

# GPS Approach Minima — “How Low Can YOU Go?”

by Martin Heller

**T**he Global Positioning System (GPS) has revolutionized the manner in which we fly. Additional GPS improvements have lowered instrument approach minima. These improvements increased the types of GPS and Area Navigation (RNAV) instrument procedures and associated minima, which now include: conventional overlays, Lateral Navigation (LNAV), LNAV/Vertical Navigation (VNAV), Localizer Performance with Vertical Guidance (LPV), and circling. Do you know which minima line you can fly? This article clar-

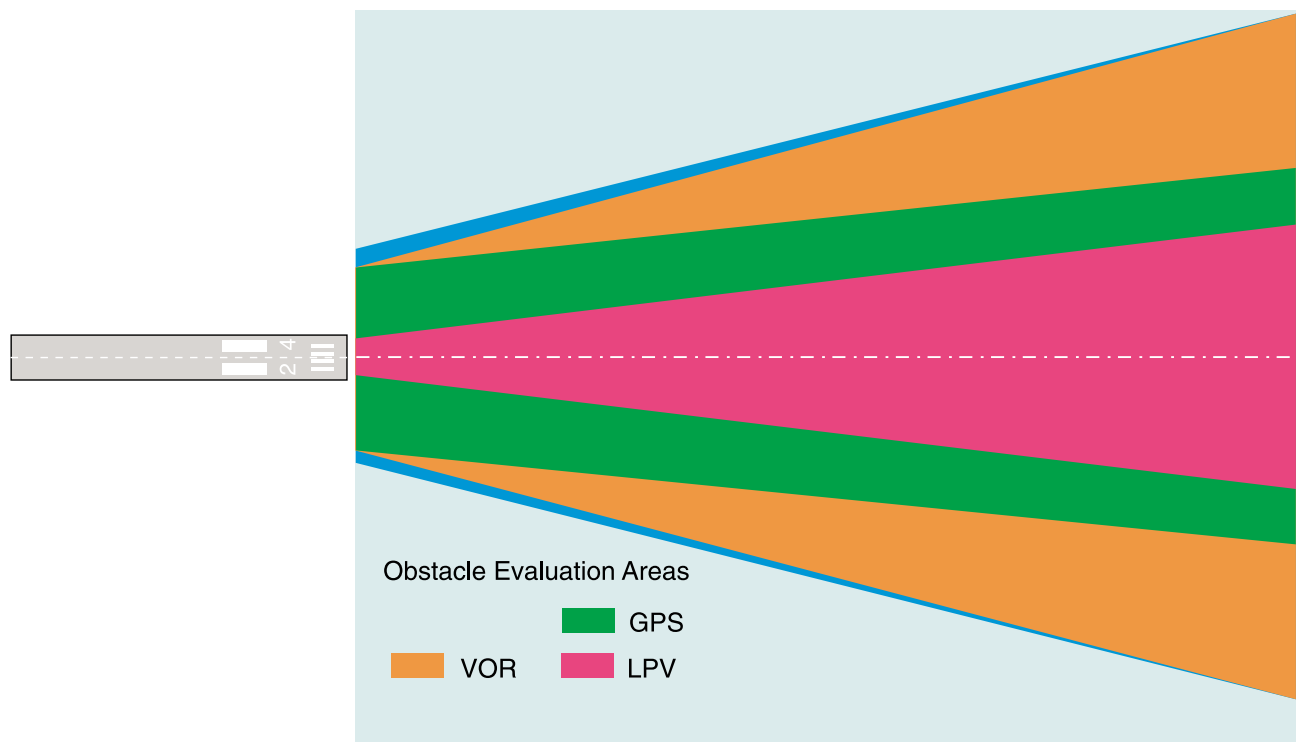
ifies the nomenclature and requirements to fly each of these different instrument approach procedures.

