Appendix B

Staying Within Protected Airspace

At higher altitudes, protected airspace helps to maintain separation between aircraft. At lower altitudes, protected airspace also provides separation from terrain or obstructions. But, what does it mean to be established on course? How wide is the protected airspace of a particular route? How can you tell from the cockpit whether your aircraft is nearing the limits of protected airspace? The intent of this appendix is to answer these questions and explain the general limits of protected airspace by means of typical instrument indications.

Some pilots assume that flying to the tolerances set out in the FAA Instrument Practical Test Standards (PTS) (http://www.faa.gov/education_research/testing/airmen/test_standards/) will keep them within protected airspace. As a result, it is important to observe the last sentence of the following note in the PTS:

“The tolerances stated in this standard are intended to be used as a measurement of the applicant's ability to operate in the instrument environment. They provide guidance for examiners to use in judging the applicant's qualifications. The regulations governing the tolerances for operation under Instrument Flight Rules (IFR) are established in 14 CFR Part 91.”

The in-flight presentation of course data can vary widely based upon the selection and distance from a Navigational Aid (NAVAID) or airfield. Consequently, you need to understand that in some cases, flying to the same standards required during your instrument rating flight test does not necessarily ensure that your aircraft will remain within protected airspace during IFR operations or that your aircraft will be in a position from which descent to a landing can be made using normal maneuvers.

For example, the PTS requires tracking a selected course, radial, or bearing within 3/4 of full-scale deflection (FSD) of the course deviation indicator (CDI). Since very high frequency omnidirectional ranges (VORs) use angular cross track deviation, the 3/4 scale deflection equates to 7.5 degrees, and means that the aircraft could be as much as 6.7 NM from the centerline when 51 NM from the VOR station. A VOR receiver is acceptable for IFR use if it indicates within four degrees of the reference when checked at a VOR test facility. If the maximum receiver tolerance is added to the allowable off-course indication, an aircraft could be 11.5 degrees from the centerline, or about 10.4 NM off the course centerline at 51 NM from the station. The primary protected airspace normally extends only 4 NM to each side of the centerline of published airways. (This example does not take into account any misalignment of the signals transmitted by the VOR.) [Figure B-1]

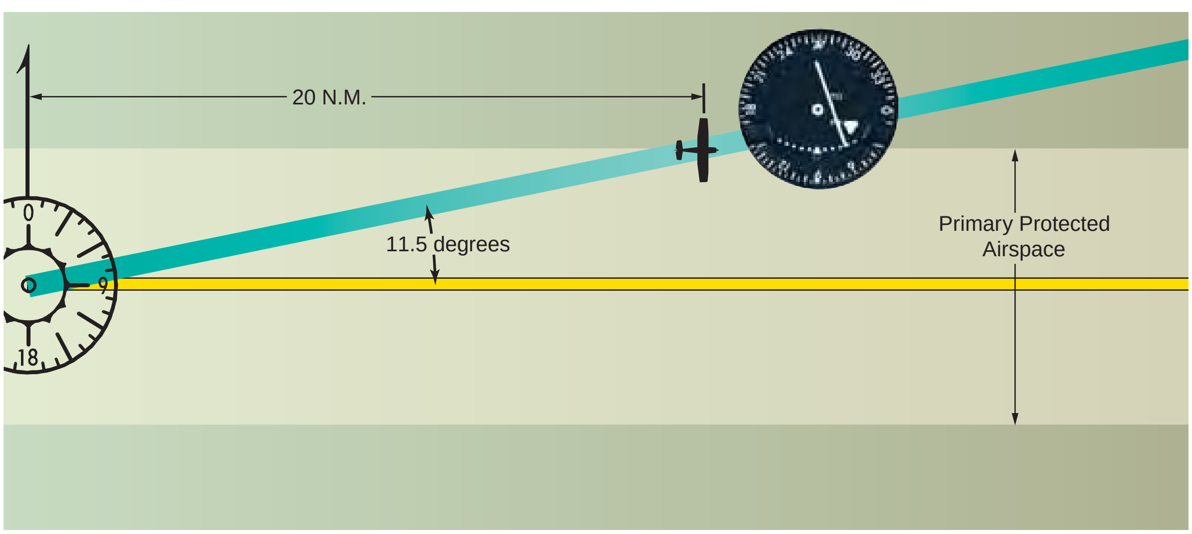

Figure B-1. With 3/4 scale CDI deflection, the aircraft could leave primary protected airspace when 20 NM from the station, assuming the transmitter is accurate and the receiver has a four degree error.

