on the airport surface may be required depending on the level of service provided, and the airport map data CRC will be checked to ensure there has been no change or corruption.

Special: A special flight inspection evaluation shall be required subsequent to select maintenance actions, for a change in VDB antenna, antenna type or antenna phase center location, whenever physical changes occur at the site having the potential to effect GPS signal reception and VDB coverage, such as new obstructions or construction or in response to multiple user complaints. Evaluations shall be required when an existing approach or TAP procedure is modified or when a new approach or TAP procedure added to an operational facility.

3.2.1 LAAS VHF Data Broadcast Coverage

The service volume for LAAS is constrained by both the RF signal coverage provided by the ground-based VDB antenna(s) and maximum range (Dmax) from the LGF for which the broadcast differential corrections are applicable (See Figure 2-3). RF signal coverage refers to those regions where the signal strength is sufficient to ensure reliable, continuous reception of the data broadcast by the aircraft. RF signal coverage can extend 100 to 200 NM, dependent on the output power of the VDB transmitter, VDB antenna type, aircraft altitude, and the horizon (line-of-sight) profile about the VDB antenna site.

The applicability, or accuracy, of the differential corrections degrade with increased distance from the LGF, specifically, the reference receive antenna locations. In general, the vertical/horizontal protection levels (VPL/HPL) must not exceed the vertical/horizontal alert limits (VAL/HAL) for the differential corrections and satellite status information to be applicable. The values for VAL/HAL are dependent on the flight operation being conducted. For LAAS, the maximum use distance, Dmax, is site dependent and it is usually broadcast by the LGF. In order to use the LAAS differentially corrected position/velocity/time (PVT) information, the aircraft must be within the range defined by Dmax. That is, the LAAS positioning service is available when within the RF coverage service volume out to the Dmax range. Outside of Dmax, the uncorrected PVT or SBAS corrected PVT information provides performance equivalent to GPS or the associated SBAS performance requirement, respectively.

The service volume required is depedent on the operations to be supported and Dmax is set accordingly. The value for Dmax will typically be 23 nm when the LGF is used to support terminal and approach procedures.

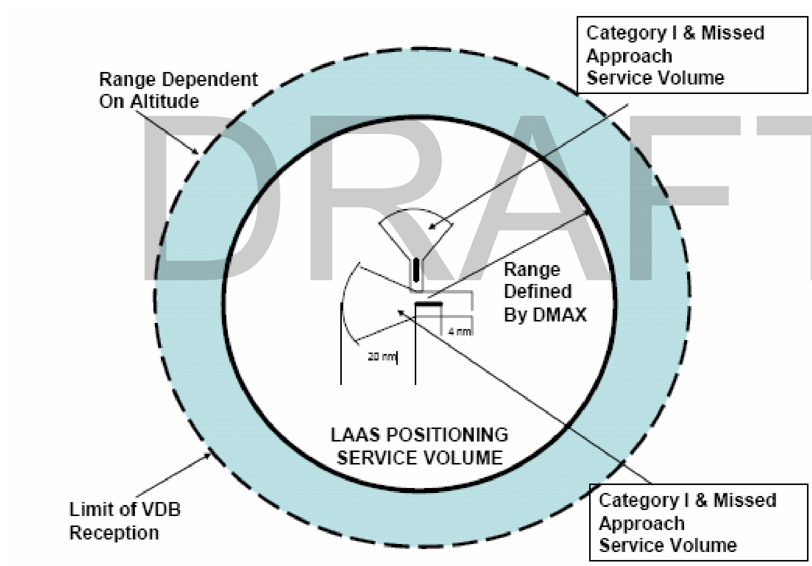

Figure 2-3. LAAS Coverage/Service Volume (courtesy RTCA DO-245).

3.2.1.1 VDB Signal Polarization. The VDB transmits either a horizontal or elliptically polarized signal. This allows the data broadcast to be tailored to the operational requirements of the local user community. The majority of aircraft will be equipped with a horizontally polarized VDB receive antenna, which can receive the VDB from either a horizontally or elliptically polarized transmitter. Aircraft equipped with a vertically polarized antenna are limited to the reception of elliptically polarized transmissions only.