## Background

GPS vastly improves situational awareness for both visual and instrument flight rule (VFR and IFR) flying, reducing circuitous travel and airspace incursions. As importantly, GPS provides an instrument approach capability for airports that in the past have not had either the ground-based navigational aids (NAVAIDs), and/or terrain

that supported an instrument procedure. Evolutions in avionics and satellite navigation systems have improved accuracy and alerting capabilities, which result in smaller integrity limits. Smaller integrity limits allow smaller obstacle evaluation areas (OEAs). Smaller OEAs reduce the potential for obstacles. Since obstacles raise approach minima, the smaller the chance of obstacles, the greater the opportunity for lower minima. (See Figure 1) If you have the proper equipment, you can take advantage of these new procedures. A circling ap-

*(Figure 1. Obstacle Evaluation Areas Differences Based on Navigational Aid)*



proach is actually a procedure based on the aircraft's approach category, not the source of the navigational aid signal. Therefore, circling minima do not change between different types of approaches to the same airport.

## Overlays – 1994

The first authorization for using GPS to fly approach procedures was known as GPS overlays. These procedures authorized use of approved GPS receivers to fly existing non-precision instrument approaches. The only difference was that course guidance could come from the GPS system. These procedures are identified with "or GPS" in the title. (See Figure 2, Moncks Corner/Berkeley NDB or GPS rwy 5). The advantage for these procedures was twofold. First, overlay approaches provide the aviator greater position awareness than that derived from using the ground NAVAID.

Second, although they didn't provide lower minima, GPS overlays also introduced and validated GPS approaches to aviation. This initial validation was critical for future GPS improvements.

**Containment:** Since overlays were GPS approaches designed to overlay the ground-based NAVAID approach, the minimum Required Obstruction Clearance (ROC) and OEA was the same as for the underlying ground-based NAVAID. VOR (Very High Frequency Omni-directional Range) and VOR/DME (Distance Measuring Equipment) approaches have a ROC of 250 feet, while Non-directional Beacons (NDB) have a ROC of 300 feet. The approach chart minima line did not change; "S - (runway number)" identified straight-in approach minima.

**Alerting:** Alerting for GPS approaches became more involved than the ground-based

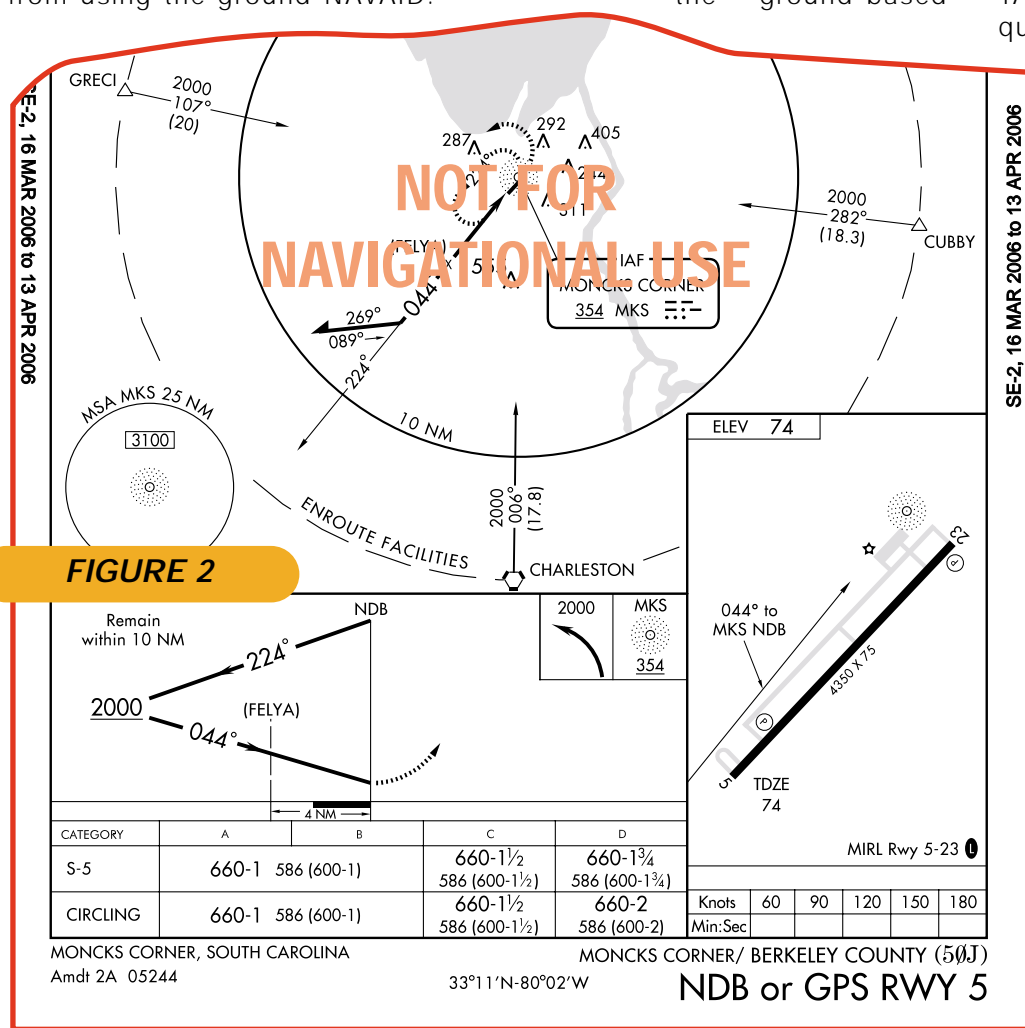
NAVAID system. Ground NAVAID failure results in cockpit warning flags for VORs and Instrument Landing Systems (ILS), Morse code identification removal, and triggering the remote status indicators in the air traffic control facility. GPS avionics alert via an internally calculated integrity alarm. One of the major differences between IFR-certified GPS avionics and other GPS systems is that IFR GPS avionics provide alerting by using Receiver Autonomous Integrity Monitoring (RAIM) algorithms to detect any system faults. Non-IFR certified GPS units do not have this alerting capability.