Lateral guidance is more intuitive with Area Navigation (RNAV) systems. For basic GPS, the CDI scale uses linear cross track deviation indications. During approach operations, a Wide Area Augmentation System (WAAS) navigation receiver combines the best of linear and angular deviations resulting in reduced Flight Technical Error (FTE). For departures, en route, and terminal operations, WAAS uses a linear deviation with varying scales. With linear scaling, if the CDI scaling is at 1 NM, a half scale deflection indicates that the aircraft is 1/2 NM off the course centerline, regardless of how far the aircraft is from the waypoints of the route segment. You need to be familiar with the distance and approach parameters that change the CDI scaling, and monitor the navigation unit to be sure the CDI scaling is appropriate for the route segment and phase of flight, e.g., **GPS C129 – Class C1** equipment used with a flight management system (FMS), unlike a C129A receiver, normally remains at the terminal scale of ±1 NM FSD during the approach (instead of ramping down to ±0.3 NM scaling beginning at 2 NM from the FAF). For this class of equipment, if a deviation of ±3/4 FSD is made from centerline during the approach, the aircraft will exceed the primary protected airspace width of ±0.5 NM by 1/4 NM.

Likewise, if a Category (CAT) I ILS is flown with ±3/4 FSD it can preclude an aircraft from safely transitioning to a landing on the runway. At a decision altitude (DA) point located 3,000 feet from the threshold with 3/4 FSD from centerline and above glidepath, the aircraft will be approximately 400 feet from centerline and 36 feet above the glidepath. If the aircraft were operating at 130 knots it would require two track changes within the 14-second transit time from the DA point to the threshold to align the aircraft with the runway. This may not allow landing within the touchdown zone (typically the first 3000 feet of a runway) when combined with strong crosswinds or Category C, D, or E airplane approach speeds.

Staying within protected airspace depends primarily on five factors:

- Accurate flying
- Accurate navigation equipment in the aircraft
- Accurate navigation signals from ground and space-based transmitters
- Accurate direction by air traffic control (ATC)
- Accurate (current) charts and publications

Incorporated within these factors are other related items, for example, flying accurately includes using the navigation equipment correctly, and accurate navigation equipment includes the altimeter.

- It is important for pilots to understand that the altimeter is a barometric device that measures pressure, not altitude. Some pilots may think of the altimeter as a true "altitude indicator," without error. In fact, the pressure altimeter is a barometer that measures changes in atmospheric pressure, and through a series of mechanisms and/or computer algorithms, converts these changes, and displays an altitude. This conversion process assumes standard atmospheric conditions, but since we fly in weather conditions other than standard, errors will result. Also, certain procedures may be annotated "NA" below a given temperature.
- The Instrument Flying Handbook (FAA-H-8083-15), Chapter 3, and the Aeronautical Information Manual (AIM), Chapter 7, include detailed discussions about altimeters and associated errors. Each includes the International Civil Aviation Organization (ICAO) Cold Temperature Error Table for altitude corrections when operating with an outside air temperature (OAT) below +10 degrees C.

The design of protected airspace is a very detailed and complex process, combining the professional skills of many different experts. Terrain elevations and contours, runway configurations, traffic considerations, prevailing winds and weather patterns, and the performance capabilities of the aircraft that will use the procedures must be balanced to create airspace that combines functionality with safety. Although it is not necessary for pilots to have an in-depth knowledge of how airspace is protected, it is useful to understand some of the terms used.