3.2.1.2 VDB Coverage Evaluation. The service volume of the VDB must encompass the area of intended terminal and approach operations. Since the outer limit of the service volume is defined by Dmax, Dmax must be set appropriately for each facility. The suitability of the value used for Dmax will be evaluated for each LGF (facility-based coverage assessment). In addition, RF signal coverage within the service volume defined by Dmax will be evaluated for procedurally significant airspace (procedure-based coverage assessment).

VDB coverage will be evaluated based on loss of signal and data continuity alerts. LAAS sensor annunciation of operation in GBAS mode will confirm adequate coverage. VDB signal coverage validation must be made for both horizontally and vertically polarized signals. No data continuity alerts are allowed. The LGF shall be configured for normal data transmission except the power output shall be at the RF power alarm point and the Dmax data field populated for test mode. The initial coverage checks will either confirm or establish the RF power alarm point.

3.2.1.2.1 Facility-based Coverage Assessment. Orbits are required at the extremes of the VDB coverage service volume. The orbit maneuver is used primarily to check the lateral VDB coverage volume of the LGF. LGF coverage will be verified by flying an orbit at the maximum distance required to support the terminal and approach procedures to be supported by the LGF. This distance will typically be 23 nm, that is, Dmax is expected to be 23 nm. Two orbits are required during the initial coverage evaluation: 1) at a height above the antenna elevation as computed using equation 1; and, 2) at 10,000 ft above the antenna elevation. Clear line-of-sight (LOS) from the VDB transmit antenna to the lower extreme coverage limit may not exist for the entire 360 degrees of azimuth. Such situations may cause unavoidable outages of the VDB signal during inspection of the lower coverage limit. In this case, an additional orbit (partial or whole, as required) should be performed at the lowest altitude where clear LOS from the VDB transmit antenna to the lower extreme coverage limit exists for the entire 360 degrees of azimuth.

Note 1: Enable "Test Override" during coverage orbit to override test message/Dmax limit.

Note 2: Facility-based coverage assessments are performed with the power output at the RF power alarm point.

Orbit Altitude (ft) = (Dmax – 3) * 100+(Dmax-3)^2*0.883, Dmax in nautical miles (1)

Note 3: Orbit height is 2,300 feet above site level for Dmax equal to 23 nm

a) **Facilities Broadcasting Dmax:** The LAAS sensor and AFIS will display integrity status "GBAS" when VDB coverage is satisfactory in side Dmax. Verify Dmax is properly set by flying across the Dmax distance specified. "GBAS" integrity/correction and course guidance will only be available inside the Dmax limit.

b) **Facilities Not Broadcasting Dmax:** (Reserved)

c) Spectrum Analyzer (Reserved)

Other validation checks may be requested by facilities maintenance. All restrictions should be defined and noted on the commissioning inspection report.

3.2.1.2.2 Procedure-based Coverage Assessment.

a. Terminal Area Path (TAP) Coverage. The VDB transmitter power is set at the lower limit of the VDB monitor. The TAP procedure shall be flown from the initial waypoint to the final waypoint, flying on course and on path. Augmented coverage profiles are flown for the indicated segments, as required. GPS signal reception is confirmed and VDB coverage is evaluated. LAAS sensor annunciation of GBAS mode will confirm adequate coverage will inside D_{max}.

b. Approach Coverage. Table 1 provides the requirements for assessing VDB coverage for each approach procedure and is based primarily on RTCA D0-245 recommendations. The maneuvers listed in table 1 are intended to provide assessment of the coverage requirements illustrated in Figure 2-4. For LGFs servicing multiple runways, each approach procedure shall be evaluated in accordance with table 1, except for the case of parallel runways.

When the LGF to be evaluated supports approach procedures to parallel runways, approach sectors are defined, one for each landing direction. Table 2 provides modified requirements for assessing parallel runway configurations, and the measured values are the same as those specified in Table 1.

Note 1: Approach coverage assessments are performed with the power output at the RF power alarm point.

c. Airport Surface. The VDB transmitter power is set at the lower limit of the VDB monitor. The flight inspection aircraft or inspection vehicle shall taxi along all runway centerlines and major taxiway centerlines within the airport surface area to be serviced. GPS signal reception is confirmed and VDB coverage is evaluated. LAAS sensor annunciation of GBAS mode will confirm adequate coverage when with the area intended to be serviced.