In order to fly an overlay GPS approach, neither the underlying conventional instrument procedure NAVAID(s) nor the associated aircraft avionics need be installed, operational, or monitored. However, flight planning is slightly different. In addition to checking RAIM availability and GPS NOTAMs, if an alternate airport is required, this airfield must have a non-GPS approach and the ground-based and associated aircraft navigation equipment installed and operational.

**Equipment availability:** Several IFR GPS units are certified according to Technical Standard Order (TSO)-C129, *Airborne Supplemental Navigation Equipment Using the GPS*. IFR GPS units must be either panel mounted or a sensor which provides data to an integrated navigation system, and must be installed in accordance with Advisory Circular (AC) 20-138A, *Airworthiness Approval of Global Positioning System (GPS) Navigation Equipment for Use as a VFR and IFR Supplement Navigation System*, or AC 20-130A, *Airworthiness Approval of Navigation or Flight Management Systems Integrating Multiple Navigation Sensors*, as applicable.

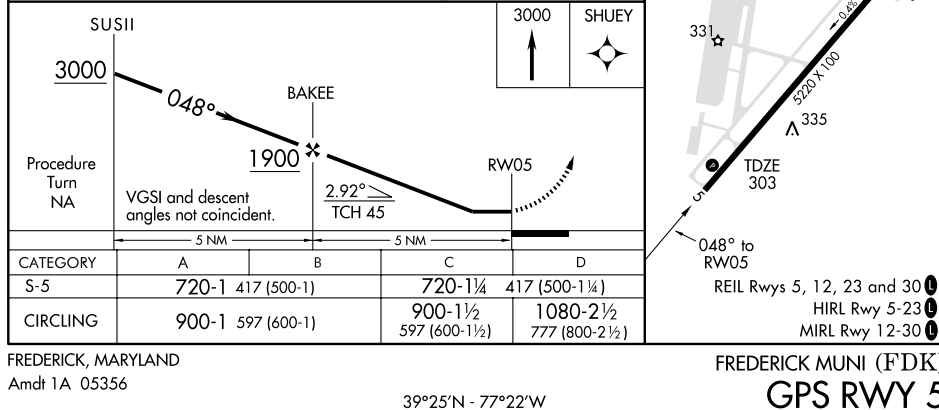
## GPS Approaches – 1994

The next implementation of GPS procedures were no longer dependant on the NAVAID posi-



**FIGURE 3**

**NOT FOR NAVIGATIONAL USE**



locations which could have instrument approaches. As with the overlay approaches, if the IFR flight plan requires an alternate, the pilot must flight plan to use an approved operational instrument approach procedure (other than GPS) that the aircraft is equipped to fly.