Required Obstacle Clearance (ROC) is the minimum vertical clearance required between the aircraft and ground obstructions over a specific point in an instrument procedure. Procedure designers apply the ROC when designing instrument approach procedures. On the initial segment, the ROC is approximately 1,000 feet, and it is at least 500 feet on the intermediate segment. Obviously, an imaginary surface 1,000 feet above the actual terrain and obstacles would be as rough and irregular as the surface below, so for practical reasons, airspace planners create smooth planes above the highest ground features and obstructions. These are called obstacle clearance surfaces (OCSs). Procedure designers use both level and sloping obstacle clearance surfaces when designing approaches.

Fix Displacement Area (FDA) is an area created by combining the permissible angular errors from the two VOR or nondirectional beacon (NDB) NAVAIDs that define the fix. When the NAVAIDs are close together and the angle that defines the fix is near 90 degrees, the

FDA is relatively small. At greater distances or less favorable angles, the FDA is larger. Airspace planners use the FDA to define the limits of protected airspace. [Figure B-2]

Fix Displacement Tolerance (FDT) is an area that applies to area navigation (RNAV) and equates to a FDA for VOR or NDB NAVAIDs. The FDT has an Along Track (ATRK) tolerance and a Cross Track (XTRK) tolerance.

Flight Technical Error (FTE) is the measure of the pilot or autopilot's ability to control the aircraft so that its indicated position matches the desired position. For example, FTE increases as the CDI swings further from center. If the cockpit instruments show the airplane to be exactly where you want it, the FTE is essentially zero.

Navigation System Error (NSE) is the error attributable to the navigation system in use. It includes the navigation sensor error, receiver error, and path definition error. NSE combines with FTE to produce the Total System Error (TSE). TSE is the difference between true position of the aircraft and the desired position. It combines the flight technical errors and the navigation system tracking errors.

Actual navigation performance (ANP) is an estimate of confidence in the current navigation system's performance. ANP computations consider accuracy, availability, continuity, and integrity of navigation performance at a given moment in time. Required Navigation Performance (RNP) necessitates the aircraft navigation system monitor the ANP and ensures the ANP does not exceed the RNP value required for the operation. The navigation system must also provide the pilot an alert in the primary field of view when ANP exceeds RNP. [Figure B-3 on page B-4]

While you may have thought of protected airspace as static and existing at all times whether aircraft are present or not, protection from conflicts with other aircraft is dynamic and constantly changing as aircraft move through the airspace. With continuous increases in air traffic, some routes have become extremely congested. Fortunately, the accuracy and integrity of aircraft navigation systems has also increased, making it possible to reduce the separation between aircraft routes without compromising safety. RNP is a standard for the navigation performance necessary to accurately keep an aircraft within a specific block of airspace.

Containment is a term central to the basic concept of RNP. This is the idea that the aircraft will remain within a certain distance of its intended position (the stated RNP value) at least 95 percent of the time on any flight.