3.2.2 Terminal Area Path. The TAP procedure should be flown from the initial waypoint to the final waypoint, flying on course and on path. Evaluations shall include procedure design, segment alignments, obstacle clearance, supporting navigation systems, GPS signal reception, and VDB signal reception within the coverage volume. Augmented coverage profiles are flown for the indicated segments, as required.

3.2.3 Initial and Intermediate Approach Segments. Fly the procedure from the Initial Approach Fix (IAF) to the Final Approach Fix (FAF). Maintain procedural altitudes. Evaluation shall include obstructions, procedure design, supporting navigation systems, and VDB coverage where required.

3.2.4 Final Approach Segment. Fly the final segment at procedural altitudes until intercepting the glidepath, and then descend on the glidepath to the LTP/FTP. Evaluation shall include obstructions, procedural design, horizontal alignment, glidepath alignment, and VDB coverage. Procedures that support azimuth only approaches shall be evaluated to the MAP.

Table 1. VDB Approach Coverage Assessment – Single Runway (See Note 3)

Requirement	**Evaluation Area**	**Method**	**Evaluation Criteria**
Normal Approach	From 20 NM to LTP	Fly on Path, on course	1) LAAS Receiver maintains "GBAS" Integrity. 2) No CDI Flags.
Lower-Limit of Approach	From 20 NM to LTP	From 21 NM and 5000 above LGF, fly on course, intercept and fly glide path within 1 dot of full scale below path.	Same as above. Note 1 Note 2
Upper-Limit of Approach	From 20 NM to LTP	From 21 NM and 8000 above LGF, fly on course, intercept and fly glide path within 1 dot of full scale above path.	Same as above. Note 1 Note 2
Left-Limit of Approach [Note 4]	From 20 NM to LTP	From 21 NM, fly on path and offset course to within 1 dot of full scale of "fly right".	1) LAAS Receiver maintains "GBAS" Integrity. 2) No CDI Flags Note 2
Right-Limit of Approach [Note 4]	From 20 NM to LTP	From 21 NM, fly on path and offset course to within 1 dot of full scale of "fly left".	1) LAAS Receiver maintains "GBAS" Integrity. 2) No CDI Flags Note 2
Coverage from MVA [Note 4]	From 20 NM to 7° glide path	From 21 nm, on course and the MVA or 2,300 feet above LTP, which ever is higher, fly at level altitude until 7-degree path.	1) LAAS Receiver maintains "GBAS" Integrity. 2) No CDI Flags Note 2
Coverage from Upper Service Volume [Note 4]	From 20 NM to 7° glide path	From 21 nm, on course and 10,000 feet above LTP fly at level altitude until 7 degree path.	1) LAAS Receiver maintains "GBAS" Integrity. 2) No CDI Flags Note 2
Missed Approach	From Runway Stop End to 4 NM	Fly runway course, climb at 200 feet per NM	1) LAAS Receiver maintains "GBAS" Integrity. 2) No CDI Flags
Roll Out	From Runway End to Runway End	Taxi Along Runway	1) LAAS Receiver maintains "GBAS" Integrity. 2) No Lateral CDI Flags

Note 1: Determine that guidance is available and the CDI is active at the upper and lower vertical procedure extremities.

Note 2: Determine that guidance is available and the CDI is active at the lateral procedure extremities.

Note 3: VDB transmitter power set at the lower limit of the VDB monitor.

Note 4: See Table 2 for requirement when evaluating parallel runway configurations.

