U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

NOTICE
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July 6, 2006

Cancellation Date:
July 6, 2007

SUBJ: GUIDELINES FOR AIRWORTHINESS AND OPERATIONAL APPROVAL AND PROCEDURE DESIGN FOR NON-14 CFR PART 97 RNP SAAAR APPROACH PROCEDURES

1. PURPOSE. This document outlines the operational approval process for special (non-14 CFR Part 97) required navigation performance (RNP) special aircraft and aircrew authorization required (SAAAR) operations and addresses the implementation of special aircraft and aircrew authorization requirements similar to current ILS Category II/III approvals. These approvals utilize mature procedure design criteria and aircraft evaluation criteria, and require the applicant to demonstrate the capability to meet requirements as part of the application package. This notice is comprised of the basic document and eight appendices. Appendix 5 is unique since it is divided into chapters containing approach construction and obstacle clearance guidance.

2. DISTRIBUTION. This notice is distributed in Washington headquarters to the branch level in the Offices of Airport Safety and Standards and Communications, Navigation, and Surveillance Systems; to Air Traffic, Airway Facilities, Aircraft Certification and Flight Standards Services; to the National Flight Procedures Group and the Regulatory Standards Division at the Mike Monroney Aeronautical Center; to branch level in the regional Flight Standards, Airway Facilities, Air Traffic, and Airports Divisions; section level in all Aircraft Certification Directorates, all Aircraft Certification Offices (ACOs), and all Aircraft Certification Chief Scientific and Technical Advisors, and Flight Standards District Offices (FSDOs), special mailing list ZVS-827, and to special military and public addressees.

3. BACKGROUND. An approval process that includes the CHDO/FSDO, AWO, and a National Aircraft Evaluation Team (NAET) has been established to enable initial special Required Navigation Performance (RNP) special aircraft and aircrew authorization requirements (SAAAR) operations. These approvals use mature procedure design criteria and aircraft evaluation criteria where the applicant demonstrates the capability to meet the performance and functional requirements associated with the requested special RNP SAAAR. These approvals use mature RNP procedure design criteria in conjunction with FAA Order 8260.3B, United States Standard for Terminal Instrument Procedures (TERPS), and Advisory Circular AC 120-29A, Criteria for Approval of Category I and Category II Weather Minima for Approach, and aircraft evaluation criteria where the applicant demonstrates the capability to meet the performance and functional requirements associated with the requested special RNP SAAAR. For air carriers, this notice is intended for use in conjunction with provisions of FAA AC 120-29A.

Distribution: A-W(AS/ND/AT/AF/IR/FS)-3; AJW-32 (200 CYS); AMA-200 (80 CYS) **Initiated By:** AFS-420
A-X(FS/AF/AT/AS)-3; A-X(CD)-4; A-FAC-0 (LTD); FFS-7 (LTD); ZVS-827;
Special Military and Public Addressees

4. APPROVAL.

a. Air Carrier/Commercial Operator Approval. Operators should notify their intent to seek special RNP SAAAR operational approval to the Certificate Management Office (CMO) or certificate-holding district office (CHDO) which holds their air carrier or operating certificate. Upon satisfactory completion of the evaluation, special RNP SAAAR authorizations will be addressed through issuance of approved Operations Specifications (OpSpecs) that identify any conditions or limitations necessary (for example, navigation systems or procedures required, routes, areas, procedures authorized).

b. General Aviation Approval. Operators should notify the Flight Standards District Office (FSDO) of their intent to seek special RNP SAAAR operational approval. Upon satisfactory completion of the evaluation, special RNP SAAAR authorizations will be addressed through issuance of a Letter of Authorization (LOA) identifying any conditions or limitations necessary (e.g., navigation systems or procedures required, routes, areas, procedures authorized). CFR Part 91 operators requesting special RNP SAAAR procedures must meet the requirements of this document.

c. Approval Process. For carriers, provisions of FAA AC 120-29A and standard Operations Specifications serve as the basis for operational authorization. The process described below is written as a sequential phased process. (See appendix 1, 2, and other appropriate appendices.) However, each phase is interrelated and dependent on FAA and applicant coordination. Therefore, although depicted sequentially, the entire process is accomplished concurrently. The process for obtaining operational approval for special RNP SAAAR operations follows:

(1) **<u>Phase I:</u>** The applicant requests special RNP SAAAR authorization from the FAA. Where Phase I has traditionally been a pre-application meeting, the purpose of this phase is to submit the applicant's special RNP SAAAR approval package. A pre-application meeting between the applicant and CHDO/FSDO may take place if desired, to provide a common understanding of the process. The application package for the specific special RNP SAAAR operation(s) requested must include, at a minimum:

(a) Aircraft evaluation.

(i) Type of equipment planned for use.

(ii) Documentation addressing the performance and functional requirements referenced in appendix 4.

(b) Operational qualification.

(i) Crew qualification and training.

(ii) Operating procedures. Consideration should be given to Operational Considerations in appendix 3.

(iii) Revisions to Manuals, checklists, QRHs, etc.

(iv) Continuing airworthiness.

(v) Database.

(vi) Maintenance training.

(vii) Dispatch training.

(viii) Minimum Equipment List.

(ix) Validation test plan.

(c) The CHDO/FSDO ensures the application package is complete and in an acceptable format before forwarding the aircraft evaluation section (reference appendix 4) to the AWO. The CHDO/FSDO initiates preliminary coordination at the local, regional, and national levels; and becomes familiar with the applicant's manuals, procedures, and policies. The AWO reviews and forwards the package to the NAET.

(d) The NAET determines if the aircraft meets performance and functional requirements necessary for the special SAAAR as defined in appendix 4. The findings of the NAET are sent to the CHDO/FSDO through the AWO. Findings should include applicable procedures; and any limitations associated with the aircraft evaluation, e.g., use of autopilot, flight director, limitations on types of procedures, etc.

(2) <u>Phase II:</u> The CHDO/FSDO reviews the NAET findings and then evaluates the complete submission package (aircraft and operational qualifications). The CHDO/FSDO forwards the complete package to Flight Standards Flight Technology and Procedures Division (AFS-400) through the AWO. AFS-400 will forward a copy of the airworthiness portion to AFS-350 for review and comment. AFS-410 then reviews the entire package and AFS-350 comments for sufficiency; and returns the package to AFS-400 for signature, noting consensus and/or comments. The entire package will then be returned to the CHDO/FSDO through the AWO.

(3) <u>Phase III:</u> The AWO reviews the package and forwards the package to the CHDO/FSDO.

(a) The CHDO/FSDO analyzes the package for safe operating procedures (as described in the appropriate manuals), logic of sequence, training programs, flight crew and dispatcher qualifications, flight following requirements, acceptable participants, and schedules. The CHDO/FSDO evaluates all elements of the package, e.g., observe training, maintenance schedules, preventive maintenance, dispatch, MEL, procedures, etc.

(b) Validation tests will be conducted when an applicant is required to demonstrate its capability to conduct operations before being granted FAA authorization/approval. FAA Order 8400.10, Air Transportation Operations Inspector's Handbook, Volume 3, chapter 9, contains instructions for conducting the validation test process. The following are examples of validations.

- Conduct specific operations to collect data for either validation or FAA observation purposes.

- Demonstrate ability to conduct RNP operations.

- Determine if applicant has satisfied all test objectives or is unable to satisfactorily complete them.

(4) **<u>Phase IV:</u>** After successfully completing the validation test process, if necessary, the CHDO/FSDO issues the applicant an operational approval. Operational approvals are issued either as an appropriate Operations Specification (OpSpecs) or Letter of Authorization (LOA).

5. PROGRAM TRACKING AND REPORTING SUBSYSTEM (PTRS) INPUT. Aviation Safety Inspectors (ASI) must make a PTRS entry for each of their operators to record the actions directed by this notice as outlined in HBAT 00-13A, "Program Tracking and Reporting Subsystem (PTRS) Documentation of Action Required by Flight Standards Bulletins." The operations activity code must be 1381 and the "national use" field entry should be "HBAT Special RNP SAAAR." ASIs should use the comments section to record comments of interaction with the operators.

6. OPERATIONS SPECIFICATIONS. Air carrier and commercial operators will be issued OpSpecs paragraph for Special RNP SAAAR.

7. DOCUMENTATION LETTER FOR PART 91 OPERATOR AIRCRAFT ELIGIBILITY. Part 91 operators will be issued a letter of authorization.

8. INQUIRIES. AFS-400, Flight Technology and Procedures Division developed this notice. Any inquiries regarding this notice should be directed to the Flight Technologies and Procedures Division (AFS-400) at (202) 385-4586.

9. DISPOSITION. This information will be incorporated in a future chapter of FAA Order 8300.10, Airworthiness Inspector's Handbook, FAA Order 8400.10, Air Transportation Operations Inspector's Handbook, and FAA Order 8700.1, General Aviation Operations Inspector's Handbook. Until the new material is incorporated into the handbook, inspectors should make written reference of this notice in the margin next to the indicated paragraph.

10. RELATED READING MATERIALS.

a. RTCA/DO-178B, Software Considerations in Airborne Systems and Equipment Certification.

b. RTCA/DO-187, Minimum Operational Performance Standards for Airborne Area Navigation Equipment Using Multi-Sensor Inputs.

c. RTCA/DO-189, Minimum Aviation Performance Standard for Airborne Distance Measuring Equipment (DME) Operating Within the Radio Frequency Range of 960-1215 Megahertz.

d. RTCA/DO-200A, Standards for Processing Aeronautical Data.

e. RTCA/DO-201A, Standards for Aeronautical Information.

f. RTCA/DO-236B, Minimum Aviation System Performance Standards: Required Navigation Performance for Area Navigation.

g. RTCA/DO-283A, Minimum Operational Performance Standards for Required Navigation Performance for Area Navigation.

h. Technical Standard Order (TSO) C66, Distance Measuring Equipment (DME) Operating within the Radio Frequency Range of 960-1215 Megahertz.

i. TSO-C115, Airborne Area Navigation Equipment Using Multi-sensor Inputs.

j. TSO-C129, Airborne Supplemental Navigation Equipment Using the Global Positioning System (GPS).

k. FAA Order 8200.1B, United States Standard Flight Inspection Manual.

l. FAA Order 8260.19C, Flight Procedures and Airspace.

m. FAA Advisory Circular (AC) 20-130A, Airworthiness Approval of Navigation or Flight Management Systems Integrating Multiple Navigation Sensors.

n. FAA AC 25-4, Inertial Navigation Systems (INS).

o. FAA AC 25-7A, Flight Test Guide for Certification of Transport Category Airplanes.

p. FAA AC 25-15, Approval of Flight Management Systems in Transport Category Airplanes.

q. FAA AC 90-94, Guidelines for Using Global Positioning System Equipment for IFR En Route and Terminal Operations and for Non-Precision Instrument Approaches in the U.S. National Airspace System.

r. FAA AC 120-29A, Criteria for Approval of Category I and Category II Weather Minima for Approach.

s. FAA AC 25.1309-1A, System Design and Analysis.

11. LIST OF APPENDICES.

Original Signed By
Carol Giles

James J. Ballough
Director Flight Standards Service

APPENDIX 1

SPECIAL RNP SAAAR APPROVAL CHECKLIST

Date Application Submitted: ________________________

1. **Operator meets Appendix 4 Requirements** ☐
2. **Navigation Database Integrity (check method below)** ☐

   a. **Approved Database Supplier** ☐
   or
   b. **Demonstrated Database Integrity Process** ☐

3. **Demonstrated Continued Airworthiness** ☐
4. **SAAAR Training (e.g., flight crew/dispatch)** ☐
5. **MEL Revision for Special SAAAR (as required)** ☐
6. **Meets Operational Procedures Requirements** ☐
7. **Validation successfully completed (as required)** ☐

POI ACTION:

Special SAAAR Approval (issue LOA or OpSpecs) ☐

Special SAAAR Disapproval ☐

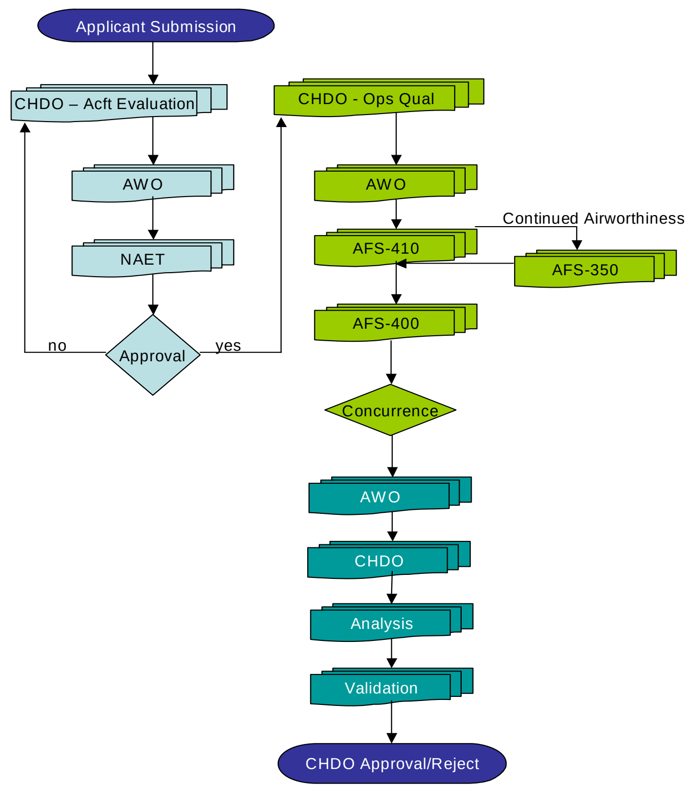
Reason for Disapproval:

Date: _________________________

POI Signature: _________________________

APPENDIX 2

APPROVAL PROCESS FLOWCHART



NOTE: *Although NAET and AFS-410 evaluation are depicted sequentially, they may be accomplished concurrently.*

APPENDIX 3

OPERATIONAL CONSIDERATIONS

1. GENERAL. General RNAV operating requirements such as checking NOTAMS to determine the availability of NAVAIDs, determining that the aircraft systems are installed and working properly, and determining that the aircrew is qualified and current need to be addressed. When conducting special RNP SAAAR procedures, some operational requirements will be determined by the specific procedure being conducted. Examples are listed below.

a. Autopilot. An autopilot may be required to be used for procedures with small RNP values. The autopilot must operate with suitable accuracy to track the lateral and vertical paths required by a specific procedure. This may be a lateral or vertical path. With an autopilot required procedure, dispatch must determine that the autopilot is installed and operational. Prior to take-off the manufacturer's auto pilot check must be satisfactorily completed. (This check may be "no flags" or more detailed check depending on manufacturer's procedures.)

b. NAVAID Exclusion. Procedures to determine and exclude NAVAID facilities identified as out-of-service need to be addressed. Reasonableness checks may not be adequate for small RNP levels in that reasonableness checks are not designed to eliminate all errors, but eliminate errors of a specific magnitude or larger.

c. Track Deviation Monitoring. A course deviation indicator (CDI) with proper scale is required for lateral and/or vertical deviation monitoring unless an autopilot can be shown to provide accurate path steering appropriate to the phase of flight. The aircraft flight manual (AFM) should state which RNP types and operations the aircraft supports and the operational effects on the CDI scale. The CDI full-scale deflection value must be known or available for display to the flight crew. The scale may be automatic (dependant on phase of flight) or may be manually set. If the flight crew manually selects the CDI scale, procedures must be established to assure the CDI scale is appropriate for the intended RNP operation.

d. Predictive Capability. A predictive capability is required which will forecast whether RNP of a specified type will be available at the time and location of a desired RNP operation accounting for known and predicted outages of NAVAIDs or other sensors used by the system. This capability is not required to be resident in the avionics equipment itself, but could be a ground service. Procedures must be established that use this capability as a pre-flight dispatch or flight following function to ensure that the equipment will be able to provide the desired level of RNP throughout the entire flight. This capability must consider the specific combination of aircraft capability (sensors and integration) and available infrastructure (e.g., ground based navigation aids or approval to use GNSS). In addition, the flight crew must have the means to identify facilities that are not expected to be available, e.g., excluding the use of NOTAM'd navigation facilities.

e. MEL. The MEL must specifically address equipment required to achieve and maintain special RNP SAAAR operations. For example, lower special RNP SAAAR types may require FD/AP and GPS as the navigation sensor. These items will be required for dispatch for planned operations performing these special RNP SAAAR types, as well as for the operation itself.

f. Contingency Procedures. Contingency procedures will need to be developed by the operator to address the following conditions:

(1) Failure of the RNP system components, including those affecting flight technical error (e.g., failures of the flight director or automatic pilot). Some aircraft require the autopilot to be used to achieve a certain RNP level. Procedures should be in place for an alternate course of action if this type of failure occurs.

(**2) Failure of the Navigation Sensors.** If a navigation sensor becomes inoperative, the RNP system may not be able to achieve the required RNP level. The flight crew must be able to assess the impact of equipment failure on the remainder of the flight plan and take appropriate action. Procedures should be in place for an alternate course of action if this occurs.

(3) Loss of signal-in-space (loss or degradation of external signal). When the loss or degradation of an external signal decreases the performance of an RNP system below the required RNP level, the procedure should be discontinued. The flight crew must be able to assess the impact of ground NAVAID failure on the remainder of the flight plan and take appropriate action. Procedures should be in place for an alternate course of action if this occurs.

(4) Coasting on Inertial Sensors Beyond a Specified Time Limit. Upon loss of auto-updates or loss of GPS coupling of an IRU, an IRU will navigate using inertial guidance only. In this mode, the inherent drift of the IRU will continuously degrade the navigation solution offered by the IRU. Thus, operations relying on an IRU "coasting" using inertial guidance exclusively can only continue for a specified amount of time before the navigation solution offered by the IRU exceeds the containment region and a loss of RNP navigation capability occurs. In essence, IRUs "coasting" under these conditions can provide limited support for RNP. As a result, contingency procedures must reflect the length of time an IRU is capable of supporting the various levels of RNP.

APPENDIX 4

PERFORMANCE AND FUNCTIONAL CRITERIA FOR RNP SAAAR APPROACHES

1. INTRODUCTION.

This appendix describes the performance and functional criteria for special RNP SAAAR approaches, as well as summarizing the capability of several existing aircraft to facilitate their operational approval. This appendix does not result in a new set of certification criteria for systems. The criteria are based on the desired operations and applications. Aircraft may be evaluated against this criteria and appropriate operational procedures and mitigations developed as appropriate to satisfy the operational objectives. Many of these characteristics are also addressed in RTCA/DO-236B. Also, for lower RNP types than discussed herein, a higher integrity requirement may be considered appropriate. This could significantly affect the system hardware fault detection/monitor design and software level.

2. SUMMARY OF AIRCRAFT CAPABILITY.

a. Aircraft with a demonstrated RNP capability, as documented in their AFM or AFM supplement, are considered eligible for special RNP SAAAR procedures. These aircraft are only subject to examination where the aircraft AFM or AFM Supplement, supporting documents, and application package do not provide sufficient information to address the specific performance and functional criteria applicable to the proposed procedure.

b. Aircraft evaluation is only one component of the implementation of special RNP SAAAR approach procedures. The other major components are the procedure design (appendix 5) and the operational approval criteria such as training, aircrew qualification, etc.

c. The following aircraft are considered compliant with the functional criteria defined in section 5 of this appendix, subject to the items identified in paragraph d. These aircraft also provide some aircraft monitoring that can be used in support of compliance to the performance requirements, see the reference documents for the applicable aircraft.

(1) Boeing 737NG, B757, B767, and B777 aircraft with AFM-specified RNP capability to RNP-0.3 or less.

(2) Airbus A318, 319, 320, 321, 330, 340 aircraft with AFM-specified RNP capability to RNP-0.3 or less.

d. Functional review items for Boeing and Airbus aircraft with AFM-specified RNP capability of 0.3 or less.

(1) <u>Position Estimation – GPS:</u> Following a loss of GPS signals, the navigation system will provide a capability to safely complete the flight operation or execute the missed approach. This requires any reversionary capability be evaluated to determine what level of operations can be conducted, and any procedural mitigation.

(2) <u>Position Estimation – DME (if applicable):</u> The RNP demonstrated performance using DME is based on assumptions of DME sensor and signal accuracy that should be confirmed for the operation. The use of ILS DMEs, TACANs that are not included in the NAS, and facilities that are temporarily down for maintenance need to be addressed for the operation.

(3) <u>Position Estimation – VOR (if applicable):</u> The RNP demonstrated performance using VOR is based on assumptions of VOR sensor and signal accuracy that should be confirmed for the operation. Out-of-tolerance facilities and facilities that are temporarily down for maintenance need to be addressed.

(4) Some aircraft do not have the ability to fly a constant radius arc between two fixes.

NOTE: *Airbus 2nd Generation FMS, 737NG FMS U10, 757/767 Pegasus FMS, and 777 FMS are known to provide this capability.*

(5) <u>Fly-by Turns:</u> Ensure that the FMS path stays within the theoretical transition area under the foreseen wind conditions.

(6) For RNP transitions, the transition must be complete by the turn initiation point for the fix that defines the transition. Any operational procedures or database limitations necessary **to accomplish this must be identified.**

(7) <u>Path Steering:</u> Crew action should be taken to ensure that the aircraft does not exit the defined obstacle clearance area when the displacement relative to the defined path (cross track or vertical deviation) becomes too large. This may be accomplished by monitoring these displacements in relation to RNP containment, or by defining a specific procedure for initiating a go-around based on excessive cross-track/vertical deviation (for example, half-scale deflection).

(8) <u>Navigation Database:</u> The database supplier must be one whose data quality, integrity and quality management practices have been accepted by the FAA and are consistent with the criteria of DO-200A. Prior to DO-200A based acceptance, it is expected that procedural checks at the database supplier and by the airline operators will be necessary to ensure that exposure to any database errors is minimized. Consideration should be given to continuing database verification for special RNP SAAAR procedures, even when they are obtained from an accepted data supplier.

e. Aircraft other than those identified above need to be evaluated more thoroughly for their compliance against the SAAAR requirements.

f. Where the aircraft do not meet all of the performance or functionality in this section, the applicant may propose operational or procedural mitigations.

g. It is expected that, as experience is obtained with the special RNP SAAAR operations and RNP aircraft, the approval process will be streamlined by defining different groups of aircraft to recognize that many aircraft have already addressed various aspects of this criteria.

3. BACKGROUND ON PERFORMANCE AND FUNCTIONAL REQUIREMENTS.

a. The criteria for special RNP SAAAR approach procedures were developed to build upon the performance-based NAS concept, whereby the performance requirements to conduct an approach are defined, and aircraft are qualified against these performance requirements. Unlike conventional obstacle clearance surfaces for ground-based navigation aids, which are based on a predefined aircraft capability and navigation system, the special RNP SAAAR criteria are flexible tools designed to adapt to unique operational environments and allow approach-specific performance requirements to be specified (as necessary for that approach procedure). Consequently, the aircraft and operational approval take on a new significance, and each new aircraft/operation qualification replaces the flight test and validation of the procedure design criteria. To maximize the flexibility afforded to the aircraft manufacturers and operators, the qualification criteria described in this document are provided at the highest, most abstract level. Guidance on how to show compliance to the requirements in this document for typical aircraft configurations is under development. In many cases, compliance is expected to be determined for the integrated operation, including some constraints on the SAAAR procedure and some requirements for operational procedures. All such conditions should be identified and documented in a checklist that can be used by the operator in evaluating specific procedures. The allocated performance requirements must also be documented to support continuing qualification for SAAAR procedures. A sample list of operational issues that would be addressed in the checklist is provided in appendix 3.

b. The special RNP SAAAR application is predicated upon navigation systems providing a capability for track keeping accuracy supported by performance integrity and continuity, and system functions that exceed the guidance in the RNP concept promulgated by ICAO in Documents 9613 and 9650. Therefore, any special RNP SAAAR applications will expand upon the ICAO RNP concept. However, any systems and applications that only follow the ICAO RNP guidance may not satisfy special RNP SAAAR application requirements.

4. PERFORMANCE REQUIREMENTS.

a. <u>Accuracy</u>. The total system error components in the cross-track and along track directions must be less than the RNP value 95% of the flying time. Accuracy is defined relative to a WGS-84 geodesic path along the published route or defined procedure. The three error components that must be considered in complying with the accuracy requirement are the path steering error (PSE), the position estimation error (PEE), and path definition error (PDE). The accuracy requirement must be met for each specific procedure, considering the geometry and accuracy of the navigation aids that are available (see section 3).

> ***NOTE 1:*** *Path steering error is defined as the combination of flight technical error and display error. In the event that the display error cannot be shown to be negligible, then a reduction in FTE should be accounted for within the total PSE budget. The vertical path steering error budget must reflect altitude reference as well as other factors such as aircraft configuration changes, roll compensation, and speed protection, as applicable.*

__NOTE 2:__ Flight Technical Error: Aircraft that have demonstrated compliance to AC 20-130A can be assumed to have FTE of 0.25 NM (for equipment using GPS data) or 0.5 NM (for equipment not using GPS data) for approach operating modes on a 95 percent basis. Approval for lower FTE with manual flight operations on curved path segments will require separate evaluation of path steering error. Guidance on demonstrating better flight technical error for low visibility operations can be found in paragraphs 5.19.2 and 5.19.3 of AC 120-29A.

__NOTE 3:__ If WGS-84 geodesic paths are not used by the equipment, any differences between the selected earth model and the WGS-84 earth model must be included as part of the path definition error. Errors induced by data resolution must also be considered. For approach procedures with RNP-0.1 and greater, these errors can be neglected provided the aircraft navigation database uses data with the same resolution as that published in the AIP.

__NOTE 4:__ Position estimation error varies depending on the sensors used, the means of integrating the sensor data, and the supporting infrastructure. See sections 2d and 3a.

b. Failure Classification. Malfunction and loss of function are generally considered hazardous (severe-major) failure conditions for RNP SAAAR approaches. Aircraft systems developed consistent with the "major" failure classification may qualify for SAAAR operations where it is demonstrated or evidence is provided to show that the operational safety objectives of the SAAAR procedure are satisfied.

c. Airspace Containment. The obstacle clearance criteria in appendix 5 have been defined based upon an operational objective. This is unlike conventional instrument approach procedures where the obstacle clearance criteria are validated by the FAA based on testing and analysis of a particular navigation system. Under the Containment Concept, the obstacle clearance requirements are established by an operational need. The performance level and functional characteristics required to assure that aircraft are contained within the obstacle clearance specifications are then established. The FAA then uses the aircraft evaluation and approval process to determine the acceptability of the aircraft and airborne system performance and functionality. The objective is to provide for safe operations using the criteria of AC 120-29A, paragraph 4.3.1.1, and the following as appropriate. The average NTSB commercial air carrier accident rates from 1984 through 2003 are 0.39 per 100,000 departures for all accidents and 0.04 per 100,000 departures for fatal accidents. The current three-year commercial air carrier fatal accident rate is 0.022 per 100,000 departures. New operations should provide an equivalent level of safety and not result in an increase in the accident rate for overall operation of the NAS.