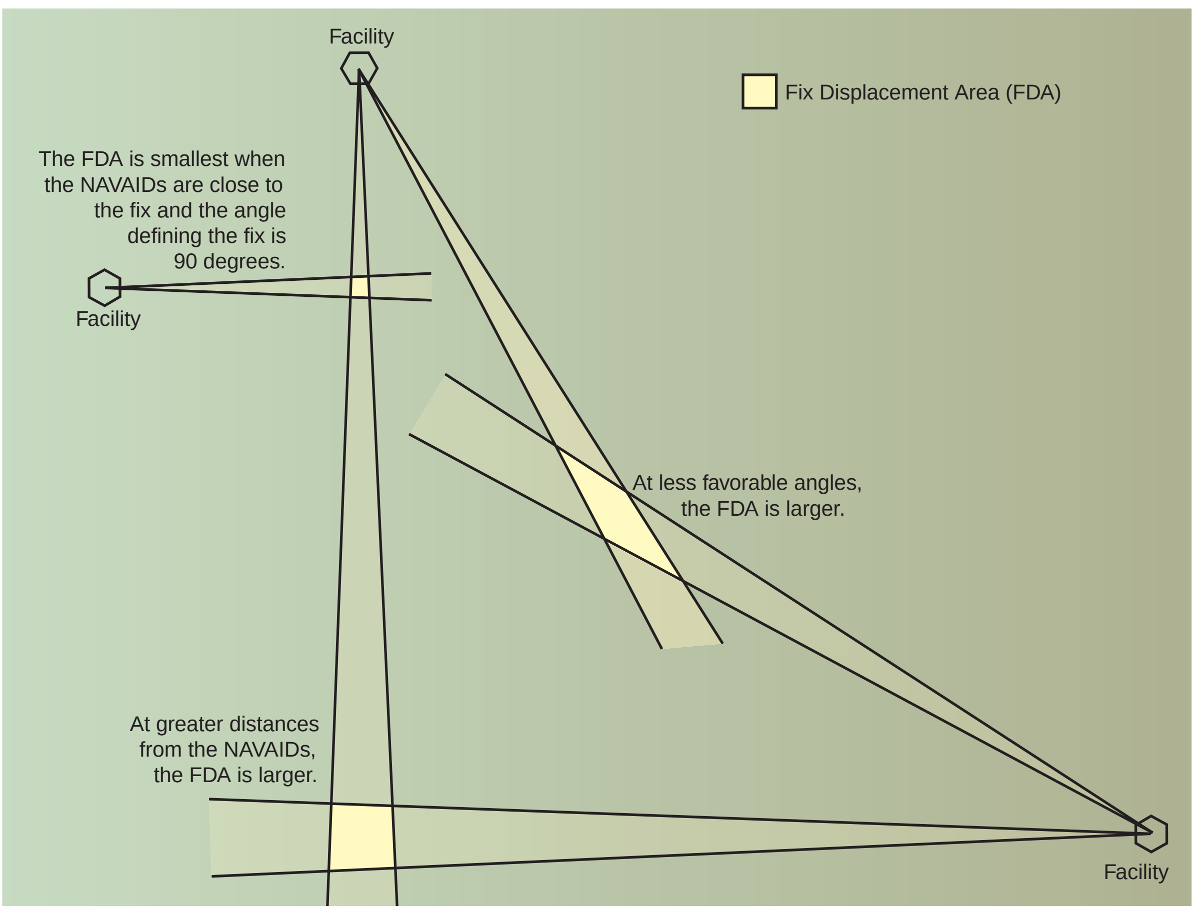

Figure B-2. **The size of the protected airspace depends on where the terrestrial NAVAIDs that define it are located.**

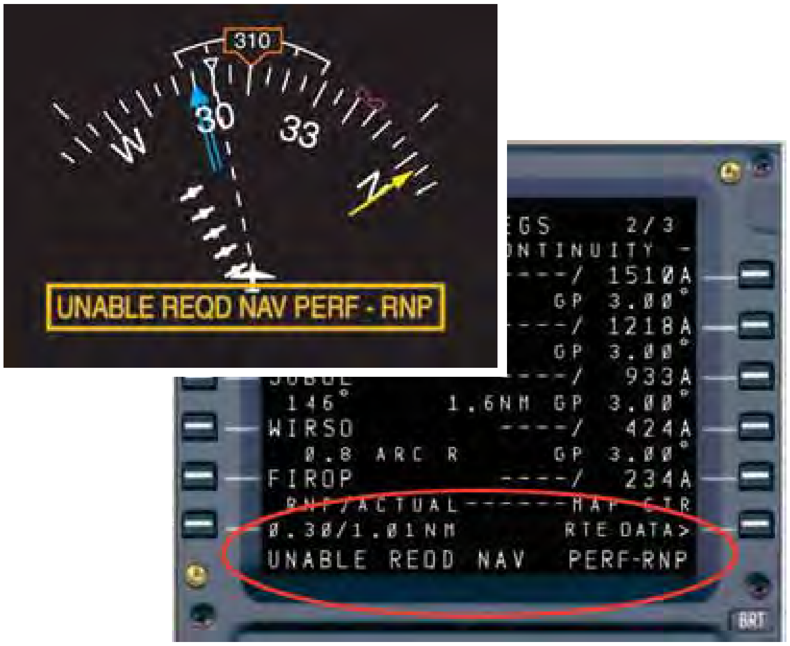

Figure B-3. An alerting system in the pilot's primary view must warn if ANP exceeds RNP. This alerting system is comparable to an "OFF" flag for a VOR or ILS.