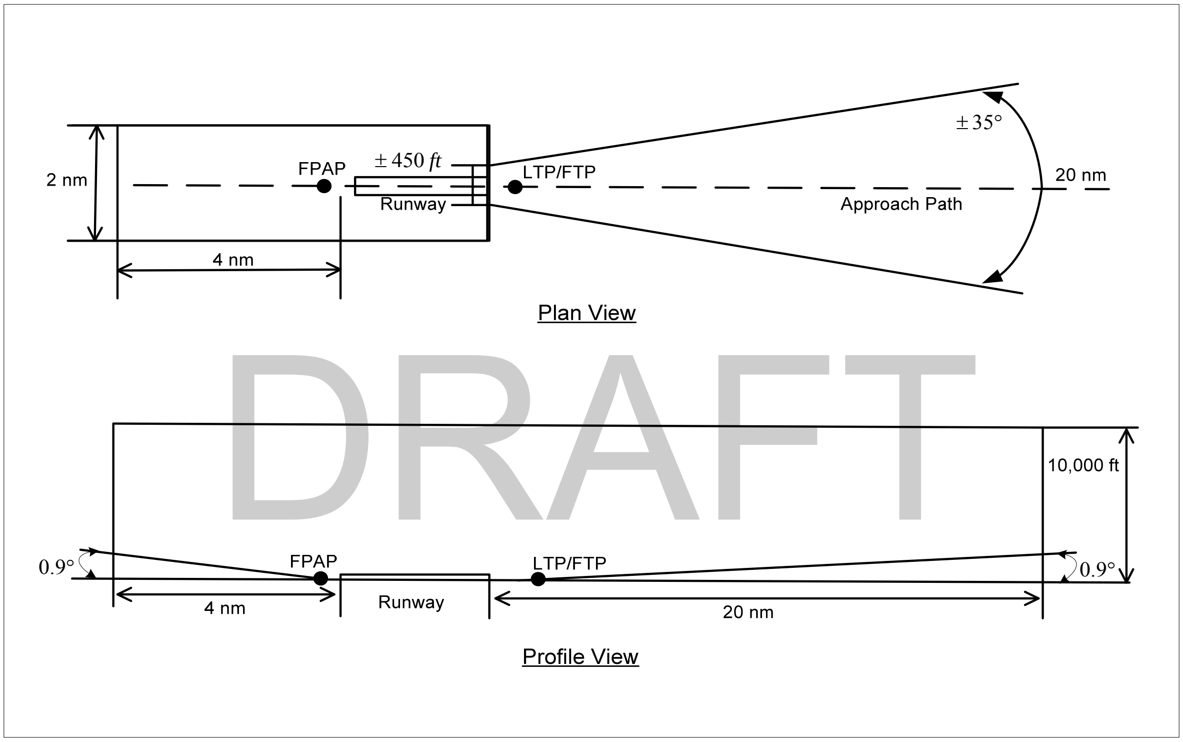

Figure 2-4. Approach Coverage Requirements

Table 2. VDB Approach Coverage Assessment – Parallel Runways			
Requirement	**Evaluation Area**	**Modified Method**	**Performed For**
Normal Approach	From 20 NM to LTP	No change	Each approach procedure
Lower-Limit of Approach	From 20 NM to LTP	No change	Each approach procedure
Upper-Limit of Approach	From 20 NM to LTP	No change	Each approach procedure
Left-Limit of Approach	From 20 NM to FASTLP	From 21 NM, fly on path and on sector left boundary to within 1 dot of full scale of "fly right".	For left limit of each approach sector
Right-Limit of Approach	From 20 NM to FASLTP	From 21 NM, fly on path and on sector right boundary within 1 dot of full scale of "fly left".	For right limit of each approach sector
Coverage from MVA	From 20 NM to 7° glide path	From 21 nm, on approach sector centerline and the MVA or 2,300 feet above FASLTP, which ever is higher, fly at level altitude until 7-degree path relative to FASLTP.	For each approach sector centerline
Coverage from Upper Service Volume	From 20 NM to 7° glide path	From 21 nm, on course and 10,000 feet above FASLTP fly at level altitude until 7 degree path relative to FASLTP.	For each approach sector centerline
Missed Approach	From Runway Stop End to 4 NM	No change	For each approach procedures
Roll Out	From Runway End to Runway End	No change	Once for each runway

3.2.5 Missed Approach Segment. Fly the missed approach procedure from the MAP using the procedural waypoints or associated navigation systems. Evaluation shall include obstructions, procedural design, transition to the missed approach and VDB coverage.

3.2.6 Standard Instrument Approach Procedure. The instrument approach procedure shall be evaluated to ensure flyability and safety. This evaluation and analysis shall be performed in accordance with FAA Order 8200.1 (USSFIM).

3.2.7 Airport Surface. The flight inspection aircraft or inspection vehicle shall taxi taxing along all runway centerlines and major taxiway centerlines within the airport surface area to be serviced. Evaluations shall include assessing alignment/agreement of the electronic airport map with runway and major taxiway surfaces, GPS signal reception, and VDB signal reception within the coverage volume intended to be serviced.