Pilots flying GPS approaches can descend to the straight-in (S-runway number) Minimum Descent Altitude (MDA) for their approach category on GPS RWY XX approaches or the LNAV MDA on RNAV (GPS) RWY XX approaches. There are approximately 4,000 GPS (LNAV) approach procedures as of May 2006.

**GPS - Vertical Guidance**

The next system improvement added a calculation derived glide path. While not an electronic glideslope, vertical navigation (VNAV) guidance is displayed as a glideslope on the pilot's vertical deviation indicator. This capability came from a combination of Barometric

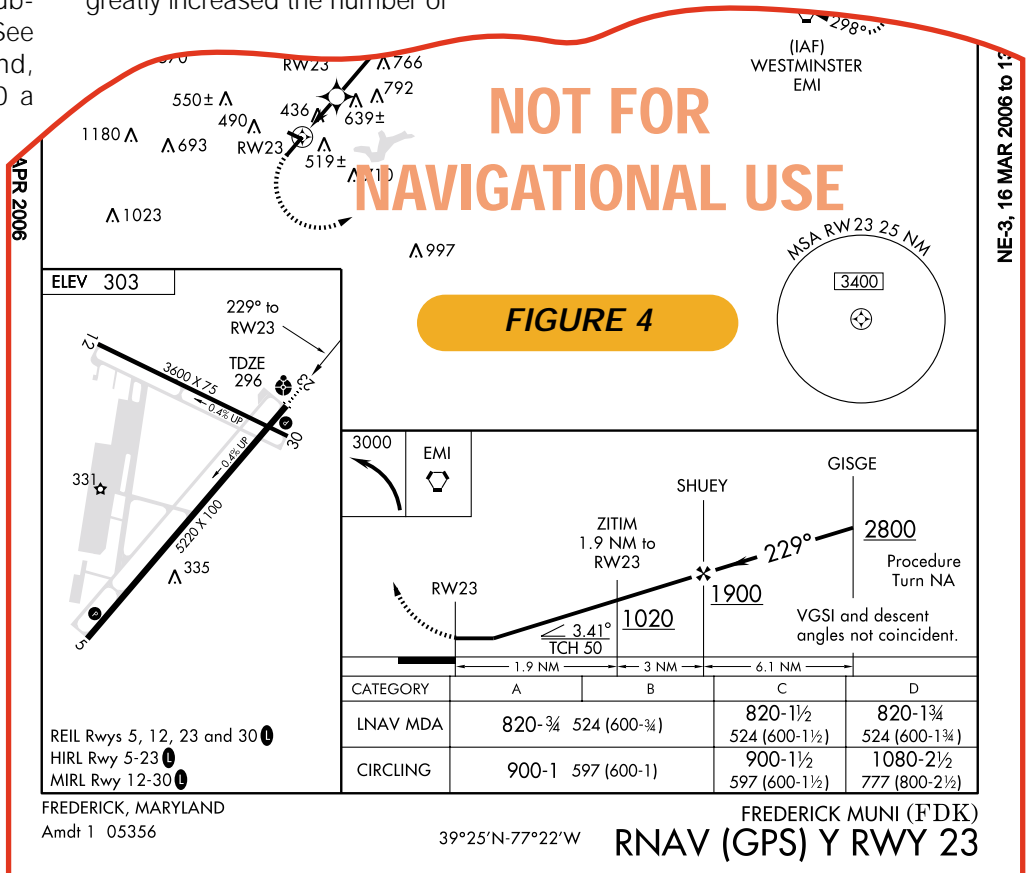
tion and coverage. This major improvement provides instrument approaches to airports that didn't have ground-based NAVAID coverage. These approaches were initially published in the GPS RWY XX format (See Figure 3, Frederick Muni, Maryland, GPS RWY 5). However, in 2000 a new approach chart format was adopted by the FAA and GPS approaches began to be published in the RNAV (GPS) RWY XX format (See Figure 4, Frederick Muni, Maryland, RNAV (GPS) Y RWY 23) using the lateral navigation (LNAV) minima line. (Note: All GPS non-precision approaches are considered to be LNAVs, regardless of the publication format.)