This is a very high percentage, but it would not be enough to ensure the required level of safety without another layer of protection outside the basic containment area. This larger area has dimensions that are twice the RNP value, giving the aircraft two times the lateral area of the primary RNP area. Aircraft are expected to be contained within this larger boundary 99.999 percent of the time, which achieves the required level of confidence for safety. [Figure B-4]

Figure B-5 on pages B-6 through B-9 helps explain the cockpit indications and tolerances that will comply with criteria to keep you within protected airspace. The tolerances are predicated on zero instrument error unless noted otherwise. Special Aircraft and

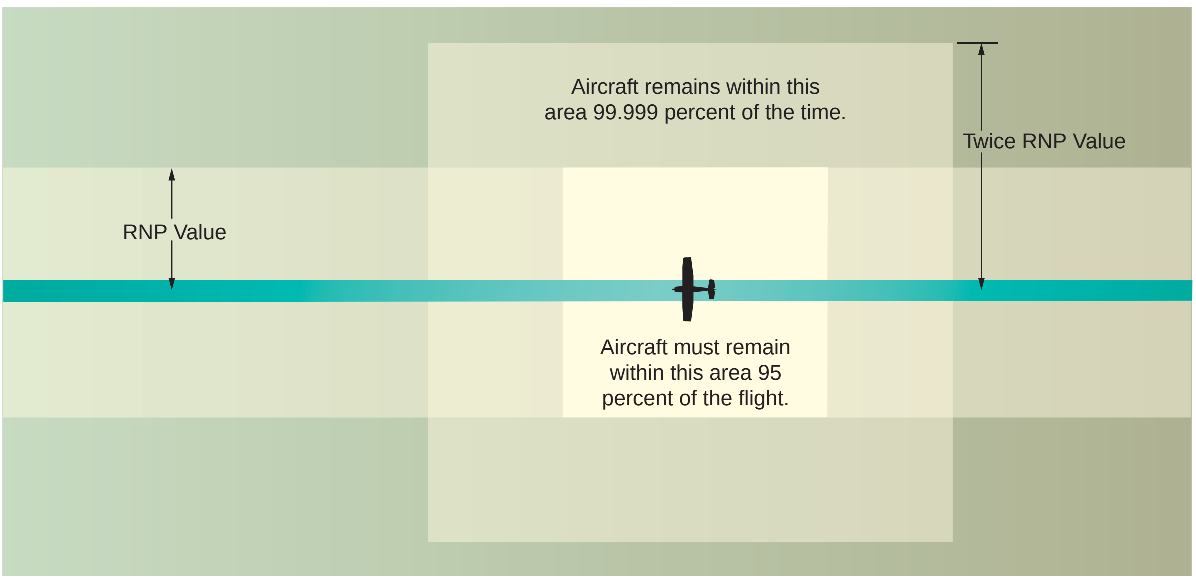

Figure B-4. RNP Containment.

Aircrew Authorization Required (SAAAR) routes are not covered in this table.

For approaches, it is not enough to just stay within protected airspace. For nonprecision approaches, you must also establish a rate of descent and a track that will ensure arrival at the MDA prior to reaching the MAP with the aircraft continuously in a position from which a descent to a landing on the intended runway can be made at a normal rate using normal maneuvers. For precision approaches or approaches with vertical guidance, a transition to a normal landing is made only when the aircraft is in a position from which a descent to a landing on the runway can be made at a normal rate of descent using normal maneuvering.

For a pilot, remaining within protected airspace is largely a matter of staying as close as possible to the centerline of the intended course. There are formal definitions of what it means to be established on course, and these are important in practice as well as theory, since controllers often issue clearances contingent on your being established on a course.