3.3 Periodic Evaluation. The purpose of periodic evaluation is to ensure that there has not been any degradation of the VDB coverage due to environmental changes or equipment repair/replacement and to ensure that new sources of RF interference have not come into existence. Commissioned facilities shall be inspected initially on a 360-day interval. The subsequent periodic interval may be increased based on both performance of the individual facility and as NAS wide experience with LAAS is gained. Until such interval criteria are establish, the 360-day interval will be used.

3.3.1 Facility-based Coverage. VDB coverage along the lower orbit will be evaluated based on loss of signal and data continuity alerts. The altitude established for the lower orbit during commissioning shall be used. LAAS sensor annunciation of operation in GBAS mode will confirm adequate coverage, while inside the Dmax area.

3.3.2 Approach Procedures. The LGF broadcast FAS data block CRC will be checked for each SIAP to ensure there has been no change or corruption. The evaluation shall be performed during the orbit specified in paragraph 3.3.1. Additionally, VDB coverage and the LGF broadcast FAS data block CRC should be checked when runway-based obstacle clearance evaluations are performed for runways provide LAAS approach service.

3.3.3 Terminal Area Path (TAP). The TAP procedure shall be flown from the initial waypoint to the final waypoint, flying on course and on path. Evaluations performed shall include obstacle clearance, GPS signal reception, and VDB signal reception, the TAP procedure data block CRC will be checked for each procedure to ensure there has been no change or corruption. Augmented VDB coverage assessments shall be performed when degradation of the VDB signal or a change in VDB signal characteristics in a containment region is observed during the on-path evaluation.

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3.3.4 Airport Surface. For operations limited to visibility conditions where the pilot or vehicle driver has sufficient visibility to steer and avoid other aircraft/obstacles based on visual observations, no periodic inspection is required. Otherwise, the flight inspection aircraft or inspection vehicle shall taxi taxing along all runway centerlines and major taxiway centerlines within the airport surface area to be serviced. Evaluations shall include GPS signal reception, and VDB signal reception within the coverage volume intended to be serviced, and the airport map data block CRC will be checked to ensure there has been no change or corruption.

3.4 Special Evaluation. A special flight inspection evaluation shall be required subsequent to select maintenance actions (as detailed below); for a change in VDB antenna, antenna type or antenna phase center location; when an existing procedure is modified or a new procedure added; whenever physical changes occur at the site having the potential to effect GPS signal reception and VDB coverage, such as new obstructions or construction or in response to multiple user complaints.

3.4.1 Approach Procedures. Special inspections shall be performed when there has been a modification of the instrument approach procedure; a new procedure has been added to a commissioned facility; whenever changes to the LGF configuration are made such as hardware/software changes having the potential to affect the internal navigation database or coding/construction of the VDB messages; when there is a change in VDB antenna, antenna type or antenna phase center location; whenever physical changes occur at the site having the potential to effect GPS signal reception and VDB coverage; or in response to multiple user complaints. As predicated by the reason for the special, VDB coverage is evaluated at the altitude established for the lower orbit during commissioning, and in operationally utilized areas where coverage is predicted or known to be affected. The VDB coverage evaluation is based on loss of signal and data continuity alerts. For each modified or new SIAP, the LGF broadcast FAS data block CRC should be checked to ensure there has been no change or corruption. A normal approach should be flown for modified instrument approach procedures (see Table 1). A normal approach, as well as upper, lower, left, and right limit profiles should be flown for new procedures (see Table 1). The evaluations performed should include procedure design, segment alignments, obstacle clearance, GPS signal reception, and VDB signal reception within the coverage volume.

3.4.2 Terminal Area Path (TAP). Special inspections shall be performed when there has been a modification of the TAP procedure; a new procedure has been added to a commissioned facility; subsequent to maintenance actions having the potential to affect TAP data; whenever there is a change in VDB antenna type or antenna phase center location; whenever physical changes occur at the site having the potential to effect GPS signal reception and VDB coverage; or in response to multiple user complaints. As predicated by the reason for the special, VDB coverage is evaluated in operationally utilized areas where coverage is predicted or known to be affected. Each modified or new TAP procedure should be flown from the initial waypoint to the final waypoint, flying on course and on path and the evaluations performed should include obstacle clearance, GPS signal reception, and VDB signal reception within the service volume. The evaluation of procedure design and segment alignments should be performed when an existing procedure has been modified or a new procedure has been added. Augmented VDB coverage assessments should be performed when degradation of, or a change in, the signal characteristics in a containment region is observed during the on-path evaluation.