It is recognized that the target level of safety may not be met by the aircraft navigation system alone. In cases such as these, it is appropriate to consider the contributions of factors such as traffic density, traffic mix, route complexity, ATC environment, etc. Where additional margins for safety are needed, consideration may be given to a combination of the navigation system, other aircraft systems, and operational procedures and mitigations. The proponent, FAA experts, and other industry experts as appropriate (e.g., from the OEM) should work together to address this requirement and determine suitable methods and issues that are appropriate to the aircraft, operational procedures, and instrument flight procedure under review.

NOTE 1: *This requirement applies to both lateral and vertical errors. All vertical errors must be considered, including the effects of along-track errors and deviations from standard atmosphere (temperature and lapse rate). This requirement applies to total probability of excursion outside the obstacle clearance volume, including latent conditions (integrity) and detected conditions (continuity) if the aircraft does not remain within the obstacle clearance volume. The monitor limit of the alert, the latency of the alert, the crew reaction time, and the aircraft response should all be considered when ensuring that the aircraft does not exit the obstacle clearance volume. The objective applies to a single approach, considering the exposure time of the operation and the NAVAID geometry and navigation performance available for each published approach (see section 2d). Any procedural restrictions that are associated with this requirement must be identified (for example, no turns within a specified distance of the decision point, possible limitation on the RNP value for the missed approach).*

NOTE 2: *It is recognized that safe operation may not be met by the aircraft system alone, but a combination of the system, other systems, and operational procedures and mitigations.*

NOTE 3: *Where aircraft have a short period without RNAV guidance shortly after initiating a go-around (at any point during the approach, including on RF legs), this effect must be considered.*

NOTE 4: *The height loss associated with executing a go-around must be considered.*

NOTE 5: *This containment requirement is derived from the operational requirement. It is notably different than the containment requirement specified in RTCA/DO-236B, which was developed to facilitate airspace design but not to directly equate to obstacle clearance areas.*

NOTE 6: *If reliance is placed on the use of ATC and radar as a mitigation to achieve airspace containment, their performance must be been shown to be adequate for that purpose for each applicable procedure. The use of radar as a mitigation must be coordinated with the ATC provider for each procedure. This is accomplished by documenting this requirement, and addressing this issue as part of the SAAAR authorization (formal agreement with the appropriate ATC facility).*

d. Specific Procedure and Infrastructure Evaluation. The navigation system is dependent on external signals (e.g., DME, GNSS) for both accuracy and airspace containment. In qualifying aircraft for special RNP SAAAR approaches, the criteria or conditions for the external signal environment must be identified. This may be accomplished through an analysis to identify basic conditions (e.g., sufficient number of GPS satellites operating, or DME/DME relative geometry requirement) or may be accomplished by a screening tool that mimics the performance of the navigation system and evaluates a specific procedure. This analysis must be accomplished using the same (or more conservative) criteria used by the aircraft during flight and signal reception validated by flight inspection.

NOTE 1: *This criteria or tool will be used to determine if a specific procedure can be flown by the aircraft and to determine the effect of outages of navigation aids or GNSS satellites. Any required ground-based navigation aids critical to the approach operation must be identified as part of this process. Procedures will be developed to ensure the appropriate aids and systems are available prior to dispatch, and to address operation if anything fails in flight. It is assumed that the support infrastructure is monitored and maintained, such that timely warnings (NOTAM) are issued when navigation aids critical to special RNP SAAAR operations are not available.*

NOTE 2: *Many GPS availability analyses have been based on the number of operational GPS satellites. However, GNSS availability is also dependent on the orbital location of the satellites, and not just how many there are. Criteria for GPS should be based on the number of operational satellites in nominal orbit slots (as defined in the GPS Standard Positioning Service Performance Standard).*

5. FUNCTIONAL REQUIREMENTS.

a. Position Estimation. The navigation system must estimate the aircraft's location. This section identifies unique issues for the navigation sensors expected to be used for special RNP SAAAR approaches. A combination of these sensors is typically used.

(1) GPS. The sensor should comply with the guidelines in AC 20-138(). GPS sensor accuracy is better than 36 meters (95%). Augmented GPS (LAAS or WAAS) is better than 2 meters (95%). When using GPS, the navigation system must detect GPS misleading satellite signals and provide performance continuity to the best level possible, consistent with the available aircraft sensors and system installation. The intent is that following a loss of GPS, the navigation system will provide a capability that supports completion of the flight operation or safe execution of the missed approach. This requires any reversionary capability be evaluated to determine what level of operations can be conducted, and any procedural mitigations. Any limitations or conditions should be identified.

NOTE: *For procedures which allow aircraft to rely only on GNSS, the impact of the loss of GNSS capability for multiple aircraft due to interference or satellite failure has been considered by the FAA and deemed to be unacceptable for SAAAR operations unless its effect is mitigated.*

(2) DME. System accuracy is dependent on and must consider the aircraft DME sensor accuracy. The originally demonstrated DME accuracy depends on the equipment requirements that were applied to the equipment. For equipment marked with TSO-C66(), the demonstrated accuracy can be determined by looking at the specific TSO marking. The previously demonstrated 95% accuracy is as follows:

- TSO-C66a: 0.5 NM or 3% of range, whichever is greater, with a maximum of 3 NM.
- TSO-C66b: 0.5 NM or the root-sum-square of 0.1 NM (95%) and 1% of range, whichever is greater, with a maximum of 3 NM.

- TSO-C66c: 0.17 NM or the root-sum-square of 0.1 NM (95%) and 0.25% of range, whichever is greater.

(a) Where DME is an element of the RNP system architecture and performance, the system must provide automatic selection and de-selection (for example, automatic tuning) of navigation sources, a reasonableness check, an integrity check, and a manual override or deselect (for example, blackballing facility).

NOTE 1: *The reasonableness and integrity checks are intended to prevent navigation aids being used for navigation update in areas where the data can lead to radio position fixing errors due to co-channel interference, multipath, stations in test, changes in station location, and direct signal screening.*

NOTE 2: *If a facility requires maintenance, ATS providers will NOTAM the facility out-of-service. However, the facility may still transmit a DME signal of unknown reliability and respond to interrogations from aircraft sensors. These signals must not be used, or shown that if they are RNP containment is maintained.*

(b) If the system excludes DME facilities which bias their DME distance to the runway threshold, or corrects for this bias, the system may use ILS DMEs as part of the navigation solution. Otherwise, ILS DMEs may not be used.

(c) Only those facilities (including TACANs) that meet the performance requirements of Annex 10, Vol I, Radio Navigation Aids, and are identified in the applicable AIP may be used. In addition, only co-axial VOR/DME or VORTAC facilities may be used.

(3) **<u>IRS.</u>** An inertial reference system must satisfy the criteria of 14 CFR Part 121, Appendix G. While Appendix G defines the requirement for a 2 NM per hour drift rate (2-sigma), that rate does not apply in the short term after loss of position updating. Systems that have demonstrated compliance with 121 Appendix G can be assumed to have an initial drift rate of 4 NM per 30 minutes (95%). Improved inertial performance may be demonstrated in accordance with appendix 1 or 2 of Order 8400.12A.

NOTE: *Integrated GPS/INS position solutions reduce the rate of degradation and immediacy of changing position by position by utilizing inertial drift rate after loss of position updating. For "tightly coupled" GPS/IRUs, the requirements of RTCA/DO-229C, appendix R, apply. If the equipment sustains a coasting capability for RNP operations, the equipment manufacturer should document the coasting performance capabilities and limitations (i.e., coasting time while sustaining 95% RNP accuracy at required performance levels). This documentation must be consistent with the RNP alerting algorithms for the aircraft.*

(4) VOR. VOR accuracy is not sufficient to support the planned RNP values for SAAAR approaches. VOR may be incorporated into a multi-sensor position solution, provided that erroneous VOR signals are shown to have no appreciable effect on the position solution. The system must provide automatic selection and de-selection (i.e. automatic tuning) of navigation sources, a reasonableness check, an integrity check, and a manual override or deselect (for example, blackballing a facility).

NOTE: *The reasonableness and integrity checks are intended to prevent VORs from being used for navigation update in areas where the data can lead to radio position fixing errors due to co-channel interference, multipath, receipt of VOR stations under test, changes in station location, and direct signal screening. Any associated operational procedures or procedure-specific criteria need to be identified. For example, the crew procedures should identify if the operator is expected to inhibit the use of such VOR facilities. Alternatively, if a reasonableness check is used to detect VOR errors, the applicant must identify the minimum navigation infrastructure necessary to support the reasonableness check to the necessary tolerances to ensure airspace containment. In evaluating the reasonableness check, note that VOR signals can routinely be in excess of 6 degrees out of alignment (no a priori credit should be assumed for a VOR signal failure).*

b. Path Definition and Flight Planning. The following capabilities are required:

(1) Capability to execute leg transitions and maintain tracks consistent with the following paths.

(a) a geodesic line between two fixes;

(b) a direct path to a fix (originating from a point, determined by the navigation system, in front of the aircraft sufficient to avoid overshooting the path to the fix);

(c) a constant radius arc between two fixes;

(d) a specified track to a fix, where the track is specified as a magnetic course offset from true north by an amount also specified by the procedure designer; and,

(e) a specified track to an altitude, where the track is specified as a magnetic course offset from true north by an amount also specified by the procedure designer.

NOTE 1: *Industry standards for these paths can be found in RTCA/DO-236B and ARINC Specification 424, referred to as TF, DF, RF, CF, and FA path terminators. Their application is described in more detail in documents EUROCAE ED-75A/ RTCA DO-236B, ED-77/ DO-201A.*

NOTE 2: *The State publishing an RNP procedure should clearly identify in the AIP where use of RF legs have been assumed in the procedure design.*

NOTE 3: *Other ARINC 424 path terminators (e.g. Heading to manual terminator (VM)) may be accommodated by the navigation system, but are not expected to be used where the reliability, predictability, and repeatability of RNP is required.*

(2) Capability for fly-by and fly-over fixes, limiting the path definition for fly-by turns to be within the theoretical transition area defined in RTCA/DO-236B. Any constraints on wind conditions or turn angles required to ensure the path is within the theoretical transition area should be identified.

(3) Capability for a "Direct to" function that can be activated at any time by the flight crew. The Direct-To function must be available to any fix. The system must be capable of generating a geodesic path to the designated "To" fix, without "S-turning" and without undue delay.

(4) Capability to define a vertical path by specifying (in navigation database) a flight path angle from a desired fix.

(5) Capability to define a vertical path by specifying altitude constraints at two fixes in flight plan. Fix altitude constraints must be defined as one of the following:

(a) An "AT or ABOVE" altitude constraint (for example, 2400A, may be appropriate for situations where bounding the vertical path is not required);

(b) An "AT or BELOW" altitude constraint (for example, 4800B, may be appropriate for situations where bounding the vertical path is not required);

(c) An "AT" altitude constraint (for example, 5200); or

(d) A "WINDOW" constraint (for example, 2400A3400B).

NOTE: *VNAV paths may be specified or bound by the application of these types of altitude constraints. For special RNP SAAAR operations, the vertical path may be defined using the following:*

1) Altitude windows (upper and lower altitude constraints) at each end of a vertical path segment, to provide for known bounds on a segment.

2) Altitude window tapered to a fixed altitude constraint, to provide for known bounds on a segment.

3) Fixed altitude constraint to an altitude window tapered to provide for known bounds on a segment.

4) Fixed altitude constraints at each end of a flight path segment, to provide for both repeatable path and known bounds on a segment.

(6) Altitudes and/or speeds associated with published terminal procedures must be extracted from the navigation database.

(7) The system must construct a path to facilitate guidance from current position to a vertically constrained fix.

(8) Capability to continuously display to the pilot flying, on the primary flight instrument for navigation of the aircraft, the RNAV defined path (DTK).

(9) Display of distance to go.

(10) Display of along track distances.

(11) Display of distance between flight plan waypoints.

(12) A display of the altitude restrictions associated with flight plan fixes must be available to the pilot. If there is a specified navigation database procedure with a flight path angle associated with any flight plan leg, the equipment must display the flight path angle for that leg.

(13) If there is a specified navigation database procedure with a flight path angle associated with any flight plan leg, the capability for the display of the flight path data for that leg.

(14) System must provide a numeric display of vertical path steering error, displayed with a resolution of 10 feet or less. The equipment must provide an altitude prediction for the active fix. A transition to/from level flight must be indicated to the flight crew.

(15) Capacity to load from the database into the RNAV system the entire procedure(s) to be flown, to include approach and missed approach procedures and approach transitions, for the selected airport and runway.

(16) Capability to load procedure vertical angles and altitude constraints from the database.

(17) Means to retrieve and display data stored in the navigation database relating to individual waypoints and navigation aids, to enable the flight crew to verify the procedure to be flown.

(18) The source of magnetic variation used for path definition computations for paths defined by a track (CF and FA path terminators) must be the value specified for that procedure in the navigation database, which is expected to be per RTCA/DO-201A.

(19) For RNP transitions, the transition must be complete by the turn initiation point for the fix that defines the transition. Any operational procedures or database limitations necessary to accomplish this must be identified.

c. <u>Path Steering</u>. The aircraft must have the following capabilities related to path steering:

(1) Capability to continuously display to the pilot flying, on the primary flight instrument for navigation of the aircraft, the aircraft position relative to the RNAV defined path (lateral and vertical). Crew action should be taken to ensure that the aircraft does not exit the defined obstacle clearance area when the displacement relative to the lateral or vertical path becomes too large. This may be accomplished by monitoring displacements in relation to RNP containment, or by defining a specific procedure for initiating a go-around based on excessive cross-track/vertical deviation (for example, half-scale deflection).

> ***NOTE:*** *To facilitate crew action when the FTE becomes unacceptable, it is recommended that a course deviation indicator (CDI) located in the pilot's primary field of view along the forward flight path. A fixed scale CDI is acceptable as long as the CDI demonstrates appropriate scaling and sensitivity for the intended RNP type. With a scalable CDI, the scale must derive from the selection of RNP, not from a separate selection of CDI scale. Alerting and annunciation limits must match scaling values. If the equipment uses default RNP types to describe the operational mode (e.g. en route, terminal area and approach), then displaying the operational mode is an acceptable means from which the flight crew may derive the CDI scale sensitivity. A numeric display of deviation may be acceptable depending on the crew workload and display characteristics.*

(2) Display of distance and bearing to the active (To) waypoint, in the pilot's primary field of view. Where not viable, the data may be displayed on a readily accessible page on a control display unit, readily visible to the flight crew.

(3) Display of ground speed or time to the active (To) waypoint, either in the pilot's **primary** field of view, or readily accessible and readily visible to the flight crew.

(4) Capability for automatic leg sequencing with display of sequencing to the flight crew.

(5) Display of the identification of the active (To) waypoint, either in the pilot's primary field of view, or on a readily accessible and visible display to the flight crew.

(6) Display of aircraft track (or track angle error).

(7) Display of To/From.

(8) Failure annunciation, visible to the pilot and located in the primary field of view when looking forward along the flight path.

(9) The course selector of the deviation display must be automatically slaved to the RNAV computed path.

d. <u>Navigation Database</u>.

(1) A navigation database, containing current navigation data officially promulgated for civil aviation, which can:

(a) be updated in accordance with the AIRAC cycle; and

(b) from which RNP SAAAR procedures can be retrieved and loaded into the RNAV system.

(2) The resolution to which the data is stored must be sufficient to achieve the required accuracy.

(3) The database must be protected against flight crew modification of the stored data.

NOTE: *When a procedure is loaded from the database, the RNAV system is required to fly it as published. This does not preclude the flight crew from having the means to modify a procedure or route already loaded into the RNAV system. However, the procedure stored in the database must not be modified and must remain intact within the database for future use and reference.*

(4) Means to display the validity period of the navigation database to the flight crew.

(5) Where the system contains a navigation database, the database supplier must be one whose data quality, integrity and quality management practices have been accepted by the FAA and are consistent with the criteria of DO-200A. Prior to DO-200A based acceptance, it is expected that procedural checks at the database supplier and by the airline operators will be necessary to ensure that exposure to any database errors is minimized. Consideration should be given to continuing database verification for RNP SAAAR procedures, even when they are obtained from an accepted data supplier.

e. <u>Operational – Required.</u>

(1) Indication of the RNAV system failure, including the associated sensors, in the pilot's primary field of view.

(2) Where the minimum flight crew is two pilots, means for the pilot not flying to verify the RNAV defined path and the aircraft's position relative to the defined path.

(3) For multi-sensor systems, automatic reversion to an alternate RNAV sensor if the primary RNAV sensor fails.

(4) Display of the active navigation sensor type and a means of determining navigation system performance, either in the pilot's primary field of view or readily accessible to the flight crew.

6. SAMPLE ISSUES TO BE IDENTIFIED IN PROCEDURE CHECKLIST.

a. <u>Approach Evaluation</u>.

(1) Specific procedure and navigation infrastructure should be evaluated using aircraft-defined criteria or tool. Critical facilities should be identified, or the tool should be incorporated into the dispatch procedures to ensure coverage for each approach.

(2) The ability of the aircraft to fly the procedure should be demonstrated, including the ability to maintain a course and capture vertical guidance, particularly whenever a vertical path discontinuity is encountered.

(3) Any other specific conditions identified as part of aircraft qualification should be identified. Examples include:

(a) Minimum straight segment after decision height to allow for initial dead reckoning segment.

(b) Evaluation to ensure there are no collocated VOR/DME or VORTACs with non-coaxial collocation within radio range.

(c) Constraints on wind conditions or turn angles for fly-by fixes or curved paths.

(d) Use of radar as a mitigation (Note that this must be coordinated with air traffic service).

(e) Identification of facilities that should be inhibited during operation (due to inaccuracy, not NAS facility, etc.).

(f) Exclusion of all special RNP SAAAR procedures with RF legs (as mitigation for system that does not have RF capability).

(g) Limitations on missed approach exposure time or on special RNP SAAAR missed approach leg length (due to continuity, affects how long a small RNP value can be used).

b. Crew Procedures.

(1) Procedure for limiting displacement relative to the lateral or vertical path.

(2) Defined limit for displacement relative to the lateral or vertical path (XTK and VXTK).

(3) Procedure for reducing exposure to blunder errors.

(4) Requirement to inhibit use of VOR facilities.

(5) Requirement to inhibit use of ground facilities under test.

(6) Procedure to ensure loss of GPS does not result in loss of required navigation capability (e.g., assuming items d) and e) above are addressed then this may be accomplished for a

GPS/INS-equipped aircraft by verifying ANP/EPE is less than a tighter threshold prior to initiating the approach).

(7) Procedure to ensure RNP transitions are accomplished in accordance with the criteria (e.g., select tightest RNP value prior to initiating the procedure).

(8) Procedure for reviewing and verifying flight path.

APPENDIX 5

REQUIRED NAVIGATION PERFORMANCE (RNP) SPECIAL INSTRUMENT APPROACH PROCEDURE CONSTRUCTION

CHAPTER 1. GENERAL

1-1. PURPOSE. This notice prescribes public domain (non-proprietary) criteria jointly developed by the Federal Aviation Administration (FAA) and the aviation industry. These criteria are approved for use without requiring the proponent to prove criteria sufficiency for use in the development of special (non-14 CFR part 97) instrument approach procedures based on RNP using area navigation (RNAV) avionics systems. (Before the issuance of this notice, proponents desiring required navigation performance (RNP) special procedures developed proprietary criteria that required formal FAA approval in order to be applied. The proponent was solely responsible for demonstrating the criteria were suitable and sufficient. Advisory Circular (AC) 120-29A, Criteria for Approval of Category I and Category II Weather Minima for Approach, provides operators a benchmark based on industry best practices, for use in developing proprietary criteria for development of special RNP procedures.) Minimal changes have been made to figures 1-4, 2-5, 2-7, 3-3, 3-4, 4-8, 4-9, 5-5, 5-6, 5-7, and formula 5-4.

a. These criteria are consistent with the RNP RNAV lateral containment methodology described in RTCA DO-236.

b. This notice is used to determine acceptable aircraft/navigation system combinations and the aircrew and dispatcher training and procedures required for operator approval to fly procedures designed under this notice.

c. FAA Order 8260.51, United States Standard for Required Navigation Performance (RNP) Instrument Approach Procedure Construction**,** dated December 30, 2002, was issued to provide initial FAA criteria for the development of public (14 CFR Part 97) RNP Instrument Approach Procedures. The criteria in 8260.51 do not enable the expansion of current RNP operations or provide critical RNP criteria sanctioned within AC 120-29A and the resultant advanced operational benefits described in this notice.

d. Criteria contained in AC 120-29A, appendix 5, serves as a foundation for these criteria. In turn, these criteria provide the foundation of future criteria for design of public RNP SAAAR procedures. Developing approach procedures under these future criteria will enable operators to exploit their advanced aircraft navigation capabilities on public approach procedures under the Special Aircrew and Aircraft Authorization Required (SAAAR) concept.

1-2. RESERVED.

1-3. RESERVED.

1-4**. RESERVED.**

1-5. GENERAL. The following basic conditions are considered in the development of obstacle clearance criteria for RNP approaches and missed approaches:

The aircraft descends and decelerates from the en route environment or a terminal transition route through the initial/intermediate approach segments to the precision final approach fix (PFAF).

- The aircraft arrives at the decision altitude (DA) and continues with visual reference to a landing on the runway or initiates a missed approach.

An additional obstacle evaluation will be provided for aircraft arriving at the DA, continuing with visual reference to the runway then initiating a rejected landing at the end of the touchdown zone and flying a prescribed RNP route. This evaluation is based on aircraft performance capability, environmental and operating conditions, and the process to be used is addressed in this notice.

a. This notice attempts to minimize procedure complexity and avoid unnecessary turns, speed adjustments, and other unique adverse path characteristics whenever possible. Unlike navigation before RNAV, any number of fixes and course changes can now be designed into a procedure, potentially adding complexity and unnecessary operator confusion. Hence, to avoid unnecessary complexity, these criteria recommend use of a “Standard Configuration” to be applied to procedures when possible. This is because there is an operational and safety benefit in consistency of procedure appearance. Therefore, the default or nominal procedure design should incorporate the ‘basic T’ construction utilizing TAAs. See Order 8260.45A, Terminal Arrival Area (TAA) Design Criteria. Variations on the basic T construction may be appropriate where a benefit of at least 50 feet in DA or ¼ statute mile in visibility can be achieved, or where airspace, terrain, or other factors indicate that a different configuration may offer significant operational advantage (e.g. predominant traffic flow directions).

b. The AFS-400 approval process must be used for application of any procedure design parameters beyond those specified in this notice.

c. Procedure identification. RNP procedures will be identified as RNAV followed by the letters R-N-P in parenthesis, e.g., RNAV (RNP) Rwy XX.

d. Some Drawings in this Notice are not to Scale. All possible construction scenarios cannot be anticipated and addressed; therefore, sound judgment and common sense based on procedure development experience is necessary in some construction scenarios. Appendix 6 contains “Explanations and Assumptions” for those topics that require a more extensive explanation, rationale, or critical comments. Obstacle accuracy standards contained in Order 8260.19C, Flight Procedures and Airspace, paragraphs 272, 273, and appendix 2 applies.

e. RNP Instrument Procedure Documentation.

(1) RNP instrument procedures must be documented on FAA 8260-series forms as described in Order 8260.19C, chapter 8.

(2) In the “NOTES” section of Form 8260-7, enter “Chart Note: SPECIAL AIRCREW AND AIRCRAFT AUTHORIZATION REQUIRED**.”**

(3) The RNP value associated with each segment (except Final) must be documented in the Terminal Routes section on Form 8260-7, in the "FROM" block, following the segment type. Adjacent to the RNP value, indicate the maximum Indicated Airspeed used in the design of each segment. See Table 2-1 for the maximum speeds. The RNP value(s) for the Final Approach Segment (FAS) will be published in the left-hand column of the "MINIMUMS" block on the form. The RNP value and maximum airspeed that applies to the Missed Approach Segment must also be documented. Prior to the Missed Approach instructions, define the RNP value and the maximum speed limits, e.g., "RNP 1.0/240K CLIMB VIA 007.52 TRACK TO LARRY AND HOLD."

(4) All deviations from the criteria prescribed in this notice must be described and documented on Form 8260-10, Continuation Sheet. A detailed explanation on why the deviation was necessary with assurance that flight safety is not jeopardized, must accompany each item. Additionally, when the criteria permit more than one method to construct a particular portion of the procedure, the method used must also be described (with reference to applicable paragraph) on Form 8260-10.

(5) Document on Form 8260-10 the VEB OCS used for final segment evaluation. Documentation must specify the OCS slope and distance in feet from LTP to OCS origin. Document at least the items specified in paragraph 4-5. Additionally, attach a printed copy of the VEB spreadsheet results for VEB source documentation. If temperature deviation is based on local history, document the data and determination.

(6) Document on Form 8260-10 the slope used for the missed approach OCS based on the engine-out missed approach climb gradient.

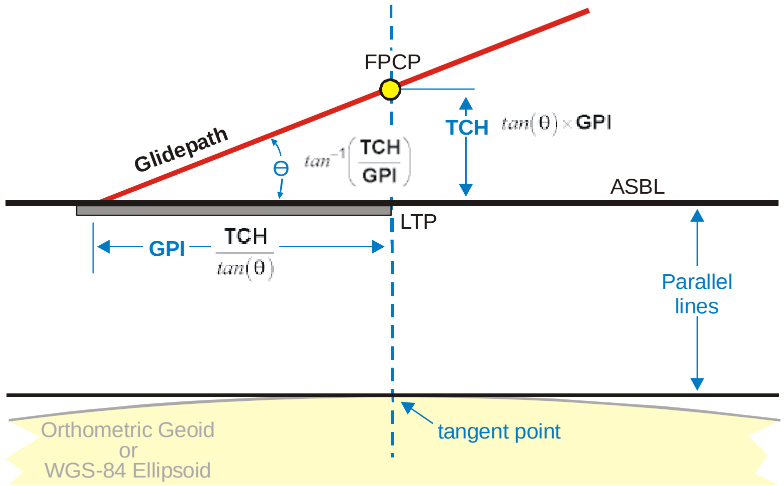
(7) Annotate the Form 8260-7 with the minimum and maximum allowable temperature limits for the procedure. Example: **"PROCEDURE NA BELOW -15°F OR ABOVE 104°F".**

f. RNP Instrument Procedure Processing. Process all SAAAR instrument procedures as prescribed in Order 8260.19C, Chapter 4, Section 4, *Special Instrument Procedures Processing.*

1-6. DEFINITIONS. For the purposes of this document, the following definitions apply.