You must be established on course before a descent is started on any route or approach segment. The ICAO Procedures for Air Navigation Services – Aircraft Operations (PANS-OPS) Volume I Flight Procedures, specifies, "Descent shall not be started until the aircraft is established on the inbound track," and that an aircraft is considered established when it is "within half full scale deflection for the ILS and VOR; or within ±5 degrees of the required bearing for the NDB."

In the AIM "established" is defined as "to be stable or fixed on a route, route segment, altitude, heading, etc." The "on course" concept for IFR is spelled out in Part 91.181, which states that the course to be flown on an airway is the centerline of the airway, and on any other route, along the direct course between the NAVAIDS or fixes defining that route.

As new navigational systems are developed with the capability of flying routes and approaches with increased resolution, increased navigation precision and pilot situational awareness is required. For safety, deviations from altitudes or course centerline should be communicated to ATC promptly. This is increasingly important when flights are in close proximity to restricted airspace. Whether you are a high time corporate pilot flying an aircraft that is equipped with state of the art avionics or a relatively new general aviation pilot that ventures into the NAS with only a VOR for navigation, adhering to the tolerances in Figure B-5 will help facilitate your remaining within protected airspace when conducting flights under IFR.

	Phase of Flight		
NAVAID	**DEPARTURE**	**EN ROUTE**	**TERMINAL**
NDB	RMI ±5 degrees. For departures, the climb area protected airspace initially splays at 15 degees from the ±500-foot width at the departure end of runway (DER) to 2 NM from the DER. The initial climb area width at 2 NM is ±3,756 feet from centerline. After the initial splay, the splay is 4.76 degrees until reaching an en route fix.	RMI ± 5 degrees. Because of angular cross track deviation, the NDB needle becomes less sensitive as you fly away from the NDB and more sensitive as you approach the station. The airway primary width is 4.34 NM either side of centerline to 49.6 NM. From 49.6 NM to the maximum standard service volume of 75 NM, the primary protected airspace splays at 5 degrees.	RMI ± 5 degrees. The maximum standard service volume for a compass locator is 15 NM. The feeder route width is ±4.34 NM.
VOR	CDI ±3/10 FSD (scale ±10 degrees). Same as NDB except after the initial splay, the splay is 2.86 degrees until reaching an en route fix.	CDI ±1/2 FSD up to 51 NM and beyond 51 NM CDI ±2/5 FSD (scale ±10 degrees). Like the NDB, the farther you are from the VOR, the more the signal diverges. The airway primary width is 4 NM either side of centerline to 51 NM. From 51 NM to the maximum standard service volume of 130 NM, the primary protected airspace splays at 4.5 degrees.	CDI ±1/2 FSD (scale ±10 degrees). The maximum standard service volume for a T VOR is 25 NM. The feeder route width is ±4 NM.
ILS	N/A	N/A	CDI ± 3/4 FSD for both lateral and vertical. The standard service volume for a localizer is 18 NM. The localizer total width at 18 NM is ±2.78 NM from centerline and tapers to approximately ±5,000 feet from centerline at the FAF. The standard service volume for the glide slope is 10 NM.

Figure B-5. Cockpit Indications and Tolerances to Keep You Within Protected Airspace. **(Continued on Pages B-8 and B-9)**