3.4.3 Airport Surface. The criteria herein applies when operations are authorized in visibility conditions where the pilot or vehicle driver may have some level of reliance on LAAS to steer, avoid other aircraft/obstacles, and detect upcoming runway and taxiway intersections. Special inspection may also be conducted when LAAS guidance is used in an advisory only capacity, depending on the nature of the situation and availability of inspection resources. Special inspections shall be conducted when the airport map for a facility has been revised; when there is a change in VDB antenna, antenna type or antenna phase center location; whenever physical changes occur at the site having the potential to effect GPS signal reception and VDB coverage, such as new obstructions or construction; or in response to multiple user complaints. As predicated by the reason for the special, VDB coverage should be evaluated in operationally utilized areas where coverage is predicted or known to be affected. The evaluations to be performed should include assessing alignment/agreement of the electronic airport map with runway and major taxiway surfaces, GPS signal reception, and VDB signal reception within the coverage volume intended to be serviced.

4. Flight Inspection Analysis. Paper recordings and electronic collection of data are required. Differential GPS is required. During an LAAS approach, document LAAS data starting from the Initial/Intermediate fix inbound to LTP/ FTP. A flight inspection “low approach” is required to provide data analysis. Document LAAS data during all runs.

4.1 VDB. Initial evaluation shall require the VDB signal be validated throughout the defined service volume by ensuring there are no data continuity alerts. The LGF shall be configured for normal data transmission except the power output shall be at the established RF power alarm point.

For periodic evaluation, VDB coverage along the lower orbit will be evaluated based on loss of signal and data continuity alerts. The altitude established for the lower orbit during commissioning shall be used. LAAS sensor annunciation of operation in GBAS mode will confirm adequate coverage, while inside the Dmax area. The LGF broadcast FAS data block CRC will be checked for each SIAP to ensure there has been no change or corruption. The LGF shall be configured for normal data transmission.

4.2 Procedural Design and Database Integrity. Commissioning flight inspection shall require the approach path be evaluated to verify that the instrument approach procedure delivers the aircraft to the desired aiming point. The FAS data CRC remainder will be compared with the procedural design data to insure no data changes or corruptions have occurred.

4.3 Horizontal Alignment and Glidepath Angle. Horizontal alignment and glidepath angle shall deliver the aircraft to the designed LTP/FTP.

4.4 GPS Satellite Parameters. The following parameters must be documented at the time anomalies are found during any phase of the flight inspection:

Parameter	Expected Values
HPL_{GBAS}	≤ 10m
VPL_{GBAS}	≤ 10m
HDOP	≤ 4.0
VDOP	≤ 4.0
HIL	≤ 0.3nm
FOM	≤ 22meters
Satellites Tracked	5 Minimum
Signal-to-Noise Ratio (SNR)	30 dB/ Hz minimum

Note: There are no flight inspection tolerances applied to these parameters. However, they may provide useful information should GPS signal anomalies or interference be encountered.

4.5 Electromagnetic Spectrum. The RF spectrum from 1559 to 1595 MHz should be observed when GPS parameters indicate possible RF interference. Interference signals are not restrictive unless they affect receiver/sensor performance. Loss of differential data is an indication of interference, multipath, or shadowing of the VHF transmission. The RF Spectrum ± 100 kHz either side of the VHF Data Link (VDL) frequency shall be observed on the spectrum analyzer in the case of suspected interference. Report any spectrum anomalies or suspected anomalies encountered to the National Maintenance Control Center (NMCC).

5. Tolerances.

5.1 Flight Inspection Reference System. AFIS with differential GPS (DGPS) corrected data will be used to provide FAS data analysis.