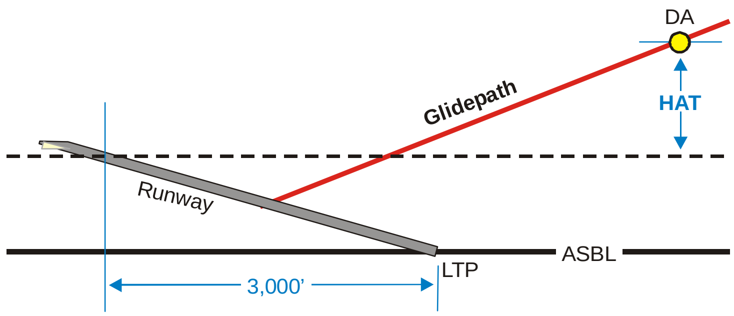
a. Approach Surface Baseline (ASBL). A line aligned to the runway centerline (RCL) that lies in a plane parallel to a tangent to the orthometric geoid at the landing threshold point (LTP). It is used as a baseline reference for vertical measurement of the height of glidepath and obstruction clearance surfaces (OCS). See figure 1-1.

Figure 1-1. ASBL, TCH, GPI, GPA, FPCP



b. Decision Altitude (DA) and Height Above Touchdown (HAT). The DA is a barometric altitude (height above mean sea level) at which a missed approach must be initiated if the visual references required to continue the approach are not acquired. The DA is derived from the minimum HAT (see figure 1-2).

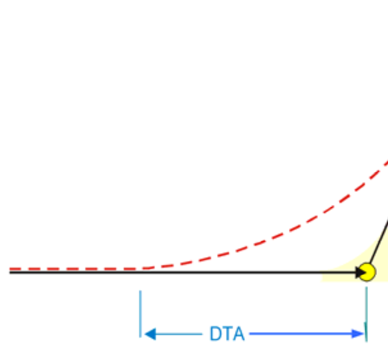
Figure 1-2. DA, HAT



c. Height Above Touchdown (HAT). The HAT is the height of the DA above the highest point in the first 3,000 feet of the landing runway (touchdown zone elevation). See figure 1-2.

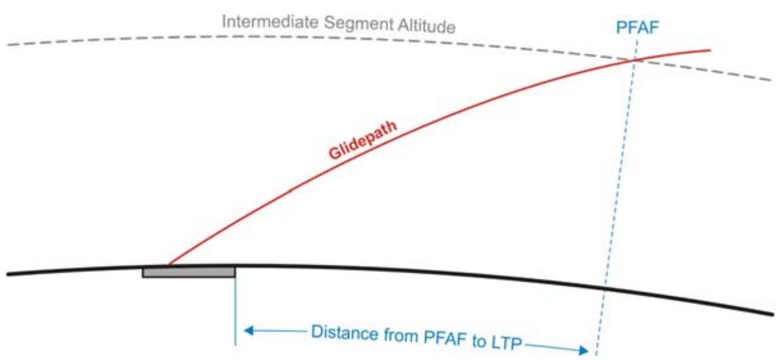
d. Distance of Turn Anticipation (DTA). The distance from (prior to) a fly-by fix that an aircraft is expected to start a turn to intercept the course of the next segment (see figure 1-3).

Figure 1-3. DTA Example



e. Final Approach Fix (PFAF). The PFAF marks the point of glidepath intercept and the beginning of the Final Approach Segment (FAS) descent (see figure 1-4).

Figure 1-4. PFAF



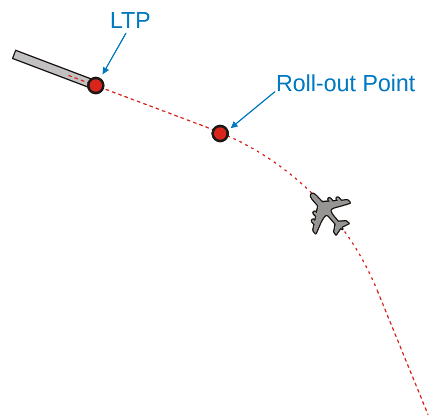
SEE APPENDIX 6, ITEM 1.

f. Final Approach Segment (FAS). The FAS begins at the PFAF and ends at the LTP. The FAS is typically aligned with the runway centerline extended.

g. Flight Path Control Point (FPCP). The FPCP is a 3D point defined by the LTP latitude/longitude position, MSL elevation, and a threshold crossing height (TCH) value. The FPCP is in the vertical plane of the final approach course and is used to relate the glidepath angle of the final approach track to the landing runway. It is sometimes referred to as the TCH point or reference datum point (RDP) (see figure 1-1).

h. Final Roll-out Point (FROP). Where a course change is required within the FAS, the point the aircraft rolls to wings-level aligned with the runway centerline extended is considered the FROP (see figure 1-5 and paragraph 4-7).

Figure 1-5. Final Roll-out Point

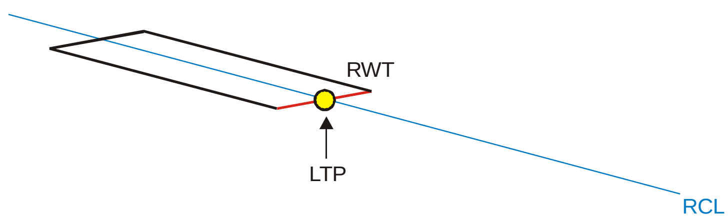


i. Glidepath Angle (GPA). The GPA is the angle of the specified final approach descent path relative to the ASBL (see figure 1-1). In this notice, the glidepath angle is represented in formulas and figures as the Greek symbol theta (θ).

j. Ground Point of Intercept (GPI). The glidepath intercepts the ASBL at the GPI. The GPI is expressed as a distance in feet from the LTP. The GPI is derived from TCH and glidepath angle values: $\mathbf{GPI} = \dfrac{\mathbf{TCH}}{tan(\theta)}$ See figure 1-1.

k. Landing Threshold Point (LTP). The LTP is the point where the runway centerline (RCL) intersects the runway threshold (RWT). It is defined by WGS 84/NAD 83 latitude, longitude, and height above mean sea level (see figure 1-6).

Figure 1-6. LTP/RWT



l. Obstacle Clearance Surface (OCS). The OCS is an inclined planar surface conforming to the lateral dimensions of the OEA used for obstacle evaluation to provide obstacle clearance from the designed flight path. The OCS may not be penetrated. An OCS is normally associated with evaluation of 3D final segments or departure climb segments. See related item in paragraph 1-6p.

m. Obstacle Evaluation Area (OEA). The OEA is an area within which obstructions are evaluated by application of the ROC, OCS or OIS. An OEA is the airspace within the lateral RNP segment width limits (2•RNP containment) and vertical ROC (above the OCS or OIS) for each segment of the RNP approach procedure.

n. Obstacle Identification Surface (OIS). The OIS is an inclined planar surface conforming to the lateral dimensions of the OEA used for identification of obstacles that may require mitigation to maintain the requisite level of safety for the applicable procedure segment. An OIS is normally associated with the part of the evaluation for the visual portion of 3D final segments and in the evaluation of rejected landing conditions in the appropriate section of this notice.

o. Required Navigation Performance (RNP). RNP is a statement of the navigational performance required to maintain flight within the OEA associated with the approach procedure segments.

p. Required Obstacle Clearance (ROC). ROC is the MINIMUM amount (in feet) of vertical clearance that must exist between aircraft and the highest ground obstruction within the OEA of instrument procedure segments.

q. Runway Threshold (RWT). The RWT marks the beginning of the portion of the runway usable for landing. It extends the full width of the runway. The LTP geographic coordinates identify the point the runway centerline crosses the RWT (see figure 1-6).

r. Visual Glide Slope Indicator (VGSI). The VGSI is an airport lighting aid that provides the pilot a visual indication in the visual segment of the aircraft position relative to a specified glidepath to a touchdown point on the runway. Precision approach path indicator (PAPI) and visual approach slope indicator (VASI) are examples of VGSI systems.

s. Special Aircraft and Aircrew Authorization Required (SAAAR). Aircraft may be equipped beyond the minimum standard for public RNP criteria and aircrews trained to achieve a higher level of instrument approach performance. These RNP SAAAR criteria contained in this notice are based on this higher level of equipage and additional aircrew requirements. Procedures that incorporate these criteria will be appropriately annotated. The aircraft equipage and aircrew requirements are specified in this notice.

t. Vertical Error Budget (VEB). The VEB is a set of the allowable values that contribute to the total error associated with a VNAV system. Application of equations using the VEB values determines the MINIMUM vertical clearance that must exist between an aircraft on the nominal glidepath and ground obstructions within the OEA of instrument procedure segments. When the VEB is used in final segment construction, its application determines the OCS origin and slope ratio.

u. Visual Segment. The visual segment is the portion of the final segment between the DA and the LTP.

CHAPTER 2. GENERAL CRITERIA

2-1. DATA RESOLUTION. Perform calculations using at least 0.01 unit of measure. Use calculation accuracy to at least 8 decimal places where calculation is accomplished by automated means. The following list specifies the minimum accuracy standard for documenting data expressed numerically. This standard applies to the documentation of final results only; e.g., a calculated adjusted glidepath angle of 3.04178° is documented as 3.05°. The standard does not apply to the use of variable values during calculation. Use the most accurate data available for variable values.

*Do not round intermediate results. Round the final result of calculations for documentation purposes.

a. Documentation Accuracy:

(1) WGS-84/NAD-83 latitudes and longitudes to the nearest one hundredth (0.01) arc second.

(2) LTP MSL elevation to the nearest foot,

(3). Glidepath angle to the next higher one hundredth (0.01) degree;

(4) Courses to the nearest one hundredth (0.01) degree; and

(5) Distances to the nearest hundredth (0.01) unit.

*Do not use the documented rounded values in paragraphs 2-1a(1) through (5) in calculations.

b. Mathematics Convention.

(1) Definition of Mathematical Functions.

$a+b$ indicates addition

$a-b$ indicates subtraction

$a \bullet b$ or ab indicates multiplication

$\frac{a}{b}$ or a/b or $a \div b$ indicates division

$(a-b)$ indicates the result of the process within the parenthesis

$|a-b|$ indicates absolute value

$\approx$ indicates approximate equality

$\sqrt{a}$ indicates the square root of quantity "a"

a^2 indicates $a \times a$

$tan(a)$ indicates the tangent of "a" degrees

$tan^{-1}(a)$ indicates the arc tangent of "a"

$sin(a)$ indicates the sine of "a" degrees

$sin^{-1}(a)$ indicates the arc sine of "a"

$cos(a)$ indicates the cosine of "a" degrees

$cos^{-1}(a)$ indicates the arc cosine of "a"

(2) Operation Precedence (Order of Operations).

First: Grouping Symbols: parentheses, brackets, braces, fraction bars, etc.

Second: Functions: Tangent, sine, cosine, arcsine and other defined functions

Third: Exponentiations: powers and roots

Fourth: Multiplication and Division: products and quotients

Fifth: Addition and Subtraction: sums and differences

For example:

$5 - 3 \bullet 2 = -1$ because multiplication takes precedence over subtraction

$(5 - 3) \bullet 2 = 4$ because parentheses take precedence over multiplication

$\frac{6^2}{3} = 12$ because exponentiation takes precedence over division

$\sqrt{9 + 16} = 5$ because the square root sign is a grouping symbol

$\sqrt{9} + \sqrt{16} = 7$ because roots take precedence over addition

$\frac{sin(30°)}{0.5} = 1$ because functions take precedence over division

$sin\left(30°/0.5\right) = 0.8660254$ because parentheses take precedence over functions

NOTE ON CALCULATOR USAGE: *Most calculators are programmed with these rules of precedence. When possible, let the calculator maintain all of the available digits of a number in memory rather than re-entering a rounded number. For highest accuracy from a calculator, any rounding that is necessary should be done at the latest opportunity.*

2-2. CALCULATING TURN RADIUS.

STEP 1: Determine the true airspeed (KTAS) for the turn using formula 2-1. Locate the highest speed aircraft category that will be published on the approach procedure and use the appropriate knots indicated airspeed (KIAS) in table 2-1. Use the highest altitude within the turn.

Formula 2-1

$$V_{KTAS} = V_{KIAS} \times \left[1 + (\mathbf{altitude} \times 0.00002)\right]$$

SEE APPENDIX 6, ITEM 2.

Table 12-1. Indicated Airspeed (Knots)

Segment		Indicated Airspeed by Aircraft Category				
		Cat A	Cat B	Cat C	Cat D	Cat E**
Initial Intermediate		150	150	240	250	250
Final		90	120	140	165	As Specified
Missed Approach (MA)		110	150	240	265	As Specified
Minimum Airspeed Restriction*	Initial	110	140	210	210	As Specified
	Intermediate	110	140	180	180	As Specified
	Missed	100	130	165	185	As Specified

*Minimum speed restriction value for use to reduce turn radius. Only one speed restriction per segment is allowed and the fastest airspeed appropriate for the highest speed category of aircraft serviced by the approach procedure must be used to determine the speed. AFS-400 approval is required when more than one speed limit is desired for a particular approach segment (e.g. Initial, Intermediate, Missed Approach). AFS-400 approval is also required for missed approach airspeed restrictions when used for other than obstacle/terrain avoidance requirements.

Table 2-1 Tailwind Component (V_{KTW}) **For Turn Calculations***

HAT	Standard Tailwind Component (Knots)**	
500	25	
1000-2500	Standard	AFS-400 Approval
1000	37.5	30
1500	50	35
2000	50	40
2500	50	45
3000	50	
3500	55	
4000	60	
4500	65	
5000	70	
5500	75	
6000	80	
6500	85	
7000	90	
7500	95	
8000	100	
8500	105	
9000	110	
9500	115	

HAT	Standard Tailwind Component (Knots)** (Continued)
10,000	120
10,500	125
11,000	130
>11,000	130

*Other Tailwind Gradients may be used after a site-specific determination of wind based on that location's meteorological history (Using available information from other sources).

** For turns initiated at an altitude located between two HAT values above, a new tailwind component may be interpolated for that turn using the standard tailwind values corresponding with the two HAT values. This new interpolated tailwind component may be used if needed provided that the tailwind values above are used. If an interpolated wind value is ever used below 500′, then the 0′ HAT value for wind begins with 15 kts.

STEP 2: Determine R using formula 2-2. Formula 2-3 is provided for information purposes. Select the appropriate tailwind component in table 2-2 for the highest altitude within the turn and add the value to true airspeed to determine V_{KGS} (groundspeed), e.g., $V_{KGS} = V_{KTAS} + V_{KTW}$

Formula 2-2

$$R = \frac{(V_{KTAS} + V_{KTW})^2 \cdot (1.4589 \cdot 10^{-5})}{\tan(\theta)}$$

For Information Purposes

Formula 2-3

$$\Phi = \tan^{-1}\left(\frac{(V_{KTAS} + V_{KTW})^2 \cdot (1.4589 \cdot 10^{-5})}{R}\right)$$

Where

ϕ = bank angle (see bank angle limitation notes below)

V_{KIAS} = Indicated Airspeed in knots from table 2-1

V_{KTAS} = See formula 2-1

V_{KTW} = Tailwind Component from table 2-2

V_{GS} = $V_{KTAS} + V_{KTW}$

Example: IF altitude=5000, Cat A-D mins Published bank angle=18°

$$R = \frac{(291.5 + 70)^2 \cdot (1.4589 \cdot 10^{-5})}{\tan(18)} = 5.868 \text{ NM}$$

a. Restrictions on Bank Angle.

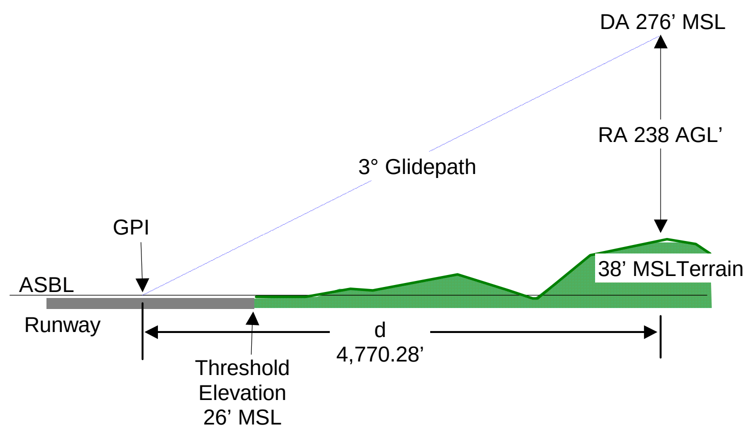
(1) Optimum design bank angle is 18°. Lower bank angles are allowed for smooth transitions, maintaining stabilized approaches, lower minima or match other leg lengths.

(2) Design bank angles greater than 18° may be used where deemed necessary and approved by AFS-400. The maximum allowable design bank angle for this notice is 25°.

(3) Some aircraft bank angles are limited below 400′ Radio Altitude (AGL). If any portion of the turn is expected to occur below 400′ AGL, the Flight Control Computer (FCC – not the FMC) bank angle limitation must be considered for the LNAV mode. In these cases, use the limited bank angle in the turn calculation. Document the limited bank angle on the 8260-10. AFS-400 approval is required for greater bank angles in these cases.

NOTE: Calculation Of Radio Altimeter (RA) Height*. To determine RA height, determine the distance (d) from ground point of intercept (GPI) to the point decision altitude (DA) occurs. Obtain the terrain elevation at point (d) feet from GPI on the runway centerline extended. Subtract the terrain elevation from the DA to calculate the RA (see figure 2-1).*

Figure 2-1. RA Height



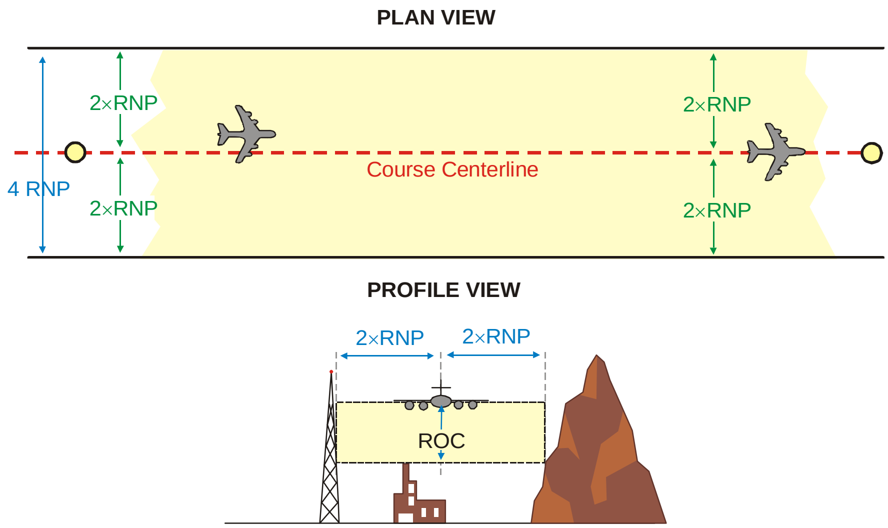
$$\mathbf{d} = \frac{\mathbf{DA} - \text{Threshold Elev}}{\tan(\mathbf{GPA})} \qquad \mathbf{d} = \frac{120 - 0}{\tan(3)} \qquad \mathbf{d} = 2{,}289.74'$$

$$\mathbf{RA} = \mathbf{DA} - \text{Terrain Elev} \qquad \mathbf{RA} = 120 - 12 \qquad \mathbf{RA} = 108$$

2-3. RNP (SAAAR) CONTAINMENT. Turns are normally accomplished at fly-by fixes connecting TF segments (see paragraph 2-4a) or using RF segments (see paragraph 2-4b).

a. RNP Segment Width. RNP values are specified in increments of a hundredth (0.01) of a NM. Segment width is defined as ± 2•RNP measured perpendicular to the segment course (see figure 2-2). In order to protect RNP approach procedures from construction of new obstacle hazards, use the maximum RNP level from table 2-3 in the initial, intermediate, and missed approach segments. Where use of the maximum values prevents procedure construction, use the largest value that accommodates procedure operational requirements.

Figure 2-2. RNP Segment Width



SEE APPENDIX 6, ITEM 3.

Table 2-3. RNP Level Values

RNP Level ⇒ / ⇓ Segment ⇓	MAXIMUM	MINIMUM	Minimum OEA Width (4•RNP)
Feeder/Initial	1.0	0.10	0.40 (±0.20)
Intermediate	1.0	0.10	0.40 (±0.20)
Final	0.50	0.10*	0.40 (±0.20)
Missed Approach	1.0	0.10*	0.40 (±0.20)

* Can be lower than 0.10 with AFS-400 approval

b. RNP Segment Length. Design segments with sufficient length to accommodate required descent as close to the optimum gradient as possible, and turns to and/or from the segment. The minimum segment length is value 1×RNP of the segment plus 1×RNP of the following segment. In all cases, when "radar vector-to-final" operations are anticipated, incorporate a straight segment (TF) leg to accommodate vectors to intercept (minimum length must satisfy construction criteria and stated requirements of the controlling ATC facility). When vectored onto a segment, obstacle clearance will be provided by AT until established on the segment.

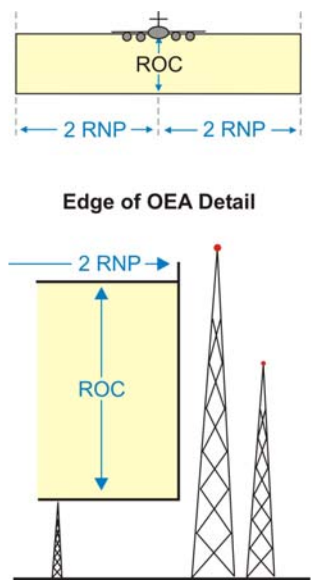
c. RNP Segment ROC. The ROC varies according to segment type (initial, intermediate, etc.). See table 2-4 and figure 2-3

Table 2-4. Minimum ROC Values

Segment	ROC Value
Feeder	2000/1000
Initial	1000
Intermediate	500 or VEB*
Final	TERPS or VEB*
Missed Approach	*

* May be variable for intermediate, final descent and missed approach climb, (see appropriate section).

Figure 2-3. Generic Segment Cross Section



2-4 SEGMENT LEG TYPES. RNP procedures are constructed by connecting segment legs together. A segment is identified by the method used to define the lateral path and how the segment terminates. There are several leg types available for RNP SAAAR operations. Track to Fix and Radius to Fix legs are the leg types normally used. Other leg types are also available when necessary and are described in DO-236A and ARINC 424 (Change 15 or later). Procedure design may incorporate leg types that are not RNP compatible when RNP is not required for that portion of the procedure (e.g., VA on missed approach). When any leg in a procedure requires RNAV containment, it must be assigned an RNP value and the procedure must be labeled as requiring RNP capability. Leg types are identified by a two-letter acronym. These acronyms are a set of defined codes referred to as Path Terminators. Each code defines a specific type of flight path and termination of flight path. For example, a Track-To-Fix (TF) leg is a great circle track between two defined fixes and terminates at a fix, while an Initial Fix (IF) is used for the initial point of all procedures.

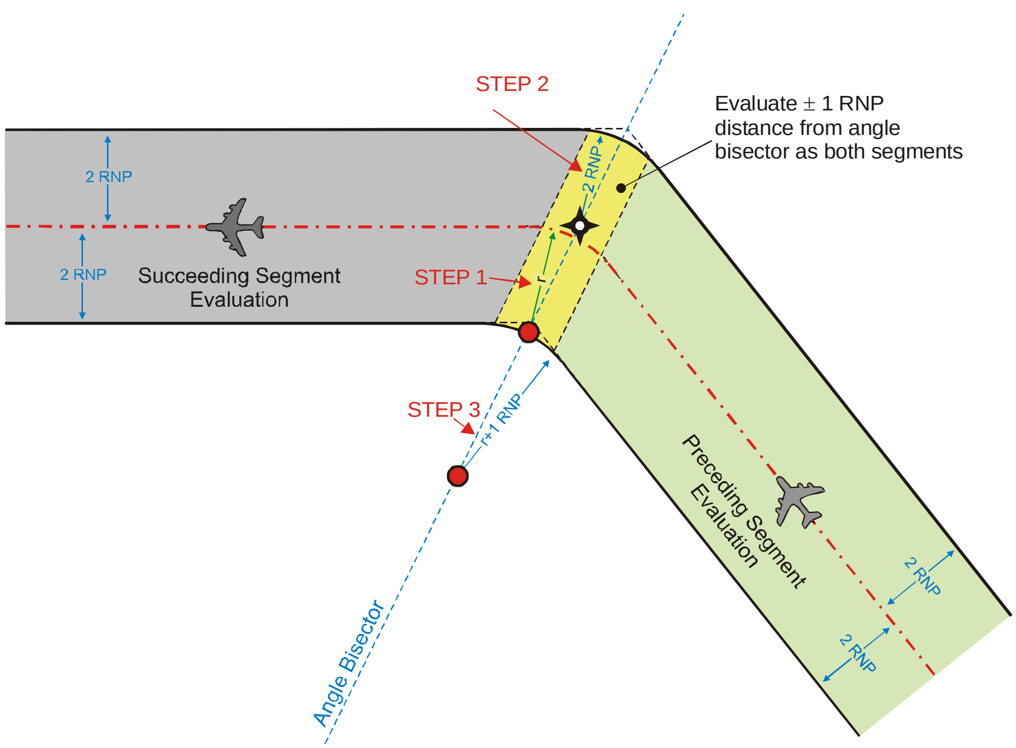
a. Track-To-Fix (TF) Legs. A TF leg is a geodesic flight path between two fixes. The first fix is either the previous leg termination fix or the initial (first) fix of a TF leg (see figure 2-4).

Figure 2-4. TF Leg

(1) Turns At Fly-By Waypoints That Join Two TF Legs – OEA Construction.

STEP 1: Construct the turning flight path. Determine the turn radius (R) as described in paragraph 2-2 (formula 2-2). Placing the origin on the angle bisector line, scribe an arc of radius R tangent to the inbound and outbound legs. This arc must not extend past the first fix of the inbound leg or the termination fix of the outbound leg (see figure 2-5).

Figure 2-5. Fly-by Turn Construction



STEP 2: Construct the outer OEA boundary line. Using the turn fix as the origin, scribe an arc of radius 2•RNP tangent to the inbound (or preceding) and outbound (or succeeding) TF legs.

STEP 3: <u>Construct inner turn expansion boundary line</u>. Placing the origin on the angle bisector line, scribe an arc of radius R+1•RNP from the tangent point on the inbound (or preceding) leg inner boundary to the tangent point on the outbound (or succeeding) leg inner boundary (see figure 2-6).