Phase of Flight		
FINAL APPROACH	**MISSED APPROACH**	**HOLDING**
RMI ±10 degrees. If flown “FROM” the NDB, RMI ±5 degrees at the visual descent point (VDP) or equivalent for a normal landing. The course width for an approach with a FAF may be as small as 2.5 NM at the NDB and as wide as 5 NM at 15 NM from the NDB. For an on-airport facility, no FAF approach, the course width tapers from 6 NM (10 NM from the NDB) to 2.5 NM at the MAP/NDB.	RMI ±10 degrees. The course width widens to ±4 NM at 15 NM from the MAP.	RMI ±5 degrees. Intersections – the size of protected airspace varies with the distance from the NAVAID. See Figure 3-27 on page 3-23.
CDI ±3/4 FSD. If flown “FROM” the VOR, CDI ±1/2 FSD at the VDP or equivalent for a normal landing (scale ±10 degrees). The course width for an approach with a FAF may be as small as 2.0 NM at the VOR and as wide as 5 NM at 30 NM from the VOR. For an on airport facility no FAF approach, the course width tapers from 6 NM (10 NM from the VOR) to 2.0 NM at the MAP/VOR.	CDI ±3/4 FSD (scale ±10 degrees). For both FAF and no FAF approaches, the course width widens to 4 NM at 15 NM from the MAP.	CDI ±1/2 FSD (scale ±10 degrees). Intersections – the size of protected airspace varies with the distance from the NAVAIDs that form the holding fix. See Figure 3-27 on page 3-23.
CAT I CDI ±3/4 FSD for localizer and glidepath at the glide slope intercept. CDI ±1/2 FSD at the DA point for a normal landing. (scale total width may vary from 3 to 6 degrees). The normal length of final is 5 NM from the threshold. The final approach obstacle clearance area width at the FAF is approximately ±5,000 feet from centerline and tapers to as small as ±500 feet from centerline at 200 feet from the runway threshold. The CAT I final approach OCS can be as small as 500 feet below glidepath at the FAF. At a DA point located 3,000 feet from the threshold, the OCS may be as close as 114 feet below the glidepath. Decision range for airplane CAT II CDI ±1/6 FSD for localizer and ±1/4 FSD for glidepath and for helicopter ±1/4 FSD for localizer and glidepath. The tracking performance parameters within the decision range (that portion of the approach between 300 feet AGL and DH) are maximums, with no sustained oscillations about the localizer or glidepath. If the tracking performance is outside of these parameters while within the decision region, execute a go-around since the overall tracking performance is not sufficient to ensure that the aircraft will arrive at the DH on a flight path that permits the landing to be safely completed.	N/A	N/A

	Phase of Flight		
NAVAID	**DEPARTURE**	**EN ROUTE**	**TERMINAL**
GPS (C-129A)	CDI centered when departing the runway with a maximum of ±3/4 FSD upon reaching the terminal route (scale ± 1NM). For departures, the climb area protected airspace initially splays at 15 degrees from the ±500-foot width either side of centerline at the DER to a nominal distance of 2 NM from the DER. The initial climb area width at 2 NM is ± 3,756 feet from centerline. After the initial splay to the Initial Departure Fix (IDF) a smaller splay continues until reaching a terminal width as small as 2 NM at 10.89 NM from the DER. The horizontal alarm limit (HAL) is ±1 NM within 30 NM of the airport reference point (ARP).	CDI ±1/2 FSD (scale ±5 NM). The airway primary width is ±4 NM from centerline at 30 NM from the airport reference point (ARP). The HAL is ±2 NM for distances greater than 30 NM from the ARP.	CDI ±3/4 FSD (scale ±1 NM within 30 NM of the ARP). For arrivals, the terminal primary width is ±2 NM from centerline at approximately 30 NM from the ARP. The HAL is ±1 NM within 30 NM of the ARP.
WAAS LPV	CDI centered when departing the runway to the IDF with a maximum of ±3/4 FSD upon reaching the terminal route (CDI scale ±1NM). The HAL in the terminal mode is 1 NM.	CDI ±3/4 FSD (scale ±2 NM). The airway primary width is ±4 NM from centerline (equivalent to 2 RNP) at approximately 30 NM from the ARP. The HAL in the en route mode is 2 NM.	CDI ±3/4 FSD (scale ±1 NM within 30 NM of the ARP). For arrivals the terminal primary width is ±2 NM from centerline at approximately 30 NM from the ARP. The HAL in the terminal mode is 1 NM. The terminal mode begins at 30 NM from the ARP or at the initial approach fix (IAF) when more than 30 NM from the ARP.