5.2 Specific Parameter Tolerances (TBC).

Parameter	**Reference**	**Tolerances**
Terminal Area Path	3.2.2	(Reserved)
Airport Surface	3.2.7	(Reserved)
Initial/Intermediate Approach Segment	4.2	FAA Order 8200.1
Final Approach Segment FAS data: Bearing to LTP Glidepath Angle FAS Data CRC TCH Course Alignment w/runway C/L	 4.2 4.2 4.2 4.2 4.2	 ± 0.1° true course ± 0.05^0 No Corruption ±2 m Centerline
Missed Approach Segment	4.2	FAA Order 8200.1
Broadcast VDB messages Coverage VDB, minimum field strength, horizontal polarization Coverage VDB, minimum field strength, vertical polarization	4.1	Required message types -99 dBW/m^2 215 µV/m -103 dBW/m^2 or 136 µV/m
Horizontal Protection Level (DO-245A) Vertical Protection Level		40m 10m
Co-channel / adjacent channels (VOR or ILS) Annex 10, V1, Attch D 7.2	4.5	No misleading information
RF Interference	4.5	No misleading information
Maximum Usable Distance (Dmax)	3.2	As defined by LGF Site.

6.0 Adjustments. (Reserved)

APPENDIX 3: ACRONYMS AND DEFINITIONS

AFIS	Automated Flight Inspection System
AGL	Above Ground Level
APL	Airport Pseudolites
ATCU	Air Traffic Control Unit
CRC	Cyclic Redundancy Check
DA	Decision Altitude
DCH	Datum crossing height
Dmax	Maximum use distance of LAAS Differential Corrections
ECEF	Earth Center Earth Fixed
FAF	Final Approach Fix
FAP	Final Approach Path
FASAP	Fictitious Approach Sector Alignment Point
FASLTP	Fictitious Approach Sector Landing Threshold Point
FTP	Fictitious Threshold Point
FAS	Final Approach Segment
FOM	Figure of Merit
FPAP	Flight Path Alignment Point
GBAS	Ground Based Augmentation System
GNSS	Global Navigation Satellite System
GPA	Glide Path Angle
GPIP	Glide Path Intercept Point
GPS	Global Positioning System
HAL	Horizontal Alert Limit
HDOP	Horizontal Dilution of Precision
HIL	Horizontal Integrity Limit
HPL	Horizontal Protection Level
IAF	Initial Approach Fix
ICAO	International Civil Aviation Organization
ICD	Interface Control Document
LAAS	Local Area Augmentation System
LBAP1	Left Boundary Alignment Point 1
LBAP2	Left Boundary Alignment Point 2
LGF	LAAS Ground Facility
LSP	Local Status Panel
LTP	Landing Threshold Point
MDT	Maintenance Data Terminal
MVA	Minimum Vectoring Altitude
NAS	National Airspace System
PVT	Position Velocity Time
RBAP1	Right Boundary Alignment Point 1
RBAP2	Right Boundary Alignment Point 2
RDP	Runway Datum Point
RSP	Remote Status Panel
SBAS	Space Based Augmentation System
SIAP	Standard Instrument Approach Procedure

SPS	Standard Positioning Service
TAP	Terminal Area Path
USSFIM	United States Standard Flight Inspection Manual
VAL	Vertical Alert Limit
VDB	VHF Data Broadcast
VDOP	Vertical Dilution of Precision
VHF	Very High Frequency
VPL	Vertical Protection Level
WAAS	Wide Area Augmentation System

Alert - an indication provided to other aircraft systems or annunciation to the pilot to identify that an operating parameter of a navigation system is out of tolerance.

Alert Limit - for a given parameter measurement, the error tolerance not to be exceeded without issuing an alert.

Availability - the ability of the navigation system to provide the required function and performance at the initiation of the intended operation. Short-term system availability is the probability that the aircraft can conduct the approach at the destination given that the service at the destination was predicted to be available at dispatch. Long-term service availability is the probability that the signal in space from the service provider will be available for any aircraft intending to conduct the approach.

Continuity - the ability of the total system (comprising all elements necessary to maintain aircraft position within the defined airspace) to perform its function without interruption during the intended operation. More specifically, continuity is the probability that the specified system performance will be maintained for the duration of a phase of operation, presuming that the system was available at the beginning of that phase of operation.

Cyclic Redundancy Check (CRC) – a very powerful form of parity check. The CRC algorithm associates a sequence of CRC code bits with a data block to preserve its integrity during storage and transmission operations.