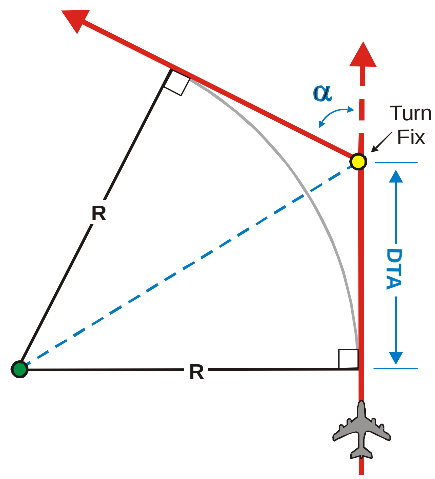
Figure 2-6. DTA

Formula 2-2

$$DTA = R \cdot tan\left(\frac{\alpha}{2}\right)$$

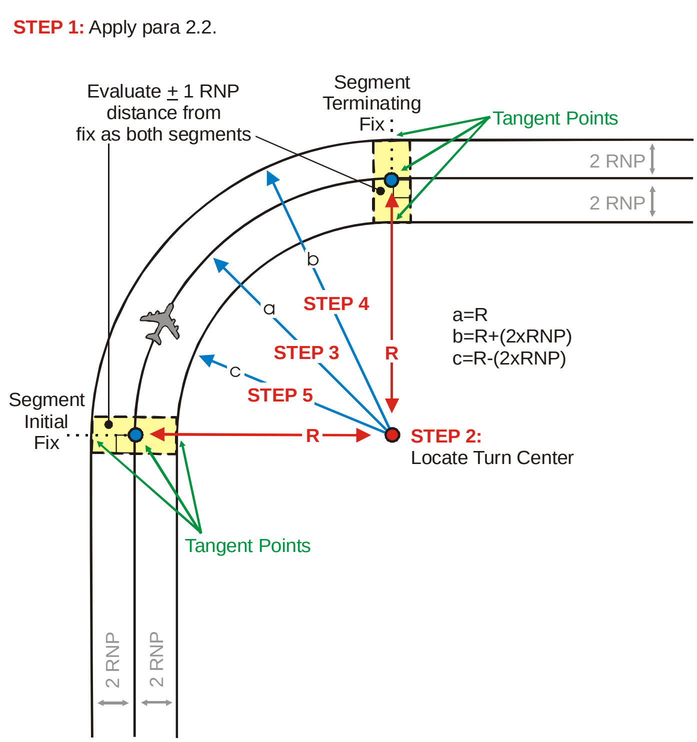
Where R = radius determined through application of paragraph 2-2

α = Course angle change



b. Radius to a Fix (RF) Leg Types. A Radius to a Fix (RF) leg is a constant radius circular path about a defined turn center that terminates at a fix. RF legs may be used to control the ground track or bank angle. The curved leg begins tangent to the previous segment course at its terminating fix and ends tangent to the follow-on course at its beginning fix (see figure 2-7). The termination fix, the turn direction of the leg, and the turn center are provided by the navigation database. The obstruction evaluation area boundaries are parallel lines.

Figure 2-7. RF Turn Construction



STEP 1: Determine the turn radius (R) using paragraph 2-2, formula 2-2,

STEP 2: Locate the turn center at a perpendicular distance "R" from the preceding and following segments.

STEP 3: Construct flight path. Scribe an arc of radius "R" from the tangent point on the preceding course to the tangent point on the following course.

STEP 4: Construct outer OEA boundary. Scribe an arc of radius R+2•RNP from the tangent point on the preceding segment outer boundary to the tangent point on the following course outer boundary.

STEP 5: Construct inner OEA boundary. Scribe an arc of radius R-2•RNP from the tangent point on the preceding segment inner boundary to the tangent point on the following course inner boundary.

SEE APPENDIX 6, ITEM 4

2-5. VISIBILITY MINIMUMS. The RNP procedure visibility requirement is the slant distance from DH to the first light of the approach lighting system of runways served by approach lights or to the landing threshold of runways without approach lights. See formula 2-4 and figures 2-8 and 2-9.

Formula 2-4

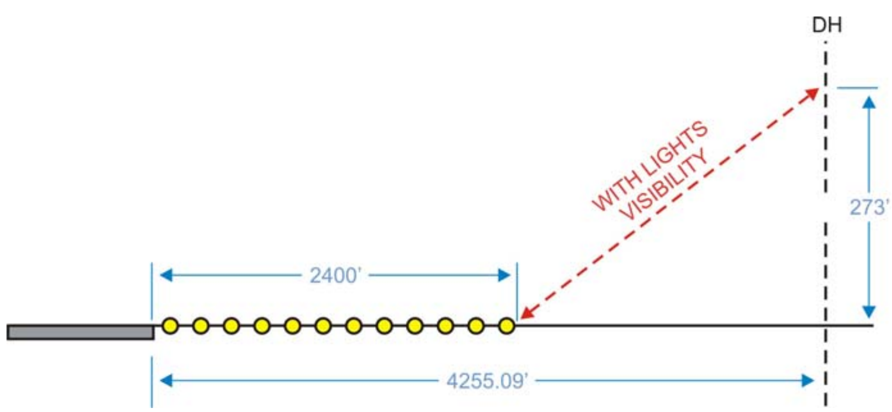
$$\textbf{Visibility} = \sqrt{(\mathbf{d}-\mathbf{l})^2 + \mathbf{H}^2}$$

Where d = distance (ft) along ASBL from LTP to DA

l = length of lighting system

H = DA height above threshold

Figure 2-8. Visibility with Approach Lights



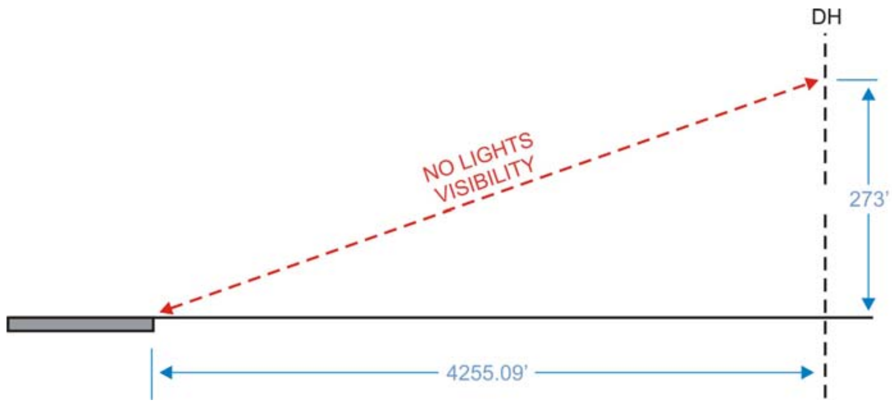
Example - w lights

$$\sqrt{(4255.09-2400)^2+273^2}=1875.07\quad\{3/8\ \text{SM}\}$$

Example - w/o lights

$$\sqrt{4255.09^2+273^2}=4263.84\quad\{7/8\ \text{SM}\}$$

Figure 2-9. Visibility without Approach Lights



2-6. RNP ASSUMED OBSTACLES.

a. RNP Vertical Application of Assumed Obstacles. In addition to the accuracy standards referenced in paragraph 1-5d, the following additives will be applied to terrain contours, unless a site inspection, local information, or site survey provides more specific obstacle elevations. If other terrain data formates are used (e.g. DEMs) in lieu of terrain contours, then the following additives still apply and the DEM data point value replaces reference to "next higher gradient line minus one unit of elevation."

(1) The next higher contour line minus one unit of elevation; and

(2) An assumed canopy height consistent with local area vegetation. One hundred fifty feet is typically used; or

(3) For those airports where CFR Part 77 surveys have been performed, a generic, uniform obstacle height of 199 feet above the next higher gradient line minus one unit of elevation, situation at any point within a radius of 3 nautical miles from the airport reference point, unless it penetrates the Part 77 surfaces (obstacles that penetrate the Part 77 surfaces are included in the DOF and are evaluated independently). This obstacle height expands from the 3 nautical miles radius in the proportion of 100 vertical feet for each additional nautical mile of horizontal distance from the airport, up to a maximum of 500 feet (see Part 77, Objects Affecting Navigable Airspace, Subparts C and D); and

(4) A generic uniform obstacle height of 500 feet above the next higher gradient line minus one unit of elevation, situated at any point greater than 6 nautical miles from the airport reference point (see Part 77, Section 77.23).

b. RNP Horizontal Application of Assumed Obstacles. The horizontal accuracy code of the obstacle is applied to the obstacle position in the direction(s) that results in the most adverse effect. This can result in the obstacle position being shifted both inward towards the flight track and in the along track direction toward the runway waypoint. An obstacle that is positioned outside the OEA boundary is moved laterally into or closer to the OEA boundary and also along track toward the runway waypoint. Obstacles within the OEA boundary are moved longitudinally along the intended flight track in the direction of the runway waypoint (see figure 2-5).

NOTE: This application of Horizontal Accuracy is not mandatory (AVN does not currently do this. The current AVN practice is to apply this to the controlling obstacle only – not to all obstacles.)

CHAPTER 3. INITIAL AND INTERMEDIATE SEGMENTS

3-1. INITIAL AND INTERMEDIATE SEGMENTS.

The initial and intermediate segments provide a smooth transition from the en route environment to the final approach segment. Descent to glidepath intercept and configuring the aircraft for final approach must be accomplished in these segments. Judicious use of airspace considering obstacle clearance, the amount of altitude to be lost, and the distance required to decelerate to final approach airspeed are primary design factors.

3-2. CONFIGURATION.

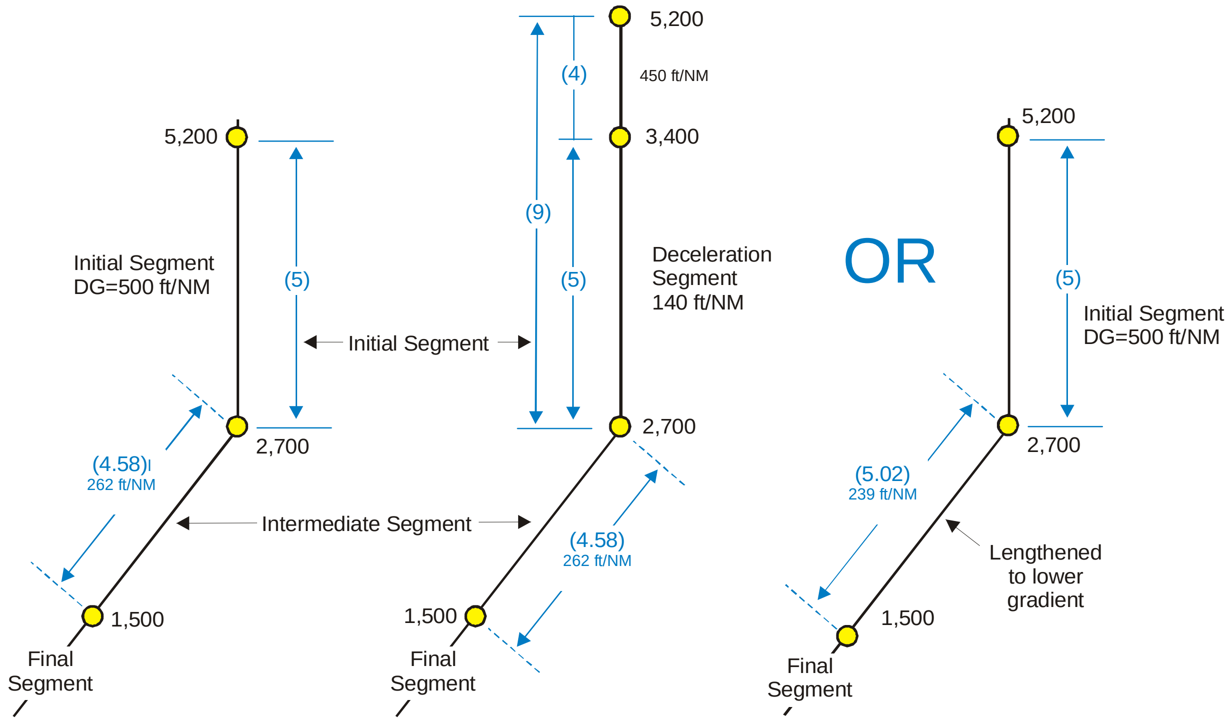
The Terminal Arrival Area (TAA) design configuration is nominal. See Order 8260.45A, Terminal Arrival Area (TAA) Design Criteria. However, where necessary, RNP enables the geometry of approach design to be very flexible. An RNP approach can follow any RNAV or conventional instrument approach configuration (VOR, ILS, etc.) within the limitation of installed equipment. The MAXIMUM initial/intermediate segment intercept angle is 120° for TF legs.

a. Deceleration Segment (applicable ONLY where minimums are published for Category "C" or faster aircraft and a deceleration segment are deemed necessary). Where the intermediate segment descent gradient exceeds 240 ft/NM without appropriate speed restrictions, a deceleration segment may be constructed in the initial segment. The MINIMUM deceleration length is dependent on segment descent gradient and magnitude of turn at the IF. The MAXIMUM allowable descent gradient in the deceleration segment is 150 ft/NM. See table 3-1 to determine the minimum deceleration segment length. Other deceleration methods may also be considered and validated during flyability evaluations (10 knots of deceleration for every 1 mile of level flight or 1 knot of deceleration for every 100 feet of descent on a 240 ft/NM gradient). See figure 3-1.

Table 3-1 Minimum Deceleration Segment Length

Segment Descent Gradient (ft/NM)	Minimum Length (NM)	
	Turn at IF ≤ 45°	Turn at IF >45°
0	2	3
75	3	4
150	5	5

Figure 3-1. Incorporation of Deceleration Segment Example



3-3. MINIMUM SEGMENT ALTITUDES.

Establish the MINIMUM altitudes in the initial and intermediate segments by adding appropriate ROC, obstacle height, and adjustments to the ROC within the OEA. The resulting value must be rounded to the appropriate 100-foot increment as necessary to assure MINIMUM ROC is provided; i.e., 1,749 feet may round to 1,700 feet, and 1,750 must round to 1,800 feet. Determine the minimum altitude (A) value for step down legs prior to rounding, using formula 3-1 below. Coded glidepath angles are not used for minimum altitudes.

Formula 3-1

$$\mathbf{A = ROC + h}$$

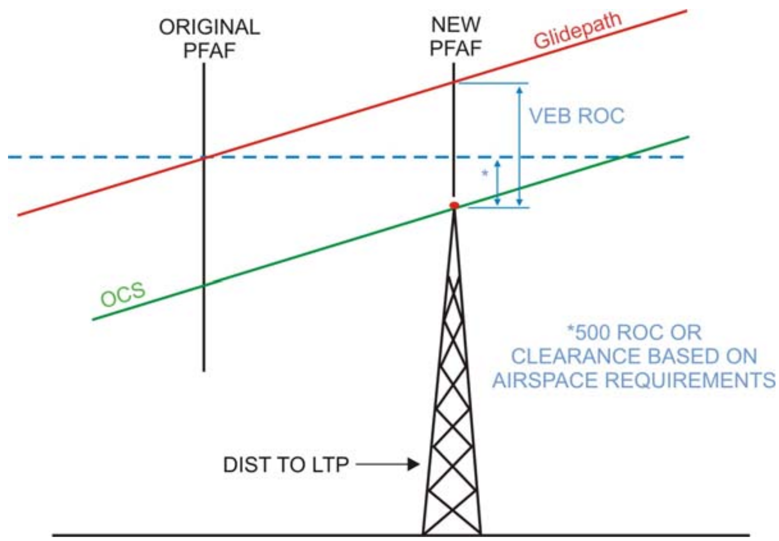
Where ROC = ROC value from table 2-4

h = MSL height of obstacle

NOTE: *The OEA for minimum altitude evaluation in a particular segment begins 1·RNP prior to the initial fix of that leg.*

a. Effects of Cold Temperature in The Intermediate Segment *(When VEB is used for final segment evaluation)*. When establishing the intermediate segment minimum altitude (glidepath intercept altitude), compare the difference between the 500-foot intermediate ROC value and the ROC value that would be provided by the VEB OCS if it extended to the controlling obstacle's along track distance from LTP. If the final segment VEB ROC value exceeds 500, apply this ROC value in lieu of 500 feet in the intermediate segment. See figure 3-2. Where 500' intermediate segment ROC is deemed insufficient at the lowest final segment design temperature, consider applying the VEB surface over the terrain of concern by lengthening the final segment to encompass it. PFAF to LTP distances greater than 7.5 NM require AFS-400 approval.

Figure 3-2. Applying VEB in Lieu of ROC



b. Descent Angle/Gradient. The following OPTIMUM and MAXIMUM descent gradients apply.

(1) <u>Initial Segment.</u> OPTIMUM 250 ft/NM, MAXIMUM 500 ft/NM

(2) <u>Intermediate Segment.</u> OPTIMUM 150 ft/NM, MAXIMUM 318 ft/NM (this may require a speed restriction or a deceleration segment if ≥ 240 ft/NM and no speed restriction). Descent gradients above 318 ft/NM (3.00 degrees) should not be used unless avoidance of terrain or obstacles is required with AFS-400 approval.

SEE APPENDIX 6, ITEM 5.

(3) <u>Calculating Descent Gradient (DG).</u> Determine the distance (d) in NM between the plotted positions of the IAF and IF or IF and FAF in feet as appropriate. Calculate the segment descent gradient using formula 3-2.

Formula 3-2

$$DG = \frac{a - b}{d}$$

Where a = Required altitude at the segment initial fix
b = Minimum segment altitude
d = Length in NM of segment (between defining fixes)

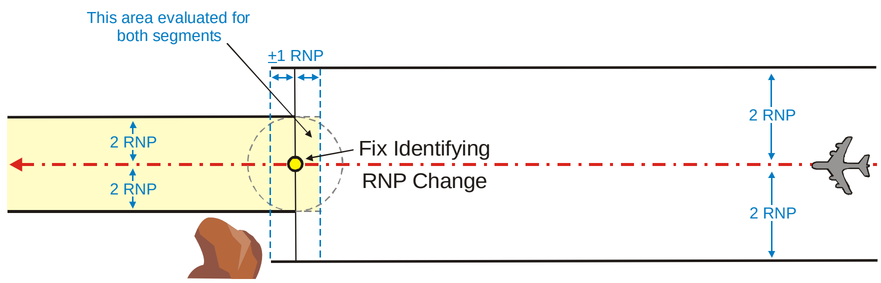
c. Change in RNP Level. Where an RNP reduction is required in the initial or intermediate segments or an RNP increase in the missed approach segment, it must occur at a waypoint. Where changes in RNP levels are required, the avionics will achieve the transition to the new RNP level at least 1·RNP prior to reaching the fix marking the change in values (see figures 3-3 and 3-4).

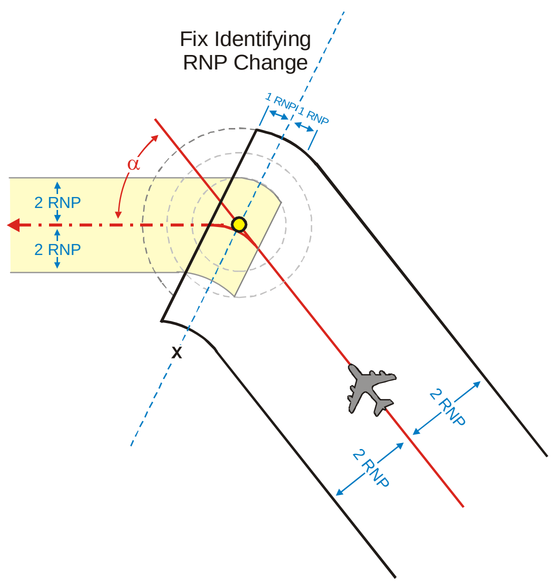
NOTE 1: *The effects of along-track fix error and the aircraft's descent path in the initial and intermediate segments are addressed elsewhere in this document. The obstacle clearance is based on the assumption that the aircraft does not descend below any given segment altitude segment al until passing the angle bisector of the fix that starts the beginning of the next segment (i.e., there is no specific accounting for starting to descend at the longitudinal turn initiation point).*

NOTE 2: *RNP reductions must not be applied on legs where VEB is applied.*

NOTE 3: *RNP reductions are not allowed after the PFAF. At locations where RNP reductions after the PFAF are crucial to procedure construction, submit a waiver request to AFS-400 for consideration, and if approved, issuance of restrictions/conditions that will enable the construction.*

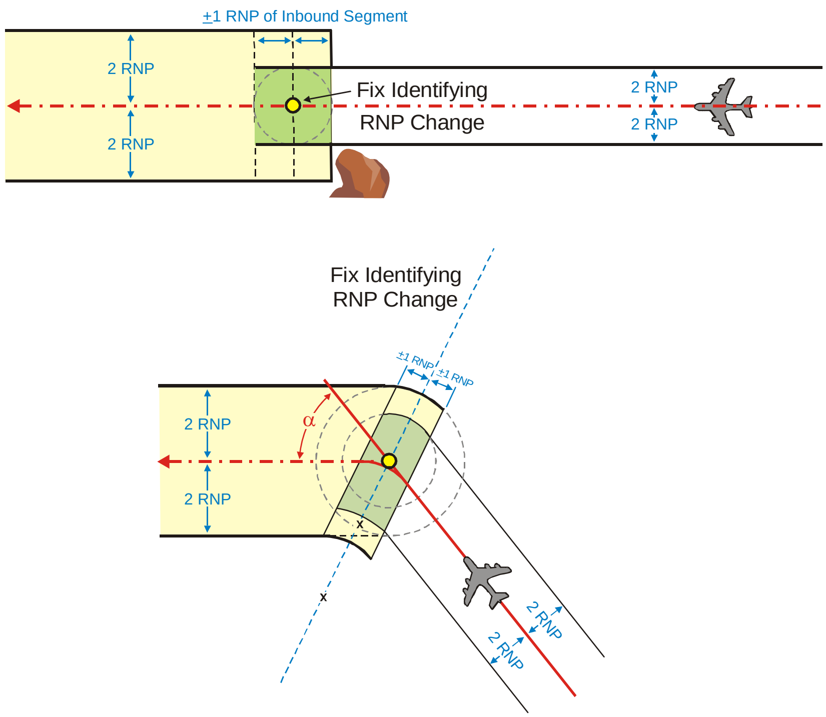
Figure 3-3. RNP Reduction (Straight and Turning Segments)





NOTE: *RNP increases are only applied in the missed approach segment.*

Figure 3-4. RNP Increase (Straight and Turning Segments)



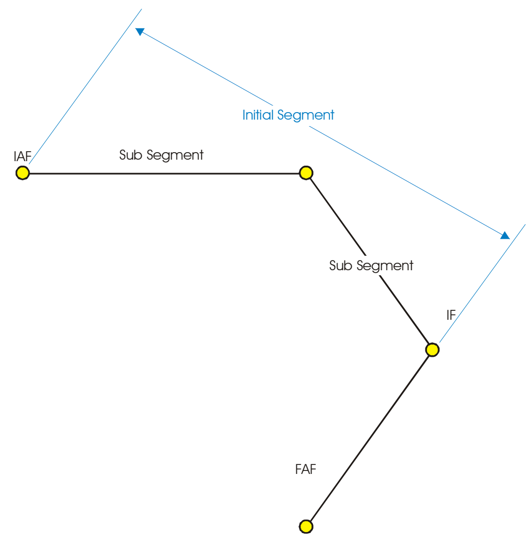
SEE APPENDIX 6, ITEM 6

3-4. INITIAL SEGMENT.

The initial segment begins at the initial approach fix (IAF) and ends at the intermediate fix (IF). The initial segment may contain sequences of straight sub segments (see figure 3-5).

a. Length. The total length of all sub segments should not exceed 50 NM. The MINIMUM length of the INITIAL segment must accommodate the descent required within the segment and must be greater than the sum of all sub-segment DTA lengths. Design an arrival holding pattern at the IAF if required.

Figure 3-5. Initial Segment



b. Width. See paragraph 2-2a.

c. Obstacle Clearance. Apply 1,000 feet of ROC, to the highest obstacle within the OEA.

3-5 INTERMEDIATE SEGMENT.

The intermediate segment begins at the intermediate fix (IF) and ends at the final approach fix (PFAF).

a. Length. The MINIMUM length of the INTERMEDIATE segment should accommodate the descent, distance of turn anticipation (for turns using TF legs), and facilitate deceleration necessary for final approach configuration. The following factors should be considered when constructing the intermediate segment length (including individual leg lengths):

(1) The amount of altitude loss required in the segment since it determines the descent gradient.

(2) The magnitude of course angle change for all turns at the IF or FAF using TF legs. The minimum segment length must be greater than the sum of all DTA lengths within that segment.

(3) Any minimum length adjustments to facilitate appropriate deceleration if descent gradients are ≥ 240 FT/NM and appropriate speed restrictions are not applied.

b. Width. See paragraph 2-2a.

c. Obstacle Clearance. The minimum ROC value is 500 feet. Where 500' intermediate segment ROC is deemed insufficient at the lowest final segment design temperature, consider applying the VEB surface over the terrain of concern by lengthening the final segment to encompass it. PFAF to LTP distances greater than 7.5 NM require AFS-400 approval.

SEE APPENDIX 6, ITEM 8

CHAPTER 4. FINAL APPROACH SEGMENT (FAS)

4-1. GENERAL.

Evaluate the final segment using the vertical OCS specified in paragraph 4-5. Annotate the approach chart with minimum and maximum temperature values applicable for the procedure. Minimum temperatures are determined as specified in the criteria below. Maximum temperatures are determined using the temperature limitation spreadsheet.

NOTE: OCS evaluation may require adjustment of the lateral path, a reduction in RNP level, or a combination of each to achieve lowest minimums.

a. Published final segment RNP values. Publish minimums for RNP 0.3 (0.5 if requested and AFS-400 approves). If the RNP 0.3 HAT value is greater than 250 feet, evaluate the final segment for a smaller value that eliminates the RNP 0.3 controlling obstacle. If the HAT value is at least 50 feet lower or visibility at least ¼ SM less, publish an additional line of minima for the lower RNP value. If the HAT value for this minima line is greater than 250 feet, evaluate the final segment for a smaller value that eliminates the controlling obstacle and attempt to achieve a 250-foot HAT value, etc. A maximum of four minimum lines are authorized. The minimum RNP value is 0.10; the maximum is 0.50. Any value (in 0.01 increments) between the maximum and minimum is allowed; e.g., 0.17, 0.24, etc.

4-2. THRESHOLD CROSSING HEIGHT (TCH).