**Containment:** Increased precision in position determination and course guidance resulted in a smaller OEA. Additionally, the plan view of the stand-alone GPS procedures uses a "T" design to develop more standardized final and missed approach fix location based on RNAV criteria.

**Alerting:** GPS stand-alone

approach availability and signal outages are determined by RAIM.

GPS stand-alone approaches greatly increased the number of

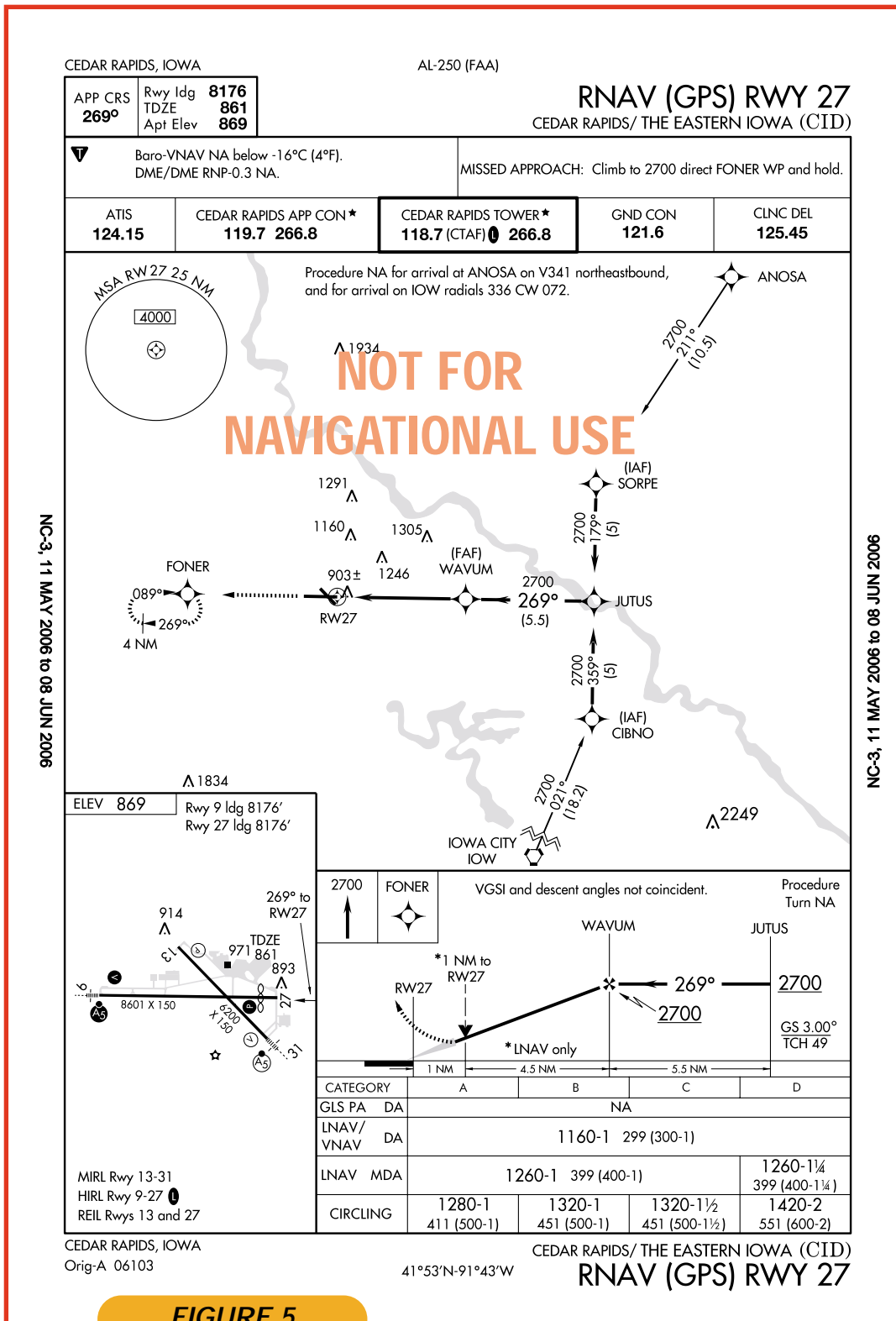


(Baro) VNAV and GPS equipment. These GPS approaches provide both LNAV based on GPS and VNAV based on barometric sensing. (See Figure 5 Cedar Rapids/The Eastern Iowa (CID) RNAV (GPS) Y Rwy 27. [Note: Wide Area Augmentation System (WAAS)

avionics approved for LNAV/VNAV can also fly these procedures without the Baro-VNAV temperature restrictions and local altimeter setting requirements.] VNAV allows for a more stabilized approach, flown like an ILS approach (but to higher minimums).

**Containment:** The ROC on final varies with distance from runway (minimum 250 feet) because the obstacle clearance is evaluated by a sloping obstacle surface rather than a set ROC value. While this occasionally results in minima higher than the LNAV minima, the added safety benefit of a stabilized descent outweighs the difference in minimums. Additionally, a glide path qualification surface (GQS) underlying the glide path from the threshold to the Decision Altitude (DA) point is evaluated to determine if the controlling obstacle's position will allow a vertically guided (LNAV/VNAV) approach to be constructed. The alerting process also uses Receiver Autonomous Integrity Monitoring (RAIM), or the WAAS avionics' integrity function. WAAS uses a complex integrity function based on information transmitted from the ground stations to the Telesat Geostationary Satellite (GEO) to the aircraft avionics.

LNAV/VNAV procedures require an approach certified barometric vertical guidance (Baro-VNAV) system; and a GPS or a WAAS system approved for LNAV/VNAV. This equipment must comply with TSO-C129, *Airborne Supplemental Navigation Equipment Using the Global Positioning System (GPS)*, or TSO-C145, *Airborne Navigation Sensors Using the GPS Augmented by the Wide Area Augmentation System*, or TSO-C146, *Stand-Alone Airborne Navigation Equipment Using the GPS Augmented by the Wide Area Augmentation System*. In addition, AC 20-130A, *Airworthiness Approval of Navigation or Flight Management Systems Integrating Multiple Navigation Sensors, or equivalent* provides guidance.



**FIGURE 5**

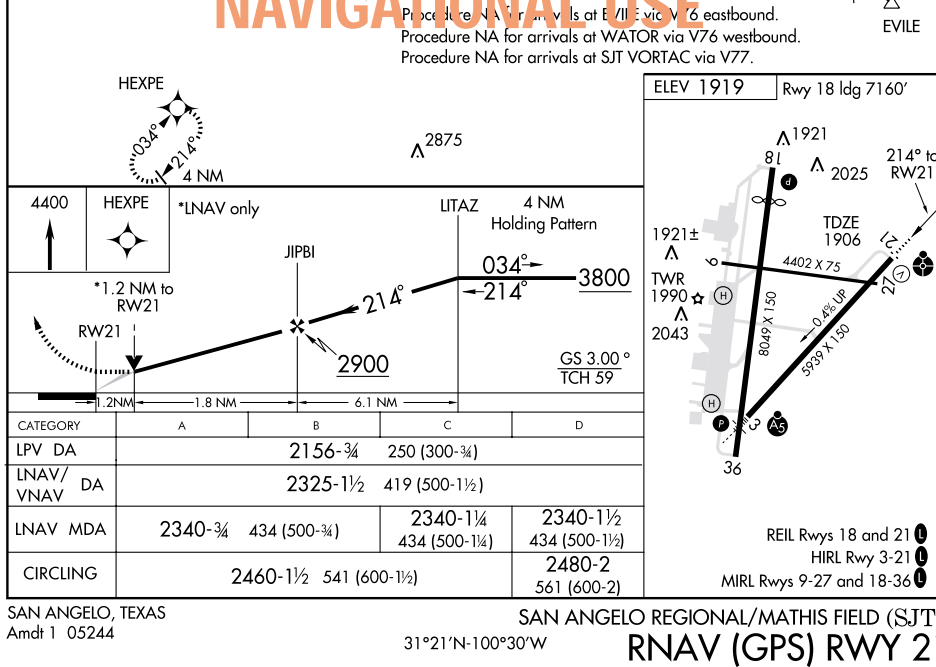


SC-3, 11 MAY 2006 to 08 JUN 2006

**FIGURE 6**

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More information is available in Advisory Circular 90-97, Use of *Barometric Vertical Navigation (VNAV) for Instrument Approach Operations Using Decision Altitude*.