Figure B-5. Continued

Phase of Flight		
FINAL APPROACH	**MISSED APPROACH**	**HOLDING**
CDI ±2/3 FSD (scale ±0.3 NM). For conventional GPS approaches the primary width is ±1.0 NM from centerline at the FAF and tapers to ±0.5 NM at the MAP. CDI ±1/3 FSD for “Copter” approaches (scale ±0.3 NM). For “Copter” approaches the primary width is ± 0.55 NM from centerline at the FAF and tapers to ±0.4 NM at the MAP. The HAL is ±0.3 NM on the final approach segment (FAS). NOTE: GPS C129 – Class C1 (FMS equipped) Flight Director/Autopilot required since 1.0 NM scaling on the CDI is used. For Airplane approaches CDI ±1/5 FSD and for Copter approaches CDI ± 1/10 FSD (scale ±1.0 NM).	CDI ±3/4 FSD (scale ±1.0 NM). For missed approaches the primary width at the MAP is 0.5 NM and splays to ±4.0 NM from centerline at 15 NM from the MAP. For Copter approaches CDI ±1/2 FSD (scale ±1.0 NM). For missed approaches the primary width at the MAP is ±0.4 NM and splays to ±1.5 NM from centerline at 7.5 NM from the MAP. The HAL is ±1.0 NM within 30 NM of the ARP.	Terminal (within 30 NM of the ARP). CDI ±3/4 FSD (scale ±1.0 NM). En route (more than 30 NM from the ARP) CDI ±1/2 FSD (scale ±5.0 NM). The HAL for terminal holding is ±1.0 NM within 30 NM of the ARP and ±2 NM when more than 30 NM from the ARP.
CDI ±3/4 FSD lateral and vertical (LPV scale is ±2 degrees or ±0.3 NM FSD at the FAF whichever is less. Nonprecision scale is ±0.3 NM). LPV/LNAV approaches are similar to ILS/LOC approaches. LNAV (nonprecision): The CDI scaling for not vectored to final (VTF) approaches starts out with a linear width of ±1 NM FSD on the intermediate segment. At 2 NM prior to the FAF the scaling begins a change to either an angular ±2 degrees taper or ±0.3 NM FSD whichever is smaller. This change must be completed at the FAF. At the landing threshold point (LTP) the angular scale then becomes linear again with a width of approximately ±350 feet from centerline. For VTF approaches the CDI scaling starts out linear at ±1 NM FSD and changes to a ±2 degrees taper FSD and then becomes linear again with a width of approximately 350 feet from centerline at the LTP. Approaching the runway, a LPV nominal 3 degrees glidepath starts out linear (±150 M FSD) and then approximately 6 NM from the landing threshold becomes angular at a width of ±0.75 degrees and then becomes linear again as early as approximately 1.9 NM from the GPI for a ±45 M FSD or as small as a ±15 M FSD at a distance of approximately 0.6 NM from the landing threshold (depending on the manufacturer). The normal length of final is 5.0 NM from the threshold. The final approach obstacle clearance area width at the FAF is approximately ±4,000 feet from centerline and tapers to ±700 feet from centerline 200 feet from the runway threshold. The final approach OCS can be as small as 500 feet below glidepath at the FAF. At a DA point located 3,000 feet from the threshold, the OCS may be as small as 118 feet below the glidepath. The HAL for LNAV is 0.3 NM. The HAL for LPV is 40 M and the vertical alarm limit (VAL) starts out at 150 M and may be as large as 45 M near the LTP.	CDI ±1/2 FSD (From the LTP to the DER the scale is approximately ±350 feet wide and then changes ±0.3 NM at the DER) The primary width at the DA point for missed approaches (aligned within 3 degrees of the final approach course) is approximately ±1,000 feet from centerline and splays outward for 8,341 feet until reaching a width of ±3,038 feet from centerline. The HAL for missed approaches aligned within 3 degrees of the final approach course is ±0.3 NM at the DER and then changes to a HAL of ±1 NM at the turn initiation point for the first waypoint in the missed approach.	CDI ±3/4 FSD for terminal or en route holding (scale ±1.0 NM terminal and ±2.0 NM en route). The HAL is 1.0 NM when within 30 NM of the ARP and 2.0 NM beyond 30 NM of the ARP.