If an instrument landing system (ILS) serves the runway, use the ILS TCH and glidepath angle. If an ILS does not exist, but a visual glide slope indicator (VGSI) system with a suitable TCH and angle serves the runway, use the VGSI TCH and angle. Otherwise, select the appropriate TCH from TERPS Volume 3, table 2-3. Publish a note indicating the VGSI is not coincident with the RNP procedure glidepath angle (GPA) when the difference between VGSI angle and the procedure GPA is more than 0.2° or the difference between the VGSI TCH and the procedure's TCH is more than 3 feet.

SEE APPENDIX 6, ITEM 9.

4-3. GLIDEPATH ANGLE (GPA) (see table 4-1).

This table specifies the allowable range of glidepath angles for procedure design. Apply the Glidepath Qualification Surface (GQS) evaluation in TERPS Volume 3, paragraph 2.12 relative to the selected glidepath angle (see note below).

Table 4-1. Allowable Range of Glidepath Angles

Design Standard	Descent Angle (degrees)	Descent Gradient (ft/NM)
MINIMUM	2.75°	292
OPTIMUM	3.0°	318
MAXIMUM*	3.77°	400

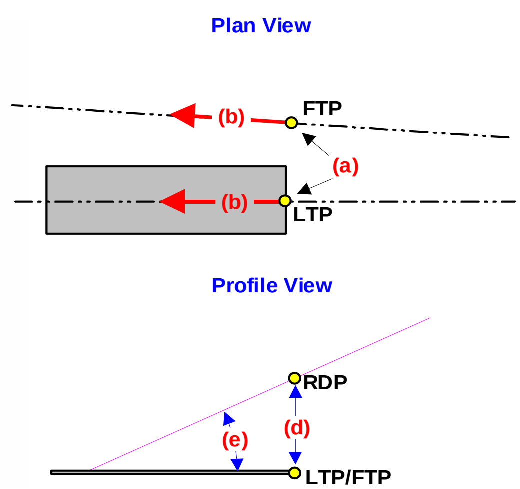
* Glidepath angles above 3.50 degrees should not be used except for terrain avoidance

NOTE: *Penetrations of the GQS may be eliminated by removing or lowering the height of the obstruction, increasing the TCH, raising the glidepath angle, displacing threshold, or a combination of these actions.*

4-4. DETERMINING DISTANCE FROM LTP TO PFAF. Apply TERPS Volume 3, paragraph 2.9 (see figure 4-1)

Figure 4-1. Determining PFAF Location

Determining PFAF Location			
		LAT	LON
(a)	LTP/FTP	042° 53' 14.36"	072° 16' 15.13"
(b)	Runway True Bearing	3.23°	
	FAF Altitude	2,100	
(c)	LTP/FTP Elevation	562.30'	
(d)	TCH	50.00'	
(e)	Glidepath Angle	3.00°	
	GPI	954.06'	
	FAF Distance From LTP/FTP	28,001.97 Feet	
		4.61 NM	
		LAT	LON
	PFAF	042° 48' 38.21"	072° 16' 36.30"



Example – Spreadsheet.

Applicants will submit printed copy of actual spreadsheet showing PFAF location. Location of current spreadsheet will be within AFS-420 website: http://av-info.faa.gov/terps/index.htm

4-5. EVALUATION USING VEB.

For OCS evaluation under RNP SAAAR, evaluate the OEA under the VEB (chapter 6). Document the OCS origin, slope, and values used for the VEB variables (see figure 4-2). Document the variables by including a print out of the VEB spreadsheet in the procedure package.

Figure 4-2. Example VEB Spreadsheet Print Out

Inputs:

Vertical Error Budget

AFS-420 Version 1.5

RNP Value	0.30
LTP MSL Elevation (h)	1,000.00
Distance (ft) LTP to PFAF	28,500.00
MSL PFAF Altitude	2500
Glidepath Angle (a)	3.00
TCH	50.00
Delta ISA (dISA)	-20.00
Semispan	107.00

Areas that are shaded green require entry of a value.

Dist (ft) LTP to OCS ORIGIN	3,778.46		
OCS Slope (run:rise)	20.70 :1		
VEB ROC @ PFAF	346.18	TERPS VNAV ROC @ PFAF	711
PFAF height above ASBL	1,500.00		

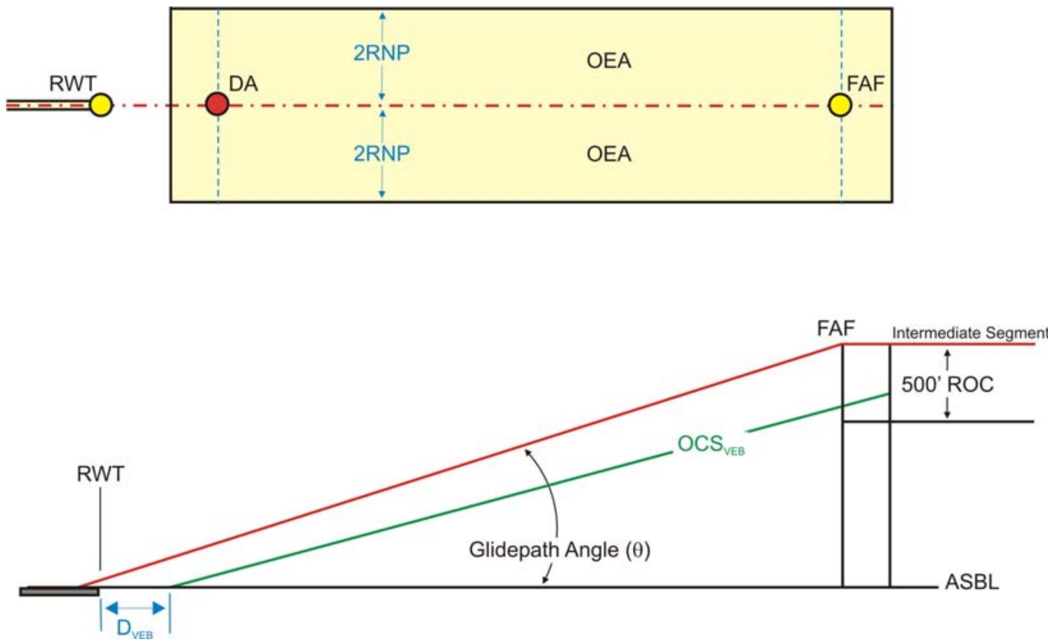
Along course distance (ft) from LTP to Intermediate Segment Obstacle	40,000.00	VEB ROC at Intermediate Segment Obstacle	391.84

Error Components	(Enter Bank Angle, WPR, FTE, and ATIS values below)		@ 250 ft	@ PFAF
ISAD	(dh x dISA)/(288 + dISA - 0.5 x .00198 x h)		-18.73	-112.36
BG	18	semispan x sin (Bank Angle)	33.06	33.06
ANPE	1.225 x rnp x tan(a)		117.02	117.02
VAE	D x (tan(a) - tan(a - .01)) D=250/tan(a)		0.83	5.01
WPR	60.0	WPR x tan (a)	3.14	3.14
FTE	65		65.00	65.00
ASE	-8.8 x 10^-8 x (h + D x tan(a))^2 + 6.5 x 10^-3 x (h + D x tan (a))+50		57.99	65.70
ATIS	20		20.00	20.00

a. Decision Altitude Determination. The decision altitude based on the final segment OEA is determined by evaluation of the final segment OCS. Then, the DA is calculated from the HAT value using formulas in 4-6a(3) below. Minimum HAT value (unless lower is approved by AFS-400) is 250.

NOTE: *The missed approach segment evaluation (chapter 5) may require this DA value to be adjusted up or down to accommodate obstacles in the missed approach OEA.*

Figure 4-3. VEB OCS



(1) OCS Area. The OCS begins at a point $\mathbf{D_{VEB}}$ from the RWT and extends 1 RNP past the FAF. The D_{VEB} is determined by the VEB methodology in chapter 6 or VEB spreadsheet. The width is ± 2 RNP (see figure 4-3).

(2) OCS Slope. The OCS slope is determined using the Vertical Error Budget (VEB) spreadsheet. The ISA Deviation VEB component is determined as follows:

<u>STEP 1</u>. The ISA deviation is based on the coldest deviation from ISA standard temperature for the airport elevation in question. Two methods are approved to arrive at a deviation value. The first is to use the STANDARD ASSUMED DEVIATION VALUE of -10°C for Hawaii, -30°C for the contiguous United States, and –40°C for Alaska.

The second, and preferred methodology, is to determine the deviation based on local historical data (see step 2). In either case, the minimum and maximum temperature limits for the procedure will be charted.

<u>STEP 2</u>. Obtain the mean low temperature of the coldest month of the year for the last five years of data. If the data is given in Fahrenheit (°F), convert the temperature to Celsius (°C). Use formulas 4-1 or 4-2 to convert between Celsius and Fahrenheit temperatures:

Formula 4-1

$$°C = \frac{°\mathbf{F} - 32}{1.8}$$

Formula 4-2

$$°\mathbf{F} = 1.8 \cdot (°\mathbf{c}) + 32$$

Examples:

$$\frac{76° - 32}{1.8} = 24.44\ °C \qquad 1.8 \cdot (24.44°) + 32 = 75.99\ °F$$

<u>STEP 3</u>. Determine deviation from ISA (Delta ISA) using formula 4-3. This is the ISA Deviation to use in the VEB spreadsheet. **Use this value in the VEB spreadsheet.**

Formula 4-3

$$\text{Delta ISA} = {}^\circ C - 15$$

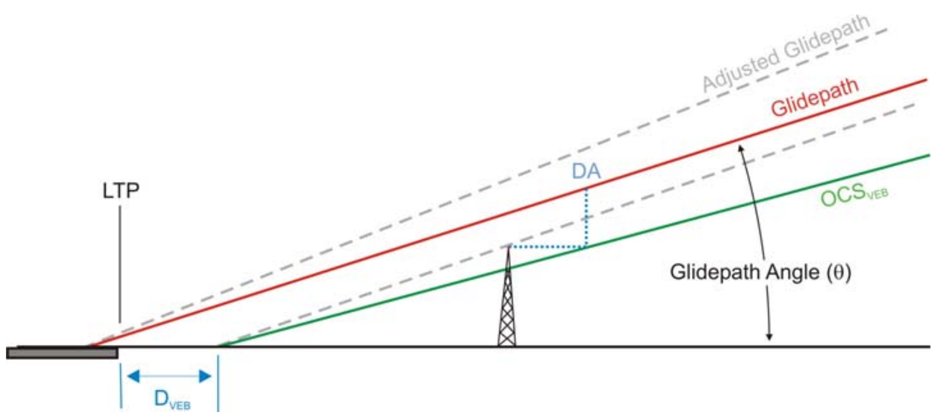
(3) **<u>Obstacle Evaluation.</u>** If the FAS OCS is not penetrated, the MINIMUM HAT value of 250' applies. A HAT value less than 250 requires AFS-400 approval. Determine the DA using formula 4-4.

Formula 4-4

$$\mathbf{DA} = \mathbf{HAT} + \mathbf{TDZE}$$

Obstacles that penetrate an OCS may be mitigated by one of the following actions: remove or lower obstacle, lower the RNP value for the segment (if appropriate), adjust the lateral path, raise glidepath angle, or adjust DA (see figure 4-4 and formula 4-5).

Figure 4-4. VEB Adjustment of DA or Glidepath Angle



NOTE: *D_{VEB} decreases slightly when glidepath angle is increased.*

Formula 4-5

$$\mathbf{DA_{adjusted}} = \tan(\theta)\cdot(\mathbf{d} + \mathbf{p}\cdot\mathbf{OCS_{VEB}}) + \mathbf{TCH} + \mathbf{LTP_{elev}}$$

Where: θ = Glidepath Angle
d = distance (ft) LTP to obstacle
p = Amount of penetration (ft)
OCS_{VEB} = Slope of VEB OCS

4-6. TURNS IN FINAL SEGMENT.

Normally, RF legs are preferred for all turns in the FAS. Design turns in the final segment to be completed by at least 1,000 feet (or 500 feet with AFS-400 approval) above the touchdown zone elevation. Locate the FROP on runway centerline extended tangent to the arc track <u>at</u> <u>least</u> distance "$\mathbf{D_{RF}}$" (in feet) from the LTP (see figure 4-5, formula 4-6). DA must occur at or after passing the FROP **or** prior to the RF leg initial fix. Determine $\mathbf{D_{RF}}$ using formula 4-6. The turn is constructed under paragraph 2-4a or 2-4b as appropriate.

Formula 4-6

$$D_{RF} = \frac{a - (LTP_{elev} + TCH)}{tan(\theta)}$$

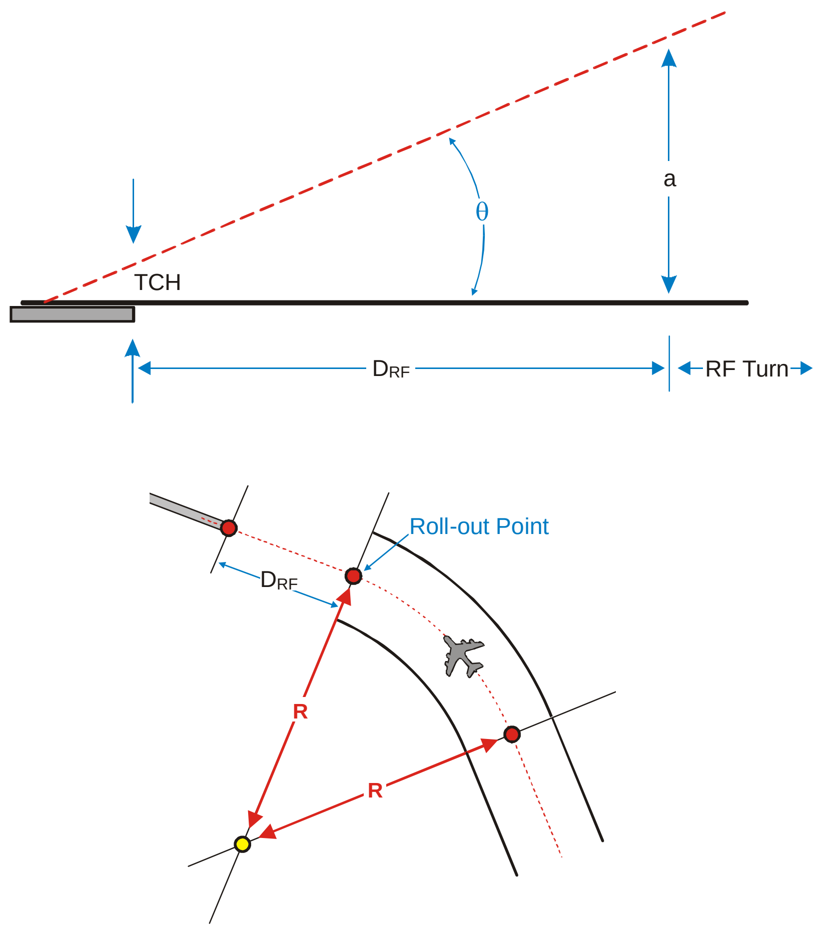
Where a = Rollout Point MSL Altitude

θ = Glidepath Angle

Example

$$\frac{620 - (120 + 52)}{tan(3.00)} = 8{,}548.35'$$

Figure 4-5. Calculating D_{RF}



a. Determining PFAF Location Relative to LTP for use in calculating WGS-84 latitude and longitude (see figure 4-6). Several software packages will calculate a geographical coordinate derived from Cartesian measurements from the LTP. Use formulas 4-7 and 4-8 to obtain the Cartesian values.

STEP 1: Determine the flight track distance (**D_{PFAF}**) from LTP to PFAF under paragraph 4-4.

STEP 2: Determine the distance (**D_{RF}**) from LTP to the FROP using formula 4-6.

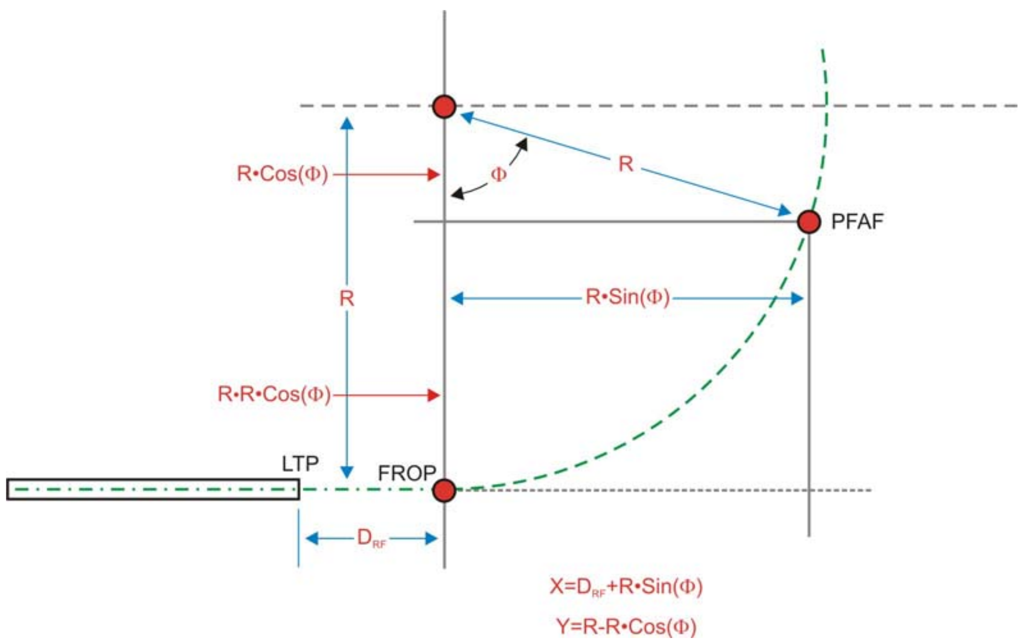
STEP 3: Subtract D_{RF} from D_{PFAF} to calculate the distance around the arc to the PFAF from the FROP. Use formula 4-7 to determine number of degrees of arc; conversely, use formula 4-8 to convert degrees of arc to length.

Formula 4-7	Formula 4-8
Degrees of Arc $[\phi]$: $\phi = \dfrac{180 \cdot \mathbf{L}}{\pi \cdot \mathbf{R}}$	Length of Arc $[\mathrm{L}]$: $\mathbf{L} = \dfrac{\phi \cdot \pi \cdot \mathbf{R}}{180}$

If the PFAF is in the RF segment, determine its X,Y coordinates using formulas 4-9 and 4-10:

Formula 4-9	Formula 4-10
$\mathbf{X} = \mathbf{D_{RF}} + \mathbf{R} \cdot sin(\phi)$	$\mathbf{Y} = \mathbf{R} - [\mathbf{R} \cdot cos(\phi)]$

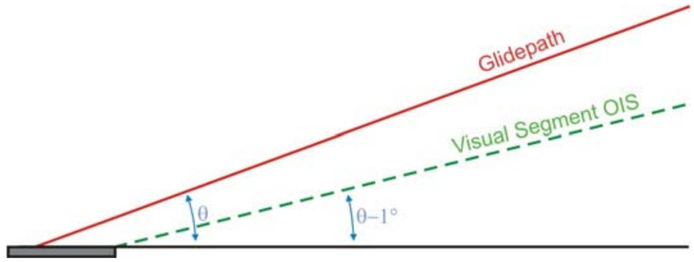
Figure 4-6. Determining PFAF Position (X,Y) Relative to LTP



4-7. RNP VISUAL SEGMENT OIS (see figure 4-7).

The OIS originates at the LTP and extends to the DA point at an angle of one degree less than the glidepath angle.

Figure 4-7. VEB Visual Segment OIS

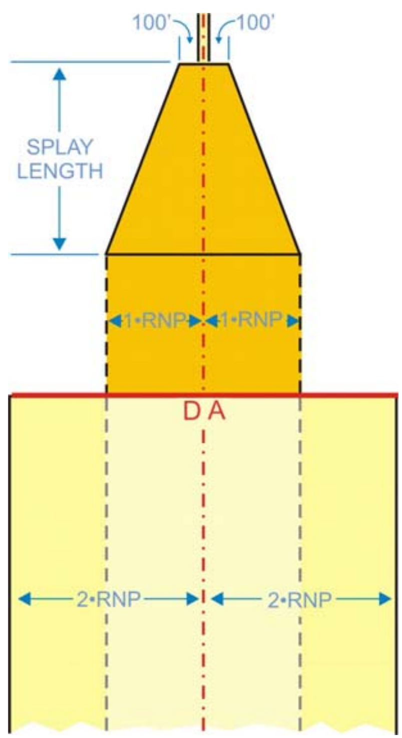


The OIS half-width at the LTP is 100 feet outside the runway edge. It splays at an angle of 10 degrees until reaching a width of ± 1•RNP, which it maintains until contacting the final segment OEA at DA (see figure 4-8 and formula 4-11).

Formula 4-11

$$\text{SPLAY}_{\text{length}} = \frac{(1 \cdot \text{RNP} \cdot 607611548) - \left(100 + \frac{\text{Rwy Width}}{2}\right)}{\tan(10)}$$

Figure 4-8. Visual Segment OIS at Full Width



Calculate the segment length required to reach ±1•RNP. If the 10 degree splay contacts the OEA at DA prior to reaching 1•RNP then a buffer area is assessed between the point the 10 degree splay contacts the OEA and the 1•RNP boundary as shown in figure 4-9. This buffer area is designed to evaluate the area necessary to realign with runway centerline and is calculated as being equivalent to 5 seconds of aircraft forward travel time based on aircraft category assuming a 10 knot tailwind and corrected for temperature and pressure altitude (see formula 4-1). The buffer OIS is a continuation of the VEB OCS. An obstacle may penetrate the visual OIS (figures 4-8 and 4-9) provided it is charted, appropriate mitigations are considered and Flight Standards approval is obtained.

$$\text{Buffer}=\frac{(V_{KTAS}+10)\times 5\times 6076.11548}{3600}$$

Simplifies to:

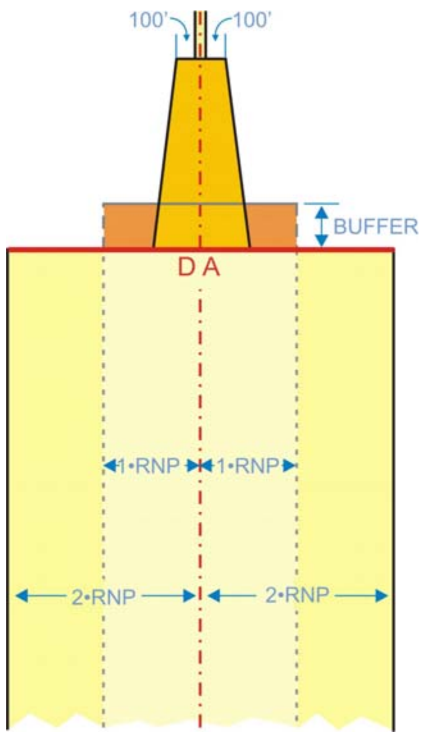
Formula 4-12

$$\textbf{Buffer}=(V_{KTAS}+10)\cdot 8.439$$

Example

$$(168+10)\cdot 8.439=1{,}502.14'$$

Figure 4-9. Visual Segment Not at Full Width



CHAPTER 5. MISSED APPROACH SEGMENT (MAS)

5-1. GENERAL.

The Missed Approach Segment will use RNP to provide obstacle clearance and fully exploit advanced aircraft performance capabilities. However, RNP may be discontinued at the MAP or any subsequent fix or segment where its application is no longer desired and where TERPS criteria can provide the necessary obstacle protection. The MAS is evaluated using a slope more representative of specific aircraft performance may be used provided the missed approach climb gradient associated with the steeper slope is published on the approach chart. This evaluation may be representative of low, medium, or high performing aircraft, but is expected to be first evaluated for the medium performing aircraft. **Reference appendix 7** for selection of the OCS slope based on airport elevation. ***SEE APPENDIX 6, ITEM 10 for further explanation.***

a. The missed approach segment RNP value may continue the FAS RNP value or increase the RNP value at the MAP or on subsequent fixes. It is the intent to limit use of RNP values less than RNP 1.0 to obstacle clearance purposes only, and for the minimum distance required before either being increased, or discontinued in favor of TERPS missed approach criteria. It is desirable that the RNP value be established as RNP 1.0 as close to the MAP as is consistent with obstacle clearance and any operational needs. It is acceptable to increase the RNP value in increments until reaching en route RNP levels.

b. The RNP track should lead the aircraft to a relatively "obstacle free location or track," an en route airway or fix, a holding pattern, or to a minimum safe altitude as expeditiously as possible without prolonged requirement for "small" RNP values to assure obstacle protection. The MAS extends from the DA point to the missed approach clearance limit (an airway fix or a holding pattern from which an en route transition may be accomplished).

c. It should be noted that the number and magnitude of turns add complexity to a procedure; therefore, their use should be limited. Where turns are required in the MAS, the MA track will continue the flight track of the FAS to the LTP (this is normally along the extended centerline of the runway) and continue down the runway centerline to the DER. The first turn must occur after the DER.

d. The missed approach climb gradient requirement for TERPS is assumed to be at least 200'/NM (3.29%) and is associated with a 40:1 OCS (regardless of airport altitude, temperature and engine-out performance capabilities). However, for the purposes of RNP SAAAR under this notice, a performance based climb gradient will be specified that is representative of SAAAR aircraft performance considering the airport elevation and temperature conditions expected for the approach. (See paragraph 5-8 for calculating the OCS slope for performance benchmark climb gradients.) For example, a representative benchmark climb gradient for sea level and 45°F (includes ice on airframe decrement) can be 227 (3.74%) feet per nautical mile. Height loss of 50' is assumed after DA. The published DA is based on the HAT determined by the FAS OCS evaluation, or a higher HAT value based on adjustments resulting from the evaluation of the MAS OCS.

5-2. MISSED APPROACH CONDITIONS TO BE ASSESSED.

Three basic conditions are considered in the development of obstacle clearance criteria for RNP approaches and missed approaches:

a. The aircraft arrives at the DA, acquires visual reference to the runway and proceeds to landing. Chapter 4 contains guidance for this evaluation.

b. The aircraft arrives at the DA, does not acquire visual reference to a landing on the runway, and initiates a missed approach. This chapter provides guidance for this obstacle evaluation.

c. The aircraft arrives at the DA, initiates a missed approach, and experiences an engine failure. Guidance for this evaluation is contained in appendix 7.

d. The aircraft arrives at the DA, continues with visual reference to the runway, initiates a rejected landing at the end of the touchdown zone, and experiences an engine failure. Guidance for this evaluation is contained in appendix 8.

5-3. MISSED APPROACH RNP LEVEL/SEGMENT WIDTH.