Datum Crossing Height (DCH) – the relative height at which the Final Approach Segment passes over the Runway Datum Point.

Datum Crossing Point (DCP) – the point on the Final Approach Segment directly above the Runway Datum Point.

Fictitious Threshold Point (FTP) – The FTP is a point functionally equivalent to a Landing Threshold Point, except that the FTP is not coincident with the designated runway threshold.

Final Approach Segment (FAS) – The straight line segment that prescribes the three-dimensional geometric path in space that an aircraft is supposed to fly on final approach.

Final Approach Path (FAP) - the prescribed straight three-dimensional path in space to be flown on final approach. For GPS/LAAS, this path is defined in the FAS Path Data by the Runway Datum Point (RDP), the Datum Crossing Height (DCH), the Flight Path Alignment Point (FPAP), and the Glide Path Angle.

Flight Path Alignment Point (FPAP) - a surveyed position used in conjunction with the Runway Datum Point to define the along track direction for the Final Approach Segment. The FPAP is specified in terms of (latitude, longitude), with height equal to the WGS-84 height of the RDP. The FPAP is used in conjunction with the LTP/FTP and the geometric center of the WGS-84 ellipsoid to define the geodesic plane of a precision final approach, landing and flight path. The FPAP may be the LTP/FTP for the reciprocal runway.

Glide Path Angle (GPA) – The glide path angle is an angle, defined at a calculated point located directly above the LTP/FTP, that establishes the intended descent gradient for the final approach flight path of a precision approach procedure. It is measured from the plane containing the LTP/FTP that is parallel to the surface of WGS-84 ellipsoid.

Glide Path Intercept Point (GPIP) – The GPIP is the point at which the extension of the final approach segment intercepts the plane containing the LTP/FTP that is parallel to the surface of WGS-84 ellipsoid.

GBAS Ground-based augmentation system.

Landing Threshold Point (LTP) – The LTP is used in conjunction with the FPAP and the geometric center of the WGS-84 ellipsoid to define the geodesic plane of a precision final approach flight path to touchdown and rollout. It is a point at the designated center of the landing runway defined by latitude, longitude, ellipsoidal height, and orthometric height. The LTP is a surveyed reference point used to connect the approach flight path with the runway. The LTP may not be coincident with the designated runway threshold.

Misleading Information - Within this standard, misleading information is defined to be any data which is output to other equipment or displayed to the pilot that has an error larger the current protection levels (HPL/VPL) for the current operation. This includes all output data, such as position and deviations.

Maximum Use Distance (Dmax) – The range from the LGF within which the required integrity for the differentially-corrected position can be assured. Dmax is the maximum distance lateral and vertical guidance are provided from the LGF antenna (Service Volume). Dmax is broadcast in Message Type 2. LGF Dmax distance value is dependent on the specific operations intended and must be defined on a case-by-case basis.

Message Type 0 – Message type broadcast from the LGF when the facility is in test mode. This message prevents an aircraft's avionics system from being able to use the LGF. AVN flight inspection aircraft have a unique capability to override "Message Type 0" in order to perform inspection and evaluation while the LGF in in test mode.

Protection Level - the statistical error value which bounds the actual error (navigation sensor error in particular) with a specified confidence.

Pseudolite - A pseudolite (pseudo-satellite) is a ground-based GNSS augmentation which provides, at GNSS ranging source signal-in-space frequencies, an additional navigation ranging signal. The augmentation may include additionally differential GNSS corrections. (Adapted from the FANS GNSS Technical Subgroup).

Runway Datum Point (RDP) - a surveyed position on the ground over which the Final Approach Segment passes at a relative height specified by the Datum Crossing Height.

Reference Receiver - a GNSS receiver incorporated into the LAAS ground subsystem, used to make pseudorange measurements that support to generation of pseudorange corrections.

Standard Service Volume for LAAS – The standard service volume and Dmax setting for LAAS is 23nm. However, the service volume for a particular LGF is dependent on the specific operations intended and may be adjusted accordingly.

Terminal Area Path (TAP)- A terminal procedure utilizing LAAS for lateral and vertical path definition, which is attached to a LAAS final approach segment. The path is defined by using ARINC 424 track-to-fix and radius-to-fix leg types