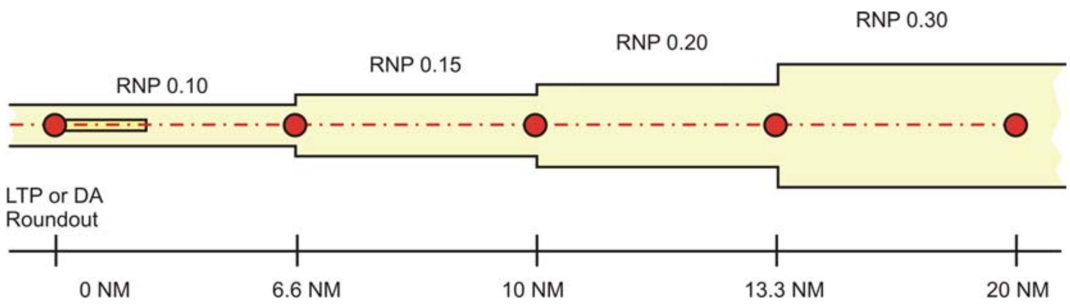
Generally, it is preferable that the missed approach segment has a greater RNP value than the final, or no associated RNP value when the MA is based on TERPS. Construction of the MAS as a routed continuation of the FAS RNP level is allowed where necessary to avoid obstacles (gain operational advantage). Minimize the distance traveled at small RNP levels. It is permissible to apply standard TERPS MA criteria if obstacle, airspace, or environmental considerations do not affect minimums. The RNP value of the MAS may be increased at the LTP or any subsequent waypoint defining the missed approach. For database coding purposes, the LTP normally marks the starting point of the MA RNP-level. Table 5-1 lists the maximum MAS length at a given RNP level. These values can be calculated using formula 5-1.

Table 5-1. Max Allowable MAS Length at Given Small RNP Levels

RNP value	Max distance from LTP [or DA round-out]
< 0.15	6.6 NM
0.15 – 0.19	10 NM
0.20 – 0.24	13.3 NM
0.25 – 0.29	16.6 NM
0.30	20 NM
0.50	33 NM

Formula 5-1
Max Distance=**RNP** • 66.6

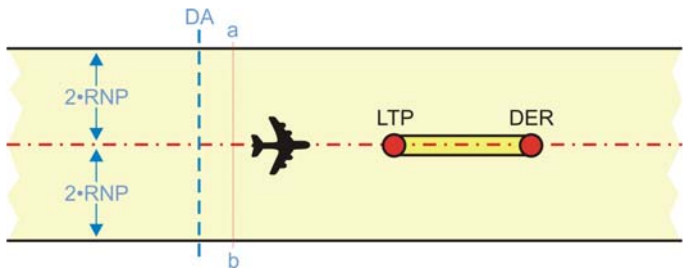
Figure 5-1. Maximum MAS Length at Small RNP Levels



5-4. STRAIGHT MISSED APPROACH CONSTRUCTION.

Straight missed approach segments are constructed using TF leg segments. In figure 5-2, the initial fix of the MA leg segment is the LTP.

Figure 5-2. Initial Missed Approach Segment



The **ab** line marks the round-out point

5-5. TURNING MISSED APPROACH.

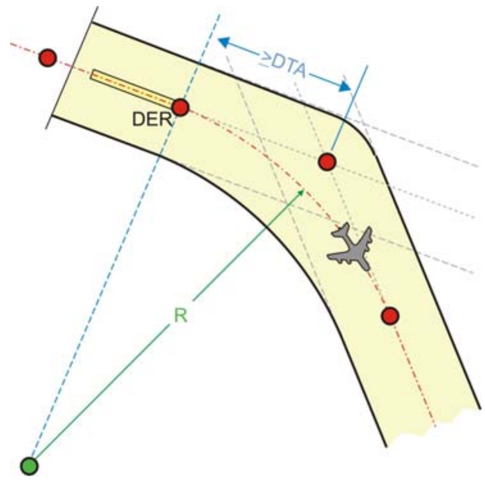
The missed approach route is a series of segments. Turns are accomplished through application of TF or RF legs. The first turn in the missed approach segment must occur at or beyond the DER.

a. TF Segments. Turns are accomplished at fly-by fixes. Calculate the DTA (formula 2-4) for the fastest aircraft Category using table 2-1 airspeeds. Locate the turn fix at least the DTA value from DER. Determine the turn radius (**R**) using formula 2-2 (see figure 5-3).

NOTE 1: *Fly-over fixes associated with TF legs are not compatible with RNP MA routing. Use Fly-By or RF turns only.*

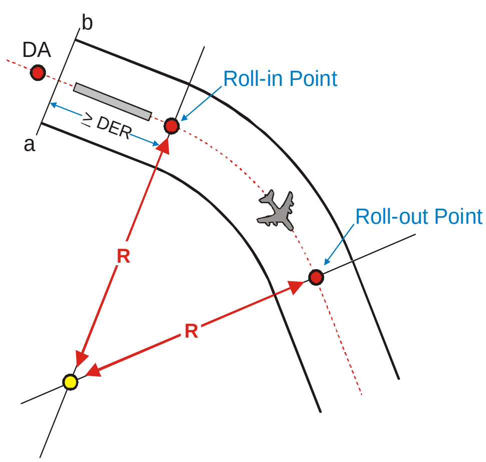
NOTE 2: For determining MAS turn radius as part of formula 2-2, to calculate the TAS, use an altitude value determined as follows: Assume a climb gradient of 500 feet per nautical mile from the DA along-track centerline to the end of the applicable turn and use this calculated altitude or the missed approach clearance limit altitude, whichever is lower.

Figure 5-3. TF Turning Missed Approach Segment



b. RF Segment. Locate the roll-in point (initial point) of an RF segment in the missed approach segment at a point not earlier than the DER (see figure 5-4).

Figure. 5-4 . RF Turning Missed Approach Segment



Where the ab line = "the round-out point"

5-6. MA OEA.

a. Length. The missed approach rising OCS begins at $\frac{50}{\tan(\text{glidepath angle})}$ after DA (round-out point). Terminate the missed approach OCS at an elevation corresponding to the en route ROC below the missed approach altitude.

(1) If the missed approach climb gradient OCS terminates prior to the clearance limit, continue the evaluation using a level OCS at the height that the OCS was terminated.

(2) If the clearance limit is reached before the OCS missed approach climb gradient terminates, continue a climb-in-hold evaluation at the clearance limit.

b. Width. Missed approach segments continue the "ribbon" of airspace with a containment of two times RNP either side of centerline. Alternatively, standard TERPS missed approach criteria may be used. MASs, turns, and lateral OEA boundaries are determined in a manner identical to the approach (see figure 5-1).

5-7. HEIGHT OF MISSED APPROACH SURFACE (HMAS).

The Height of the Missed Approach Surface (HMAS) is the minimum height of the MAS OCS and occurs at a distance of $\frac{50}{tan(\theta)}$ past (after) the DA point marked by the **ab** line. Apply formula 5-2 to calculate the MSL HMAS at the ab line.

Formula 5-2

$$\mathbf{HMAS} = \frac{\left[\left(\mathbf{DA}_{\mathbf{LTP}} - \frac{50}{tan(\theta)}\right) - \mathbf{D}_{\mathbf{VEB}}\right]}{\mathbf{FAS}_{\mathbf{OCSslope}}} + \mathbf{LTP}_{\mathbf{elev}}$$

5-8. OCS SLOPE DETERMINATION. The OCS slope is equal to the engine out climb performance of the aircraft expressed in percent grade. The %G is found from the table in appendix 7. The slope can be calculated using formula 5-3:

Formula 5-3

$$\mathbf{Slope} = \frac{100}{\%\mathbf{G}}$$

And for example, if the required percent grade is specified as 3.55% for the procedure, the OCS slope is $slope = \frac{100}{3.55} = 28.17:1$. Once the OCS slope is determined in this manner from the table lookup in appendix 7, the minimum required climb gradient for the procedure could be calculated by formula 5-4:

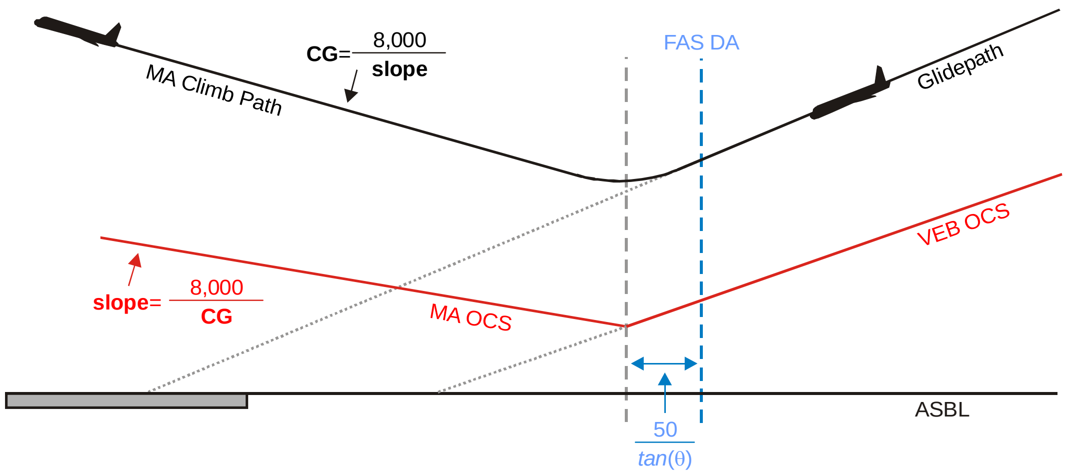
Formula 5-4

$$\mathbf{CG} = \frac{8000}{\mathbf{Slope}}$$

For example, if the performance based engine out OCS grade is 3.55% (as in the example in appendix 7), the minimum required climb gradient (ft/NM) is:

$CG = \frac{8000}{100/3.55} = 284.00$ ft/NM. See figure 5-5.

Figure 5-5 VEB OCS



5-9. OCS EVALUATION.

Calculate surface rise to the obstruction position based on the along-track distance from the obstruction to the **ab** line located at the round out (see **figure 5-2**). Calculate along-track distance in turns using formula 4-10. Obstacles must not penetrate the missed approach segment OCS. Penetrations can be avoided by removing the obstacle, reducing obstacle height, altering the MA track, raising coded vertical angle, raising DA, or a combination of these actions. The MA OCS slope is selected from the tables of appendix 7. If a missed approach climb gradient greater than the table value is specified for the procedure, the OCS slope is calculated using formula 5-5.

a. Mediation by climb gradient. To calculate the OCS slope required to clear a penetrating obstacle (see figure 5-6), use formula 5-5.

Formula 5-5

$$\textbf{Slope} = \frac{d_{ab}}{h - HMAS}$$

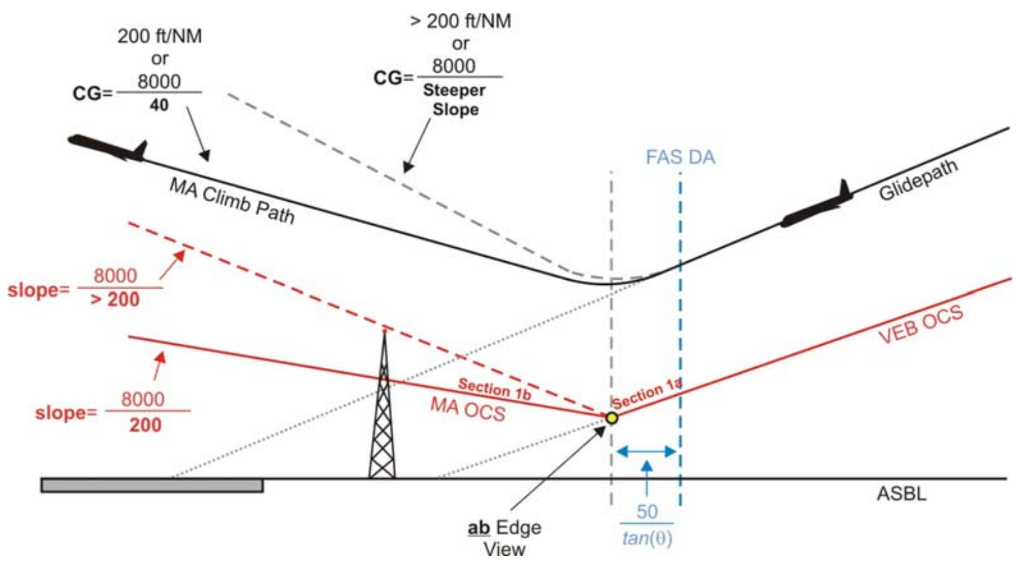
where h=obstacle MSL elevation

d_{ab}=alongtrack distance (ft) to ab line

Example

$$\frac{9164}{449 - 116} = 27.52$$

Figure 5-6. MA OCS Penetration: Mediation by Climb Gradient



Publish the required MA Climb gradient on the approach chart. In the case of the 449-foot obstacle used in the last example, the required climb gradient would be (using formula 5-4):

$$\frac{607611548}{27.52} = 220.789$$

b. Mediation By DA Adjustment. Where the MA OCS is penetrated and mediation by climb gradient is not appropriate, adjust DA using formulas 5-6, 5-7, and 5-8. See figure 5-7.

Formula 5-6

$$\mathbf{DA}_{\mathbf{adjusted}} = \frac{\mathbf{p} \times tan(\theta) \times \mathbf{MA}_{\text{OCS Slope}} \times \mathbf{VEB}_{\text{OCS Slope}}}{\mathbf{MA}_{\text{OCS Slope}} + \mathbf{VEB}_{\text{OCS Slope}}} + \mathbf{DA}_{\mathbf{FAS}}$$

Formula 5-7

$$\mathbf{HAT}_{\mathbf{adjusted}} = \mathbf{DA}_{\mathbf{adjusted}} - \mathbf{TDZE}$$

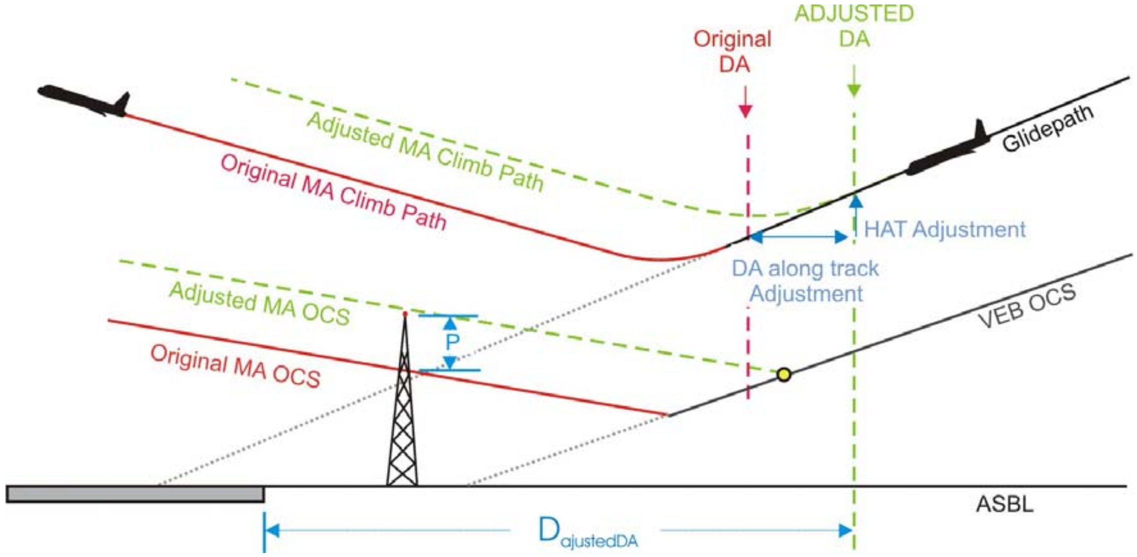
Formula 5-8

$$\mathbf{d}_{\text{LTP to DA}} = \frac{\mathbf{DA} - (\mathbf{LTP}_{\text{elevation}} + \mathbf{TCH})}{tan(\theta)}$$

$$\mathbf{HMAS@DA}_{\text{adjusted}} = \frac{\mathbf{d}_{\text{LTP to DA}} - \mathbf{VEB}_{\text{LTP to OCS Origin}}}{\mathbf{VEB}_{\text{OCS Slope}}} + \mathbf{LTP}_{\text{elevation}}$$

where:
p = amount of penetration (ft)
θ = glidepath angle
DA_{FAS} = Final Segment DA
$MA_{\text{OCS Slope}}$ = Missed approach OCS slope ratio
$VEB_{\text{OCS Slope}}$ = Final Segment OCS slope ratio

Figure 5-7. Missed Approach DA Adjustment



CHAPTER 6. VERTICAL ERROR BUDGET (VEB)

Vertical navigation utilizing barometric pressure (Baro VNAV) has a number of identifiable vertical displacement components which can cause an aircraft to be above or below the nominal procedure defined flight path without an indication to the crew. Thus, procedure design criteria based upon Baro VNAV must suitably consider these vertical path displacement components.

The following table identifies eight vertical displacement components which may be combined statistically to establish a required obstacle clearance (ROC) to be used in developing vertical path criteria.

Table 1, Vertical Error Budget (VEB)

(1) Non standard temperature induced error (ISAD)

(2) Body geometry error (BG)

(3) Actual Navigation Performance error (ANPE)

(4) Vertical Angle Error (VAE)

(5) Waypoint Resolution (WPR)

(6) Flight Technical Error (FTE)

(7) Altimetry System Error (ASE)

(8) ATIS Error (ATIS)

NOTE: *Derivation of these errors is contained in appendix 6, items 11-17.*

6-1. NON-STANDARD TEMPERATURE INDUCED ERROR (C).

A 1956 study by the National Aeronautic Committee on Atmospherics (NACA) indicated altimeter errors in the terminal area could be as much as 125 feet. This study, although well intentioned, did not adequately address errors caused by below standard temperatures. A more recent Federal Aviation Administration (FAA) study of below standard temperature induced errors is consistent with the recently adopted PAN OPS cold temperature formula shown below:

$$ISAD = \frac{\Delta h \cdot \Delta ISA}{288 + \Delta ISA - 0.5 \cdot \frac{1.98}{1000} \cdot (h + \Delta h)}$$

where: ISAD is the amount of error in feet

h is the MSL elevation of the GPI in feet

Δh is the height above the GPI in feet

ΔISA is the temperature difference from standard in degrees Celsius

For example, if h = 1000 ft, Δh = 2000 ft, and ΔISA = -20° C below standard, then

$$ISAD = \frac{\Delta h \cdot \Delta ISA}{288 + \Delta ISA - 0.5 \cdot \frac{1.98}{1000} \cdot (h + \Delta h)} = \frac{(2000) \cdot (-20)}{288 - 20 - 0.5 \cdot \frac{1.98}{1000} \cdot (1000 + 2000)}$$

$$ISAD = -150.9\ ft$$

ISAD is a bias error, i.e., for non-standard temperatures the mean error in indicated altitude will not be zero. For an aircraft above the altimeter setting source, in below standard temperatures the mean indicated altitude will be higher than actual, and in above standard temperatures the mean indicated altitude will be lower than actual.

6-2. BODY GEOMETRY ERROR (BG).

Body geometry error accounts for the low point of the aircraft below the altimeter reference point. For an aircraft whose wings are level, this low point may be the main landing gear if deployed. In some large aircraft this distance may be up to 19 feet or more. However a banking aircraft may well have a wing tip below the height of the landing gear. Some wide body aircraft have a wingspan over 200 feet, with some future aircraft having a wingspan of nearly 250 feet. If dihedral angle and wing flexing due to loading are not considered and it is assumed that the altimetry reference height is even with the underside of the wing when wings are level, then in a 25° bank an aircraft could have the wingtip approximately 50 feet below the altimetry reference elevation. This formula is shown below:

$BG = \frac{wingspan}{2} \cdot \sin(\phi)$, where ϕ represents the bank angle.

BG is a bias error, i.e., the mean lowest point of the aircraft will be lower than the altimetry height.

The commonly accepted values for body geometry noted below may be used as a conservative estimate to address a wide variety of transport aircraft types. If body geometry becomes a constraining factor in procedure design, then other smaller values may be used, considering and consistent with:

1. The largest type of aircraft expected to use the particular procedure.
2. The amount of turn expected, and
3. The height at which turns occur in the procedure. Body geometry may be reduced to 8 degrees bank assumption when below 400’ HAT. When below 400’ AGL procedure design must be based on a maximum bank of 8 degrees. The body geometry may also be reduced to 8 degrees and an appropriate value for RF turn construction is assumed. Turns below 400’ AGL or HAT may typically assume bank angles of 8 degrees or less, rather than 25 degrees used for purposes of geometry assessment at greater heights. This is due to typical current aircraft design characteristics for FD or autoflight systems performance at low altitude (RA).

6-3. ACTUAL NAVIGATION PERFORMANCE ERROR (ANPE).

Actual navigation performance is dependent upon required navigation performance (RNP). RNP is a manufacturer's assurance that the actual position of the aircraft is within the indicated RNP distance 95% of the time. That is, if RNP is 2 NM (RNP2), then 95% of the time the aircraft would be expected to be within a 2 NM radius of the indicated position. For RNP.1, this 95% radius is reduced to less than 608 ft. To convert 95% RNP to three standard deviations (3σ) a factor of 1.225 is necessary. Although ANP is probably superior to RNP, conservatively RNP will be used to determine the vertical component of this error. A horizontal position error is translated into a vertical error by the tangent of the glidepath angle. This is shown in the following formula:

$$\text{ANPE} = (6076.115)\cdot(1.225)\cdot \text{RNP}\cdot\tan(\theta)$$, where θ is the intended glidepath angle.

ANPE is a zero mean error which can be combined statistically with other zero bias errors by the root sum square (RSS) method.

6-4. VERTICAL ANGLE ERROR (VAE).

Vertical angle error is the error within the flight management system (FMS) in determining the intended glidepath correctly. This error is conservatively estimated to have a 3σ value of not greater than .01°. This is shown in the following formula:

$$\text{VAE} = \Delta h \cdot \left(\frac{\tan(\theta + .01)}{\tan(\theta)} - 1\right)$$

VAE is a zero mean error which may be RSS'd with other zero bias errors.

6-5. WAYPOINT RESOLUTION (WPR).

Waypoint resolution error is a component of vertical path definition and occurs because the indicated and actual positions of the waypoint may be slightly different. Sixty feet is considered to be a conservative 3σ estimate of the horizontal position error, based on the resolution of the computed coordinates, the value stored in the FMS database and the computational resolution of the FMS. This again translates to a vertical error based upon the intended glidepath angle. The formula is shown below:

$$WPR = 60 \cdot \tan(\theta)$$

WPR is a zero mean error which may be RSS'd with other zero bias errors.

6-6. FLIGHT TECHNICAL ERROR (FTE).

Flight technical error is a measure of the pilot's or autopilot's ability to track the presented path. The FTE is specified for the purposes of using a standard VEB as a fixed value of 65 feet.

FTE is a zero mean error which may be RSS'd with other zero bias errors.

6-7. ALTIMETRY SYSTEM ERROR (ASE).

Altimetry system error accounts for residual errors in the altitude measurement system. The ASE equation is provided by Boeing and based on flight test data. The normal static source error is applied by the Air Data Inertial Reference Unit (ADIRU) or Air Data Computer (ADC). The formula is

$$ASE = -8.8 \cdot 10^{-8} \cdot (h + \Delta h)^2 + 6.5 \cdot 10^{-3} \cdot (h + \Delta h) + 50$$

ASE is a zero mean error which may be RSS'd with other zero bias errors.

6-8. ATIS ERROR (ATIS).

The reported altimeter setting is updated hourly except when changes exceed .02" of mercury, then the altimeter setting will be updated as necessary. Since 1" of change corresponds to approximately 1,000 feet in elevation, .02" corresponds to approximately 20 feet. This 20 feet is a conservative 3σ estimate of the ATIS.

ATIS is a zero mean error which may be RSS'd with other zero bias errors.

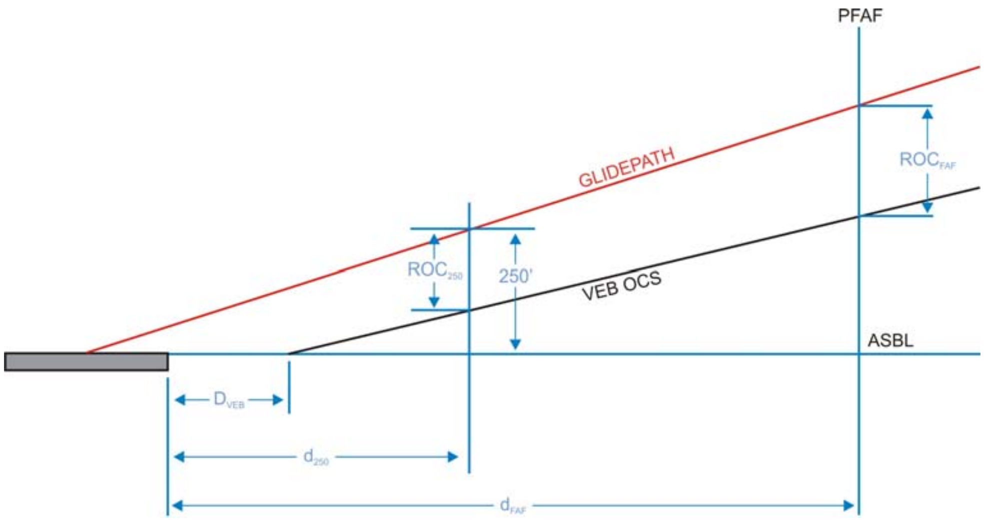
6-9. VERTICAL ERROR BUDGET (VEB).

Total System Error (TSE) is the statistical combination of error sources and will be used as the allowed Vertical Error Budget (VEB) at the designated points on the glidepath to form the OCS. These error sources fall into two categories. The first is zero mean errors which may be root sum squared to determine a combined zero mean error, and the second is non zero mean errors (bias errors) which will be added to the combined zero mean error to obtain the VEB. The Central Limit Theorem indicates the RSS'd components, even though individually not normally distributed, will tend toward the normal distribution. To take our 3σ values (one tail protection of 99.865%) to 4σ values (one tail protection of 99.99683%) a factor of 4/3 is inserted into the equation.

$$VEB = BG - ISAD + \frac{4}{3} \cdot \sqrt{ANPE^2 + VAE^2 + WPR^2 + FTE^2 + ASE^2 + ATIS^2}$$

For developing the Obstacle Clearance Surface (OCS), the TSE is found at 250 feet (ROC 250) above the landing point threshold (LPT) and at the final approach fix (FAF) height (ROC FAF). Then the OCS is the sloping plane defined by these two values as shown in figure 6-1. An accompanying Excel spread sheet (figure 6-2) accomplishes these calculations. Location of this spreadsheet will be within AFS-420 website: http://av-info.faa.gov/terps/index.htm

Figure 6-1. VEB OCS



The equation for the ROC at any distance d is:

$$ROC_d = \frac{ROC_{FAF} - ROC_{250}}{d_{FAF} - d_{250}}\left(d - d_{250}\right) + ROC_{250}$$

Figure 6-2 VEB Spreadsheet

Vertical Error Budget

AFS-420 Version 1.5

Inputs:

RNP Value	0.30
LTP MSL Elevation (h)	1,000.00
Distance (ft) LTP to PFAF	28,500.00
MSL PFAF Altitude	2500
Glidepath Angle (a)	3.00
TCH	50.00
Delta ISA (dISA)	-20.00
Semispan	107.00

Areas that are shaded green require entry of a value.

Dist (ft) LTP to OCS ORIGIN	3,778.46		
OCS Slope (run:rise)	20.70 :1		
VEB ROC @ PFAF	346.18	TERPS VNAV ROC @ PFAF	711
PFAF height above ASBL	1,500.00		

Along course distance (ft) from LTP to Intermediate Segment Obstacle	40,000.00	VEB ROC at Intermediate Segment Obstacle	391.84

Error Components	(Enter Bank Angle, WPR, FTE, and ATIS values below)		@ 250 ft	@ PFAF
ISAD	(dh x dISA)/(288 + dISA - 0.5 x .00198 x h)		-18.73	-112.36
BG	18	semispan x sin (Bank Angle)	33.06	33.06
ANPE	1.225 x rnp x tan(a)		117.02	117.02
VAE	D x (tan(a) - tan(a - .01)) D=250/tan(a)		0.83	5.01
WPR	60.0	WPR x tan (a)	3.14	3.14
FTE	65		65.00	65.00
ASE	-8.8 x 10^-8 x (h + D x tan(a))^2 + 6.5 x 10^-3 x (h + D x tan (a))+50		57.99	65.70
ATIS	20		20.00	20.00

APPENDIX 6

EXPLANATIONS AND ASSUMPTIONS (REFER TO APPENDIX 5)

1. PARAGRAPH 1-6E. DEFINITIONS - FINAL APPROACH FIX (PFAF).

Traditionally, the FAF acronym is associated with the final approach fix on 2-dimensional (2D) approach procedures and PFAF with the final approach fix on 3-dimensional (3D) procedures (initially only precision approaches were 3D-hence the “P”). Since the coining of the acronym PFAF, additional types of 3D approach procedures became available: LDA with Glide Slope, LNAV/ VNAV, LPV, and RNP. While these procedures do not qualify for the precision classification under the performance standards of ICAO annex 10, the final approach fix associated with them is considered a PFAF because they are 3D approach procedures.

2. PARAGRAPH 2-2. CALCULATING TURN RADIUS.

a. Step 1. An assumed temperature of 50°C (ISA + 35°) was used for the above KTAS standard formula. An alternative temperature may be used at specific locations based upon historic meteorological data available from the National Weather Service (NWS) Internet address: www.ncdc.noaa.gov. The alternative temperature may be determined by using the mean temperature for the hottest month of the year, for the airport of interest, for each of the five most recent calendar years of data. Then average those five values which will be the mean high temperature to be used for KTAS at that location.

b. Paragraph 2-2a(3). Calculating Restrictions on Bank Angle – Any Portion of the Turn. The worse case predictable turn radius results from standard rate turns at 35° C above standard temperature. The formula to calculate turn radius (R) is:

$$\mathbf{R} = \frac{\mathbf{V_{KTAS}}^2\left(1.4589 \cdot 10^{-5}\right)}{tan(\phi)}$$

Where ϕ = bank angle required for standard rate turn, V_{KIAS} = indicated airspeed in knots, and V_{KTAS} = true airspeed in knots. True airspeed is often difficult to accurately determine, but the following explanation and resulting approximations are sufficient for this application:

V_{KIAS} – indicated airspeed

V_{KCAS} – calibrated airspeed

V_{KEAS} – equivalent airspeed

V_{KTAS} – true airspeed

V_{KIAS} is measured by pressure differential between the ram air pitot pressure and the static pressure. Since higher altitudes have lower pressures, the aircraft must be flying faster to achieve the same pressure differential or V_{KIAS}.

V_{KCAS} is V_{KIAS} modified by configuration issues that are aircraft type specific. When flaps/slats/gear/etc. are deployed, the angle of attack of the pitot tube and therefore its ram air pressure is affected. Thus adjustments usually based upon tables in the aircraft flight manual must be made to the V_{KIAS} to find V_{KCAS}. For aircraft cleanly configured for cruise, V_{KCAS} is the same as V_{KIAS}.

$\mathbf{V_{KEAS}}$ is the airspeed necessary to achieve the aircraft dynamic behavior at the altitude that it would exhibit at standard sea level pressure for a given V_{KIAS}. V_{KEAS} again is a tabled value dependent upon V_{KCAS}, but in general results in about a 2% increase per thousand feet of altitude.

V_{KTAS} is calculated from V_{KEAS} from the formula $V_{KTAS} = V_{KEAS}\left(\sqrt{\frac{\rho_0}{\rho}}\right)$ where $\sqrt{\frac{\rho_0}{\rho}}$, known as a standard means of evaluation (SMOE), is the square root of the ratio of standard sea level density compared to density at altitude. As temperature increases while pressure remains fixed, density must decrease so the SMOE increases. At above standard temperatures, the SMOE and therefore the V_{KTAS} will be higher than under standard conditions. At 0 ft MSL and 50° C (35° C above standard), V_{KTAS} is increased by 5.9% as compared to standard conditions (15° C). At 10,000 ft MSL and 30° C (35° above standard), the V_{KTAS} is increased by 6.0%, at 20,000 ft MSL and 10° C (35° C above standard); V_{KTAS} is increased by 6.8%. Under standard conditions the V_{KTAS} at altitude can be approximated by the following formula:

$$V_{KTAS} = V_{KIAS}(1 + .00002 \cdot \text{altitude}),$$

and if the temperature is considered to be 35° C above standard, then the approximation of V_{KTAS} becomes:

$$V_{KTAS} = (1.06) \cdot V_{KIAS}(1 + .00002 \cdot \text{altitude}).$$

The formula to calculate standard rate bank angle (ϕ) is:

$$\phi = \tan^{-1}(0.00275 \cdot V_{KTAS})$$

Therefore by substitution:

$$R = \frac{V_{KTAS}^{2}\left(1.4589 \cdot 10^{-5}\right)}{0.00275 \cdot V_{KTAS}}$$

Which reduces to:

$$R = V_{KTAS} \cdot 0.005305$$

The formula to calculate the DTA prior to the turn is:

Relationship: $\frac{DTA}{R} = \tan\left(\frac{\phi}{2}\right)$

Solved for DTA: $DTA = R \cdot \tan\left(\frac{\phi}{2}\right)$

Where ϕ is the measurement of degrees track

3. PARAGRAPH 2-3A. RNP (SAAAR) CONTAINMENT – RNP SEGMENT WIDTH.

The lateral RNP Segment Width (commonly referred to as "RNP Containment") for each approach segment is centered on the nominal aircraft procedure track and bounded on either side by a line parallel to the procedure track located at a distance of 2•RNP for a total width of 4•RNP. This lateral containment of airspace exists throughout the approach and missed approach. The 4•RNP OEA represents a lateral definition for what has commonly been known as "RNP RNAV containment." The RNP level (see table 2-3) is a variable used to define the segment width. The OEA half-width value in NM is equal to 2•RNP level. For example, the half-width of the OEA for an RNP 0.30 segment is 0.60 NM (2•0.30), and the total width is 1.20 NM (4•0.30). For any given procedure, the segment requiring the lowest RNP value is defined as the limiting segment. The limiting segment determines the RNP value for the procedure e.g. if Initial = 1.0, Intermediate = 0.3, Final = 0.1, missed approach = 0.5, the limiting segment is the final segment because its RNP value is the smallest; therefore, the applicable RNP value associated with flying the procedure (minima line) is RNP 0.1.

4. PARAGRAPH 2-4. SEGMENT LEG TYPES – STEP 3.

A maximum course angle change of 120 degrees is allowed for turns past Fly-By Waypoints that join two TF legs. Fly-over waypoints are not recommended. Fly-Over Waypoint use is not consistent with how RNP legs are typically constructed, or with basic principles of how RNP paths are intended to satisfy operational requirements. Hence, Fly-over waypoints may only be used when RNP for the subsequent leg is not required. Calculating Distance of Turn Anticipation (DTA). When designing segments between Fly-By Waypoints where turns occur, the DTA on both ends of each leg may be calculated to help determine the suitability of the turn. The length of the DTA must never exceed the length of its inbound and outbound TF leg lengths (see appendix 5, chapter 2, formula 2-4 and figure 2-5).

5. PARAGRAPH 3-3B(2). MINIMUM SEGMENT ALTITUDES – INTERMEDIATE SEGMENT.

The maximum and minimum descent gradient values provide a great deal of flexibility in procedure design. It is possible to design procedures that are not safely flyable when the extreme values are compounded in a procedure. Therefore, to the greatest extent possible, do not apply MAXIMUM descent gradients in segments of MINIMUM length without considering appropriate speed restrictions and other mitigations. Implementation of LNAV/VNAV approach procedures has indicated some published <u>intermediate</u> segment descent gradients have not supported a seamless transition to a VNAV final segment for some aircraft. A gradient <240 ft/NM may be required to accommodate deceleration.

6. PARAGRAPH 3-3C. MINIMUM SEGMENT ALTITUDES.

Changes in RNP levels at the IAF are simplified when IAF altitudes are located at or above minimum en route altitudes. Not all FMSs have "look ahead" capability (therefore, constant RNP containments are required from the IAF to the LTP with these FMSs).

7. EXPLANATIONS AND ASSUMPTIONS CONCERNING FIGURE 3-5.

If the application of the above "OEA" geometry interferes with the development of minima associated with the VEB, consider delaying the RNP level increase to a subsequent waypoint as appropriate.

8. PARAGRAPH 3-5C. INTERMEDIATE SEGMENT – OBSTACLE CLEARANCE.

When necessary for cold temperature mitigation, and with AFS-400 approval, the vertical error budget methodology and obstacle clearance criteria for the final approach segment may be used in lieu of the intermediate segment ROC. The VEB may also be used to assess the adequacy of the ROC in the intermediate segment using the design limiting temperature of the procedure. When the VEB is used, the intermediate segment ROC will be the greater of the VEB ROC value or 500 ft. When the VEB is applied to the intermediate segment or the path at a distance greater than 7.5 miles from the LTP AFS-400 approval is required.

9. PARAGRAPH 4-2. THRESHOLD CROSSING HEIGHT (TCH).

This provision recommends publishing a note indicating the VGSI angle is not coincident with the glidepath angle when certain design parameters are exceeded. Since the Baro-VNAV glidepath angle of the procedures being designed will also vary based on temperature, anytime the temperature is not standard (i.e. ISA) the glidepath angle will not necessarily be coincident with the VGSI.

10. PARAGRAPH 5-1. GENERAL.

The missed approach obstacle clearance is based on an assumed minimum climb gradient of 3.29% with all engines and navigation systems operating. Balked landing, engine-out, and navigation loss evaluations are referenced in appendix 5,
chapter 5-2.

11. PARAGRAPH 6-1. EQUATION DEVELOPMENT.

The following is a derivation of a proposed vertical error budget for approach qualification surfaces in approach procedure design. It incorporates concepts from the Alaska Airlines special criteria, demonstrated aircraft performance, and FAA criteria for non-standard temperatures. These are combined to generate a 4sigma bound on the vertical system error.

Error components addressed:

These terms are combined to determine a bias plus 4σ vertical error budget.

$$H_{VEB} = -\Delta H_{ISAD} + Body_{WT} + 1.333*\left((3\sigma_{HC})^2 + (3\sigma_{VPA})^2 + (3\sigma_{WR})^2 + (3\sigma_{FTE})^2 + (3\sigma_{SSE})^2 + (3\sigma_{ATIS})^2\right)^{0.5}$$

Where the factor of 1.333 converts the 3σ RSS'd values to 4σ

Background and Assumptions:
The VNAV error budget contributors are combined in a combination of root sum square and bias corrections. This method is used to calculate the ROC at 250 feet above runway touchdown zone elevation and the elevation of the FAF based on the glidepath of the procedure. A line is drawn between the ROC at 250′ and the ROC at the FAF to create the OCS. The root sum square is used where the components have zero means and are not correlated. The root sum square components are combined using the same σ level. The target σ level of the root sum square contributors is 3σ. While the ANP and ASE effects are at a 3σ level, the other contributors are known to have conservative σ values at or beyond 3σ. The final root sum square value is multiplied by 1 1/3 to reach the final 4σ level.

Adjust ISA absolute for negative values by removing the absolute value sign for altitude correction sub-baro and inserting a negative sign in front of the term.

$$ROC = \left|AltCor_{baro}\right| + AltCor_{BG} + 1\frac{1}{3} * \sqrt{(AltCor_{wpres})^2 + (AltCor_{FTE})^2 + (AltCor_{ASE})^2 + (AltCor_{VAE})^2 + (AltCor_{ANP})^2 + (AltCor_{ATIS})^2}$$

12. PARAGRAPH 6-2. VNAV ERROR COMPONENTS.

The following error sources are accounted for in the calculation of the VNAV error budget:

Table 6-1 - VNAV Error Budget Summary

Contribution	Equation For Vertical Error Component
1) ANP effect (ANPE)	= 1.225 * RNP * tan (α)
2) Vertical Angle Error (VAE)	= (R + gsi)[tan (α)-tan (α-var)]
3) ISA Deviation Effect (ISAD)	= (R*tan(α)*ΔISA)/[288+ΔISA-0.5*(1.98/1000)*(elev+R*tan(α))]
4) Waypoint Resolution (WPR)	= wpt resolution * tan (α)
5) Flight Technical Error (FTE)	= constant
6) Altimetry System Error (ASE)	$=-8.8*10^{-8}(elev+Rtan(\alpha))^2+6.5*10^{-3}(elev+Rtan(\alpha))+50$
7) Body Geometry Error (BG)	= (wingspan/2)*sin(25)
8) ATIS Error (ATIS)	= constant (per FAA AC 91-54)

Where:

R = range from the landing threshold point (positive away from the runway)

α = glide slope angle

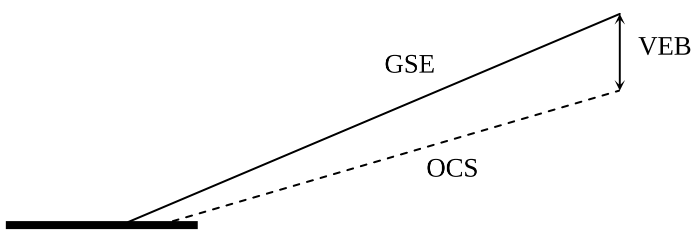
VNAV error budget = root-sum-square of 6 of the above terms. Because the ISA deviation effect and body geometry error do not have zero means, they are added outside the root-sum-square. Note that the above terms 1, 4, 5, 7 and 8 are constants for a given procedure design, terms 2, 3 and 6 are a function of range only for a given procedure design. Therefore, the VEB can be calculated as a function of range, R, only.

$$VEB = BG - ISAD + 1\frac{1}{3} * \sqrt{ANPE^2 + WPR^2 + FTE^2 + ASE^2 + VAE^2 + ATIS^2}$$

The Obstacle Clearance Surface (OCS) is defined vertically as the VNAV path glide slope elevation (GSE) minus the VNAV error budget, VEB. See figure 6-1.

$$OIS\_elevation = GSE - VEB$$

Figure 6-1. Obstacle Clearance Surface



The following pages describe this in detail, including calculation of DA (H) for an obstacle penetrating the OCS.

13. PARAGRAPH 6-2.1. EFFECT OF HORIZONTAL COUPLING.

The RNP for the approach defines the allowable along-track position uncertainty. With the vertical path angle for an approach, this uncertainty is mapped into the vertical plane via the tangent of the specified vertical angle.

$$3\sigma_{HC} = (3/2.45)*\tan(\gamma_{VP})*6076.11548*RNP$$

$3\sigma_{HC}$ = Effect of horizontal coupling (ft)

RNP = Required Navigation Performance (nm)

γ_{VP} = Vertical path angle for the approach path (deg)

Background and Assumptions:

The ANP (Actual Navigation Performance) effect is a measure based on a defined scale, which conveys the current position estimated performance under the prevailing conditions of flight. The prevailing conditions of flight include airborne equipment condition, airborne equipment in use, and external signals in use (Minimum Aviation System Performance Standards: Required Navigation Performance for Area Navigation, Document Number RTCA/DO-236, section 3.1.2).

Deviations in airplane position, conservatively taken to be solely along track deviations, translate into a vertical deviation by reflection onto the desired glidepath as shown in figure 6-2. If the FMS estimates the airplane to be closer to the runway, it could introduce a vertical displacement lower than normal, given its actual distance. The magnitude of the ANP containment is calculated at a 3σ level of safety using the following equation:

$$ANPContainment = \left(\frac{1.00}{2.45}\right) * 3 * ANP = 1.225 * ANP$$

The 1.00 value represents the conservatism in the displayed ANP. The 2.45 value is used to convert the 95 percent 2-dimensonal containment value to an along track standard deviation. The final value is multiplied by 3 to arrive at the 3σ value. Setting the RNP value equal to the ANP value, the along track deviation is 1.225 times the design RNP value.

The formula to calculate the altitude correction due to position uncertainty (ANP effect) is:

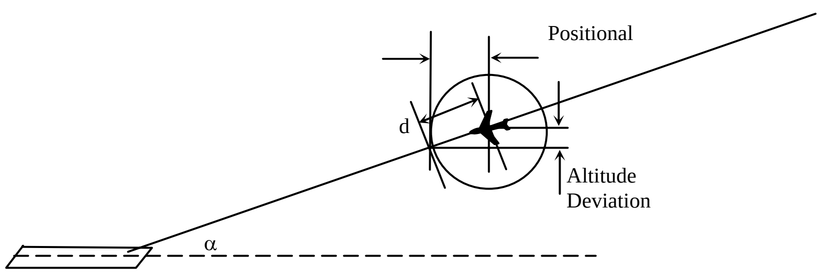
$$AltCor_{ANP} = 1.225 * (RNP)(TAN\alpha)$$

Where:

RNP = design RNP of the procedure

α = coded vertical angle

Figure 6-2



If max ANP value is equal to RNP; then max lateral error is 1.00 X RNP.

Since $d * \cos(\alpha) = 0.78 * RNP$

(1) $d = \dfrac{0.78 * RNP}{\cos(\alpha)}$

Also $d * \sin(\alpha) = vertical\_error$

(2) Substituting (1) above for d in equation (2)

$$vertical\_error = \left(\frac{0.78 * RNP}{\cos(\alpha)}\right) * \sin(\alpha)$$

vertical_error = $AltCor_{ANP} = 1.225 * (RNP)(TAN\alpha)$

14. PARAGRAPH 6-2.2. EFFECT OF VERTICAL ANGLE RESOLUTION.

The resolution of the approach vertical angle in the navigation database creates angular vertical path definition errors. The magnitude of the vertical error is a function of the along-path distance to the glidepath intercept point (location where 3-dimensional approach path intersects the runway). For mathematical simplicity this is treated as 3σ.

$3\sigma_{VPA} = D_{GPIP}*(\tan(\gamma_{VP}) - \tan(\Delta\gamma_{VP}))$

$3\sigma_{VPA}$ = Effect of Vertical angle resolution (ft)

D_{GPIP} = Distance from aircraft to GPIP along approach path (ft)

GPIP = Glidepath Intercept Point

γ_{VP} = Vertical path angle for the approach path (deg)

$\Delta\gamma_{VP}$ = Vertical path angle resolution (deg)

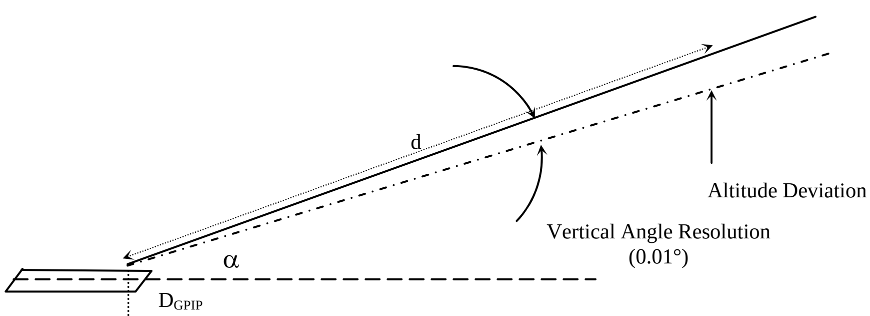
Vertical Angle Error

Vertical Angle Error (VAE) relates to the ability of the Flight Management System to precisely determine the incremental height above a reference point using the calculated distance to the reference point and the intended flight path angle. The difference between the nominal glide-path angle and the glidepath angle used by the FMS is the Vertical Angle Resolution (VAR). The specified VAR to be a fixed value of 0.01°. See figures 6-3 and 6-4.

The formula to calculate the altitude correction due to Vertical Angle Error is the following:

$$AltCor_{VAE} = D_{GPIP} * [TAN(\alpha) - TAN(\alpha - 0.01)]$$

Figure 6-3 Altitude Correction Formula



Where:

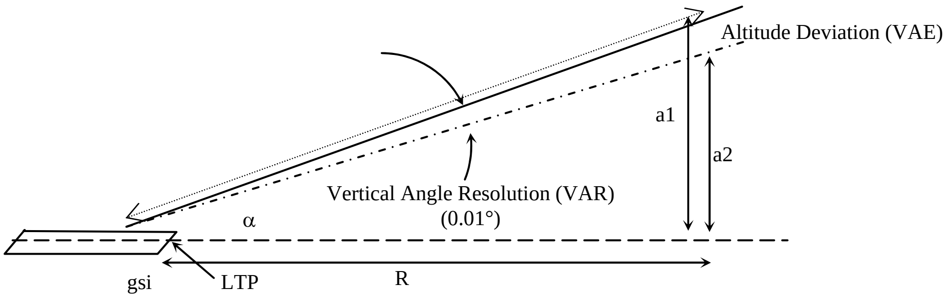
α = coded vertical angle

d = track distance from the runway threshold

D_{GPIP} = Distance to Glide Path Intercept Point

Vertical Angle Error Assumptions (see figure 6-4) :

Figure 6-4. Vertical Angle Error Assumptions



$$a1 - a2 = vertical\_angle\_error \text{ (VAE)} \qquad (1)$$

a1

$$\tan(\alpha) = R + gsi$$

$$a1 = (R + gsi) * \tan(\alpha) \qquad (2)$$

a2

$$\tan(\alpha - \text{var}) = R + gsi$$

$$a2 = (R + gsi) * \tan(\alpha - \text{var}) \qquad (3)$$

Substitute equations (1) and (2) into (3).

$$VAE = (R + gsi) * \tan(\alpha) - (R + gsi) * \tan(\alpha - \text{var})$$

$$\boxed{\therefore VAE = (R + gsi) * [\tan(\alpha) - \tan(\alpha - \text{var})]}$$

NOTE: *For any given approach, all parameters above are constant except R, the ground distance from the landing threshold point (LTP) along approach track.*

15. PARAGRAPH 6-2.3. EFFECT OF ISA TEMPERATURE DEVIATION.

Solution for ISA Deviation Error

The equation from Draft AC 91-XX, “Altimeter Errors at Cold Temperatures” defines the bias on the altimeter due to non-standard temperatures.

$\Delta H_{ISAD} = (\Delta h * \Delta ISA)/(288+\Delta ISA - 0.5*0.00198*(h)$

$\Delta h =$ Altitude above airport (ft)

$\Delta ISA =$ Temperature deviation from ISA (deg C)

$h =$ Approach path altitude (ft)

Background and Assumptions:

Non-Standard Temperature, Barometric Error

Since barometric altimeters are calibrated to the International Standard Atmosphere (ISA), actual conditions deviating from ISA conditions can lead to errors in the altimeter readings. The FAA’s white paper entitled “Instrument Procedure Cold Temperature Policy Proposal”, AFS-420, July 24, 2001(section 6) and proposed Advisory Circular “Altimeter Errors at Cold Temperatures” address this condition. The Non-Standard Temperature Error is derived by applying this Advisory Circular.

Each location is evaluated to determine, from historical records, the average monthly coldest temperature. Regional climate centers have an extensive database from which the average monthly coldest temperature can be determined. An ISA deviation value which yields a temperature below the average cold temperature is used in calculating the Non-Standard Temperature Error. This temperature is annotated on the approach chart and determines the minimum temperature at which the procedure may be flown.

Using very cold temperatures for the baro calculation can result in a higher decision altitude (DA) than is required for operation during the majority of time when the weather is warmer. In areas where the average monthly coldest temperature has a noticeably adverse effect of the DA, the procedure designer may chose to display a DA on the chart that is limited to a specific temperature and require that additional altitude be added to the DA when the temperature is lower.

The barometric error is not included in the root sum square calculation. Because the baro error does not have a zero mean, it is added to the VNAV Error Budget separately, outside the root sum square.

The formula presented in both “Instrument Procedure Cold Temperature Policy Proposal” and proposed Advisory Circular to calculate the altitude correction due to non-standard temperatures is the following:

$$AltCor_{baro} = \frac{h \times \Delta ISA}{288 + \Delta ISA - 0.5 \times \frac{1.98}{1000}(elev + h)}$$

Where:

ISA = temperature deviation from ISA

elev = elevation of the temperature source (airport)

h = measured height above the temperature source

ISA deviation error is calculated according to AC 91-XX, “Altimeter Errors at Cold Temperatures.”

$$ISAD = \frac{h * \Delta ISA}{288 + \Delta ISA - 0.5 * \frac{1.98}{1000} * (elev + h)}$$

Where:

ΔISA = temperature deviation from ISA

elev = elevation of the temperature source

h = measured height above the temperature source

To present ISAD in terms of range (R) from the LTP:

$$h = R * \tan(\alpha)$$

$$\boxed{ISAD = \frac{R * \tan(\alpha) * \Delta ISA}{288 + \Delta ISA - 0.5 * \frac{1.98}{1000} * (elev + R * \tan(\alpha))}}$$

16. PARAGRAPH 6-2.4. EFFECT OF WAYPOINT RESOLUTION.

The resolution of the waypoint position in the navigation database creates along-track path definition errors. With the vertical path angle for an approach, this uncertainty is mapped into the vertical plane via the tangent of the specified vertical angle resolution. For mathematical simplicity this is treated as 3σ.

$3\sigma_{WR} = \Delta_{VP} * \tan(\gamma_{VP})$

$3\sigma_{WR}$ = Effect of waypoint resolution (ft)

Δ_{VP} = Waypoint position resolution (ft)

γ_{VP} = Vertical path angle for the approach path (deg)

Waypoint Resolution relates to the accuracy of the FMS in calculating the location of, and therefore distance to, a waypoint. Deviations in the locations of waypoints translate into altitude deviations by reflection onto the defined glide path as shown in figures 6-5 and 6-6. This effect is primarily due to limitations to the computational accuracy attainable by the FMS when the effects of rounding and waypoint coordinate database precision are considered. This document has specified the lateral waypoint resolution for the FMS to be a fixed value of 60 feet.

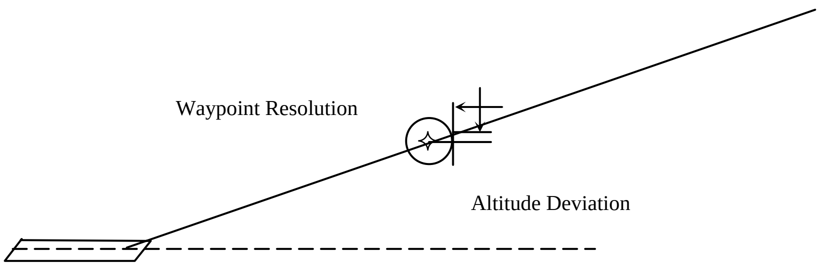
The formula to calculate the altitude deviation due to waypoint resolution is:

$$AltCor_{wpres}=60(TAN\alpha)$$

Where:

α = coded vertical angle

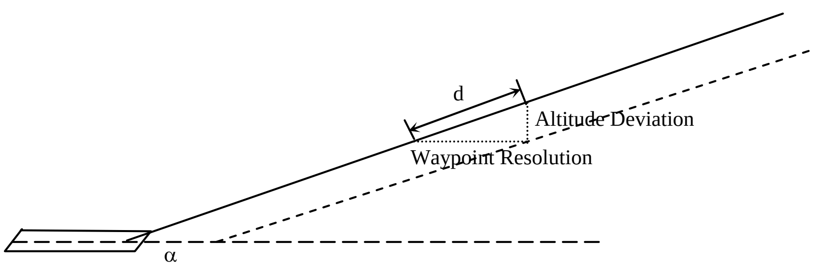
Figure 6-5. Lateral Waypoint Resolution



Background and Assumptions:

Graphically, the waypoint resolution effect is described in figure 6-6.

Figure 6-6. Altitude Deviation



$$d * \cos(\alpha) = wpt\_resolution$$

$$d = \frac{wpt\_resolution}{\cos(\alpha)} \quad (1)$$

$$d * \sin(\alpha) = vertical\_error \quad (2)$$

Substituting equation (1) into equation (2):

$$vertical\_error = \frac{wpt\_resolution}{\cos(\alpha)} * \sin(\alpha)$$

$$\boxed{\therefore vertical\_error = wpt\_resolution * \tan(\alpha)}$$

vertical_error=60*tan(α)

17. PARAGRAPH 6-2.6. EFFECT OF ALTIMETRY SYSTEM ERROR.

Altimeter Static Source Error

$3\sigma_{SSE}$ as determined from flight test (ft)

Altimetry system error (ASE) accounts for residual errors in the altitude measurement system. The ASE is dependent on the height of the aircraft and is described by the following equation:

$$AltCor_{ASE} = \left(-8.8E^{-8} * H^2\right) + \left(6.5E^{-3} * H\right) + 50$$

Where:

H = Height above sea level

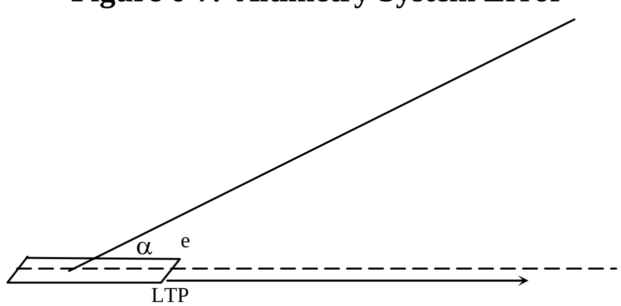
Background and Assumptions:

The Altimetry System Error (see figure 6-7) equation is provided by Boeing and based on flight test data. The normal static source error is applied by the Air Data Inertial Reference Unit (ADIRU) or Air Data Computer (ADC).

$$\boxed{ASE = \left(-8.8E^{-8} * \left(e + R\tan(\alpha)\right)^2\right) + \left(6.5E^{-3} * \left(e + R\tan(\alpha)\right)\right) + 50}$$

e = LTP elevation (MSL)

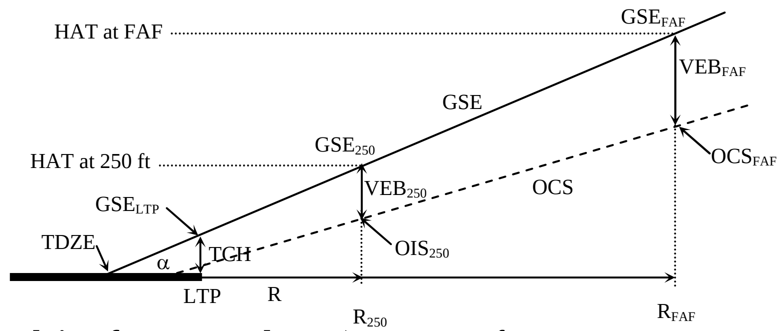
Figure 6-7. Altimetry System Error



18. PARAGRAPH 6-2.8. DEVELOPMENT OF LINEAR EQUATION FOR OCS.

Development of Linear Equation for OCS. See figure 6-8.

Figure 6-8, Obstacle Clearance Surface



a. **Lateral (Solving for R_{250} and R_{FAF}):** Distance from LTP to HAT at 250 is R_{250} and to HAT at FAF is R_{FAF}.

$$R_{250} = \frac{GSE_{250} - GSE_{LTP}}{\tan(\alpha)} \qquad R_{FAF} = \frac{GSE_{FAF} - GSE_{LTP}}{\tan(\alpha)}$$

Where:

LTP = landing threshold point

HAT = height above touchdown

GSE = glide slope elevation

b. Vertical (Solving for OCS_{250} and OCS_{FAF}): OCS elevation (OCSE) at R_{250} and R_{FAF} is now calculated:

$$OISE_{250} = GSE_{250} - VEB_{250} \qquad OISE_{FAF} = GSE_{FAF} - VEB_{FAF}$$

c. Since we now have two x, y coordinates for the OCS (R_{250}, $OCSE_{250}$ and R_{FAF}, $OCSE_{FAF}$), a linear equation for the OCS can be developed:

$$OISE = m_{OIS}R + b_{OIS} \qquad m_{OIS} = \frac{OISE_{FAF} - OISE_{250}}{R_{FAF} - R_{250}}$$

Also, at R_{250}, $OCSE_{250}$ is known, and we can solve for b_{OCS}:

$$b_{OIS} = OISE_{250} - m_{OIS} * R_{250}$$

Therefore:

$$OISE = m_{OIS} * R + b_{OIS} = m_{OIS} * R + (OISE_{250} - m_{OIS} * R_{250}) = m_{OIS}(R - R_{250}) + OISE_{250}$$

$$OISE = \left(\frac{OISE_{FAF} - OISE_{250}}{R_{FAF} - R_{250}} \right) * \left(R - R_{250} \right) + OISE_{250}$$

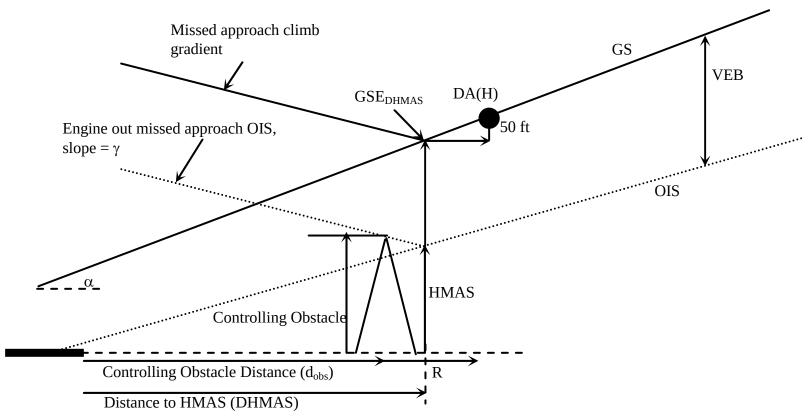
Where:

m_{OCS} = slope of the OCS

b_{OCS} = OCSE at LTP

19. PARAGRAPH 6-3. DETERMINATION OF DA FOR OBSTACLE PENETRATING OCS.

Figure 6-9. DA Adjustment



Description: DA (H) is established by starting at top of the obstacle. Go outward and down the line established by the missed approach OCS until it intersects the approach OCS. At this distance, proceed vertically to intersect the GS (see figure 6-9). The DA (H) is this elevation, plus the go-around altitude loss value of 50:

a. Equation of line representing the missed approach OCS

$$OIS = m * R + b$$

$m = -1 *$ missed approach climb gradient capability ($m = -1 * \gamma$)

To establish b:

$$b = OIS - m * R = OIS - (-\gamma) * R$$

At the top of the obstacle OCS = h_{obs}, R = d_{obs}, therefore:

$$b = h_{obs} + \gamma * d_{obs}$$

Finally, the missed approach OCS line is

$$OIS = -\gamma * R + h_{obs} + \gamma * d_{obs}$$

b. Next, solve for the range where the approach OCS intersects the missed approach OCS line, also know as the distance to the missed approach surface (DHMAS). At this point, the OCSE is equal to the approach climb OCS elevation.

Approach OCSE = Missed Approach OCSE

$$m_{OIS} * DHMAS + b_{OIS} = -\gamma * DHMAS + h_{obs} + \gamma * d_{obs}$$

$$DHMAS = \frac{h_{obs} + \gamma * d_{obs} - b_{OIS}}{m_{OIS} + \gamma}$$

c. At this DHMAS we calculate the GSE from:

$$GSE_{DHMAS} = DHMAS * \tan(\alpha) + GSE_{LTP}$$

d. Add the go around altitude loss to the GSE from step 3 above; this is the DA (H):

$$\boxed{DA(H) = DHMAS * \tan(\alpha) + GSE_{LTP} + 50\,ft}$$

e. Determine range (R) of DA (H) from runway:

$$R_{DA(H)} = DHMAS + \frac{50}{\tan(\alpha)}$$

Where:

m = slope of missed approach OCS

b = height of missed approach OCS at LTP

m_{OCS} = slope of approach OCS

b_{OCS} = height of approach OCS at LTP

γ = Engine out missed approach OCS slope

h_{obs} = controlling obstacle height

d_{obs} = controlling obstacle distance

HMAS = height of missed approach surface

DHMAS = distance to missed approach surface

APPENDIX 7

OCS SLOPE ADJUSTMENT FOR AIRCRAFT PERFORMANCE

The evaluation of the missed approach effect on DA is described in chapter 5. A performance based MAS OCS may be derived from the tables in this appendix. The method simply replaces the MAS OCS of 40:1 with the slope derived from these tables in the Chapter 5 analysis. There will be tables for low, medium and high performing aircraft provided for FAA use. The High Performance Aircraft Group table is being developed.

Match the airport elevation with the line for pressure altitude (feet). If it falls between two lines, use the higher altitude. Then:

1. Find the gradient matching the elevation in the column that represents the icing threshold temperature (9 degrees C for Medium performance aircraft or 10 degrees C for Low performance aircraft)

2. Find the gradient matching the elevation in the column that represents the hottest temperature (same as used for TAS calculations) at that airport.

3. Select the shallower of the two gradients as the slope for the MAS OCS (replacing the standard 40:1 or 2.5%) and follow the analysis detailed in chapter 5 to adjust the DA if necessary. Calculate the OCS slope from the gradient found in the table as follows: $slope = 100 / gradient : 1$

4. Please note that these are net flight path engine out gradients (compared to 2.5% gradient for 40:1).

5. Minimums can be published for each performance category of aircraft for the procedure being designed under these criteria.

Example for Medium performance aircraft (Table A7-1): If the airport is at 1,000′ and hottest temperature is 30 degrees C, then

1. From the column representing the icing threshold temperature of 9 degrees, the gradient matching the elevation is 3.55%,

2. From the column representing the hottest temperature (30 deg C) the gradient matching the elevation is 4.08%,

3. Selecting the shallower gradient results in a missed approach gradient of 3.55% (or 28.17:1) which should be used in the chapter 5 analysis.

Example for Low performance aircraft (Table A7-2): If airport is at 4,500 feet and hottest temperature is 30 degrees C, then

1. From the column representing the icing threshold temperature of 10 degrees, the gradient matching the elevation is 1.78%,

2. From the column representing the hottest temperature (35 deg C) the gradient matching the elevation is 1.6%,

3. Selecting the shallower gradient results in a missed approach gradient of 1.6% (or 62.5:1) which should be used in the chapter 5 analysis.

NOTE: These calculations and tables assume no turns in the missed approach path.

Table A7-1 - Low Performance Aircraft Group

Example: 737-400 Flaps 15 Engine-out Gross Gradient (Percent) @ 121,000 MGLW								
Pressure Altitude (Feet)	Actual Temp (Deg C)							
	10	15	20	25	30	35	40	45
0	3.13	4.3	4.25	4.25	4.15	3.65	3.15	2.65
500	2.98	4.05	4.15	4.1	3.95	3.45	2.95	2.5
1000	2.83	3.95	3.95	3.9	3.7	3.15	2.65	2.2
1500	2.68	3.85	3.8	3.75	3.45	2.95	2.45	1.95*
2000	2.48	3.65	3.6	3.6	3.15	2.75	2.25	1.75*
2500	2.33	3.55	3.45	3.4	2.95	2.45	1.95*	1.5*
3000	2.18	3.35	3.3	3.15	2.65	2.2	1.7*	1.25*
3500	2.08*	3.25	3.2	3	2.45	2.05*	1.5*	1.05*
4000	1.93*	3.1	3.05	2.85	2.3	1.85*	1.3*	0.85*
4500	1.78*	2.95	2.95	2.55	2.05*	1.6*	1.05*	0.7*
5000	1.68*	2.8	2.75	2.3	1.85*	1.4*	0.9*	0.45*
5500	1.53*	2.6	2.5	2.05*	1.6*	1.15*	0.7*	NA
6000	1.28*	2.45	2.25	1.8*	1.4*	1*	0.5*	NA

*Gross Gradient less than Regulatory Limit Gross Gradient

Table A7-2 - Medium Performance Aircraft Group

Example: 737-900 Flaps 15 Engine-out Gross Gradient (Percent) at 146,300 MGLW (7B26 Engine)										
Pressure Altitude (Feet)	Actual Temp (Deg C)									
	9	10	15	20	25	30	35	40	45	50
0	3.9	4.71	4.68	4.66	4.63	4.59	3.97	3.4	2.83	2.27
250	3.82	4.63	4.6	4.57	4.55	4.46	3.87	3.29	2.73	2.15
500	3.73	4.54	4.51	4.49	4.46	4.33	3.76	3.17	2.62	2.04*
750	3.64	4.45	4.43	4.4	4.38	4.2	3.65	3.06	2.52	1.92*
1000	3.55	4.36	4.34	4.32	4.29	4.08	3.54	2.96	2.42	1.80*
1250	3.46	4.27	4.25	4.23	4.2	3.96	3.43	2.85	2.32	1.68*
1500	3.38	4.19	4.17	4.14	4.12	3.84	3.31	2.74	2.21	1.57*
1750	3.29	4.1	4.08	4.06	4.04	3.73	3.2	2.63	2.11	1.45*
2000	3.2	4.01	3.99	3.97	3.95	3.62	3.08	2.53	2.01*	1.33*
2250	3.09	3.9	3.89	3.87	3.85	3.49	2.97	2.42	1.91*	****L
2500	2.99	3.8	3.78	3.76	3.74	3.37	2.86	2.32	1.81*	****L
2750	2.88	3.69	3.68	3.66	3.61	3.25	2.76	2.22	1.69*	****L
3000	2.78	3.59	3.58	3.56	3.48	3.13	2.65	2.11	1.58*	****L
3250	2.68	3.49	3.47	3.45	3.36	3.01	2.55	2.01*	1.46*	****L
3500	2.57	3.38	3.37	3.35	3.23	2.9	2.44	1.91*	1.35*	****L
3750	2.47	3.28	3.27	3.25	3.11	2.79	2.34	1.81*	1.23*	****L

Example: 737-900 Flaps 15 Engine-out Gross Gradient (Percent) at 146,300 MGLW (7B26 Engine) (Continued)

Pressure Altitude (Feet)	Actual Temp (Deg C)									
4000	2.37	3.18	3.16	3.15	3	2.68	2.23	1.71*	1.12*	**** L
4250	2.27	3.08	3.07	3.05	2.88	2.57	2.12	1.61*	1.01*	**** L
4500	2.17	2.98	2.97	2.95	2.76	2.46	2.02*	1.52*	.90*	**** L
4750	2.07*	2.88	2.87	2.85	2.64	2.36	1.91*	1.42*	.79*	**** L
5000	1.97*	2.78	2.77	2.76	2.52	2.26	1.81*	1.32*	**** L	**** L
5250	1.87*	2.69	2.67	2.64	2.41	2.15	1.72*	1.22*	**** L	**** L
5500	1.77*	2.59	2.58	2.53	2.3	2.03*	1.60*	1.08*	**** L	**** L
5750	1.68*	2.49	2.48	2.41	2.19	1.91*	1.47*	.95*	**** L	**** L
6000	1.58*	2.39	2.38	2.3	2.08*	1.78*	1.34*	.82*	**** L	**** L
6250	1.48*	2.3	2.28	2.18	1.97*	1.66*	1.22*	.69*	**** L	**** L
6500	1.38*	2.2	2.19	2.07*	1.86*	1.54*	1.09*	.57*	**** L	**** L
6750	1.29*	2.11	2.09*	1.96*	1.75*	1.41*	.96*	.45*	**** L	**** L
7000	1.19*	2.01*	2.00*	1.85*	1.65*	1.29*	.84*	.34*	**** L	**** L
7250	1.10*	1.92*	1.91*	1.74*	1.54*	1.17*	.71*	.23*	**** L	**** L

Example: 737-900 Flaps 15 Engine-out Gross Gradient (Percent) at 146,300 MGLW (7B26 Engine) (Continued)										
Pressure Altitude (Feet)	Actual Temp (Deg C)									
7500	1.01*	1.82*	1.81*	1.63*	1.44*	1.04*	.59*	****L	****L	****L
7750	.91*	1.73*	1.71*	1.53*	1.32*	.92*	.47*	****L	****L	****L
8000	.82*	1.64*	1.60*	1.42*	1.21*	.80*	.35*	****L	****L	****L
8250	.73*	1.55*	1.49*	1.32*	1.09*	.70*	.25*	****L	****L	****L
8500	.63*	1.45*	1.38*	1.21*	.97*	.59*	.15*	****L	****L	****L
8750	.54*	1.36*	1.28*	1.11*	.86*	.49*	.05*	****L	****L	****L
9000	.45*	1.27*	1.17*	1.01*	.76*	.39*	-.05*	****L	****L	****L

*Gross Gradient less than Regulatory Limit Gross Gradient

APPENDIX 8

REJECTED LANDING CRITERIA

1-1 REJECTED LANDING AND MISSED APPROACH CONDITION TO BE ASSESSED.

a. The rejected landing assessment protects the aircraft in the event that the aircraft arrives at the DA, continues with visual reference to the runway, initiates a rejected landing at the end of the touchdown zone, and experiences an engine failure.

b. The rejected landing has associated criteria for lateral and vertical obstacle clearance protection. Both normal, non-normal (e.g., engine failure), and rare-normal conditions must be assessed. Unless wind limitations are specified, these rare normal conditions should be considered as a wind from the most adverse direction at the certificated limit for landing.

1-2 TOUCHDOWN ZONE. A touchdown zone (TDZ) typically is considered to be the first 3,000′ of a designated landing runway. When appropriate for the purposes of this provision, Operators may propose to use a different designation for a touchdown zone. For example, alternate consideration of a (TDZ) may be appropriate for runways that:

a. **Are less than 6,000′ in length** and which do not have standard TDZ markings,

b. **Short runways requiring special aircraft** performance information or procedures for landing,

c. Runways for STOL aircraft, or

d. **Runway where markings or lighting** dictate that a different TDZ designation would be more appropriate.

1-3 OBSTACLE CRITERIA FOR REJECTED LANDING.

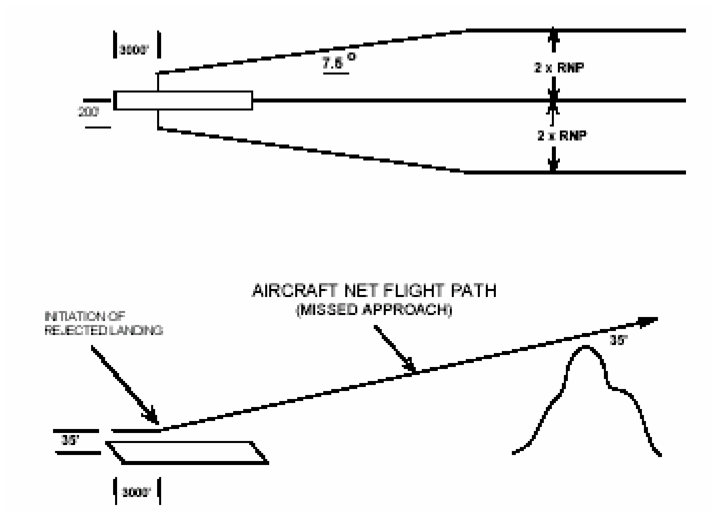
a. **The rejected landing lateral Obstacle Identification Surface** (OIS) is centered on the MAS and bounded on either side by two rays which originate from a point 200′ either side of the runway centerline at the end of the TDZ (typically 3,000 ft. from the approach end of the runway). These rays splay at an angle of 7.5 degrees out to a maximum distance from the MAS centerline of 2XRNP.

b. **Splay criteria based on ICAO PANS-Ops** may alternately be used at the discretion of the procedure designer or operator (e.g., 1:8 splay/ 7.125 degrees). For turning missed approach segments,+ an equivalent lateral splay providing equivalent lateral clearance along the path arc length may be used.

c. **The aircraft is considered** to be at an altitude of 35’ above TDZE at the end of the TDZ.

d. Within the lateral limits of this containment surface, a minimum of 35′ ROC must be provided below the one engine inoperative missed approach climb gradient (figure A8-1). Any obstacle penetrating the rejected landing OIS must be identified to the pilot (charting is acceptable). A climb gradient (all engine operating) must be computed to an altitude at which the 35′ of ROC over the obstacle is provided, and a statement must be included in the approach notes. For example, "Rejected landing requires minimum climb gradient of xxx ft/NM to yyyy" (altitude)."

Figure A8-1. RNP Lateral Area To Consider- Rejected Landing



1-4 TREATMENT OF TURNS WITHIN THE REJECTED LANDING CONTAINMENT AREA. For turns on the MAS, prior to the point at which the rejected landing containment surfaces are fully expanded to the 2XRNP value, the containment surface should be constructed in the following manner:

a. **The outside lateral containment surface** is constructed by transferring the width of the splay abeam the turn waypoint via an arc to the following segment.

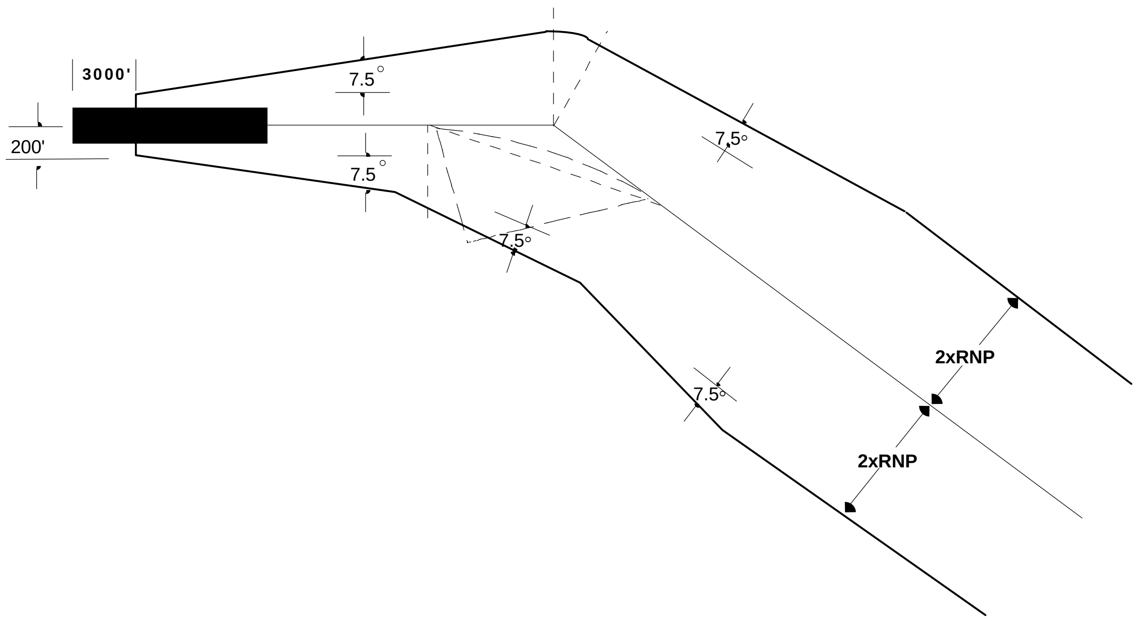
b. **The arc is of radius equal to the attained half-width** of the preceding segment and is centered at the turn waypoint.

c. **The arc is extended to a line perpendicular** to the centerline of the following segment and passes through the turn waypoint.

d. **The splay is continued** from that point by an angle of 7.5 degrees to a distance of 2XRNP from the centerline. To simplify the containment surface construction for the inside of the turn, a straight line is drawn between the earliest point of departure and the latest point of return back to the following segment for the fly-by of the turn waypoint.

e. **For other than RF legs,** the containment surface expands by a 7.5 degree splay angle using the simplified inside turn approximation as the reference centerline. This splay is continued until reaching the 2XRNP displacement from the reference centerline (figure A8-2). Splay criteria based on ICAO PANS-Ops may alternately be used at the discretion of the procedure designer or operator (for example, 1:8 splay/ 7.125 degrees).

Figure A8-2. RNP Lateral Area to Consider – Rejected Landing (with turns)



f. **For RF legs,** the RNPX2 surface is as defined by the specified RNP level.

1-5 MAS TURN CONSTRUCTION FOR FLY-OVER WAYPOINTS. Fly-Over Waypoints are not used for a MAS based on R.