Pilots flying aircraft equipped to fly LNAV/VNAV approaches may use the LNAV/VNAV or LNAV minima lines. There are almost 900 approaches with LNAV/VNAV minima.

**WAAS - 2003**

The Wide Area Augmentation System or WAAS is a major improvement to GPS. A combination of 25 WAAS ground reference stations (WRS) monitor the GPS constellation signals and send corrections through two WAAS Master Stations (WMS) up to two geosynchronous satellites. These satellites then transmit the corrections to a WAAS enabled GPS receiver. (See Figure 6, San Angelo Re-

gional/Mathis Field (SJT) RNAV (GPS) Rwy 21) More WRS are being installed in Alaska (4), Canada (4) and Mexico (5) to improve Northern Hemisphere coverage.

WAAS provides several advantages. First, the geosynchronous satellites provide additional ranging signals into the WAAS enabled receiver, increasing GPS system coverage and availability. Since WAAS monitors and corrects variations in the GPS positioning, the system is much more accurate with smaller alert limits. This smaller integrity limit supports the current generation of GPS approaches, Localizer Performance with Vertical guidance (LPV). Another advantage is that it allows WAAS-equipped users to be able to flight plan and file for alternate airfields with GPS-based approaches. (Note: This includes any procedure with GPS in the title.)

**Containment:** Similar to LNAV/VNAV and ILS approaches, LPV procedures evaluate the Glideslope Qualification Surface. Because of the smaller integrity limit and angular guidance, the size of the obstacle trapezoid is smaller than LNAV/VNAV. In 2003, the minimum height above touchdown (HAT) value was established at 250 feet. In March 2006, it was announced that the WAAS minimum HAT would be lowered to 200 feet if all other airport infrastructure requirements are met. The first procedures to the lower minima should appear in 2007.

**Alerting:** Another major improvement is WAAS alerting. The WAAS horizontal integrity limit is 40 meters on final as opposed to 556 meters for basic GPS. More importantly, WAAS provides vertical integrity, which GPS does not. WAAS eliminates the requirements for RAIM predictions, but crews still must check WAAS NOTAMS. Additionally, on procedures with an inverse W, crews must plan using non-precision approach

requirements since vertical NOTAMS are not provided. The inverse W symbols will be removed as the vertical signal availability improves at airports. Future improvements will result from the planned addition of WAAS Reference Stations which will extend and improve WAAS service. Avionics equipment guidance is found in TSO-C145 and TSO-C146.

Pilots can fly the following minima with an appropriately certified WAAS receiver: LPV, LNAV/VNAV, and LNAV. Why would one fly LNAV/VNAV or LNAV minima if they could fly LPV? The reason is that some GPS and RNAV(GPS) approaches have LNAV/VNAV, but not LPV minima. Also, if the WAAS system has an outage, the pilot can still fly the LNAV portion. Think of flying the localizer only approach when the ILS glideslope is out of service. There are approximately 400 LPV approaches al-



ready published and a production goal of 300 more LPV approaches each year.

## LAAS

The Local Area Augmentation System (LAAS) will augment the GPS and complement WAAS by providing an all-weather approach, landing, and surface navigation capability. It is expected that the end-state configuration will pinpoint the aircraft's position to within one meter or less. Curved approach paths, not possible using the current instrument landing systems, will be possible for Category I, II, and III precision approaches as the system evolves. Increased accuracy will allow more arrival and departure procedures. Approaches will be designed to avoid obstacles, restricted airspace, noise sensitive areas, or congested airspace. Similar to WAAS, LAAS works by monitoring the GPS signal, but in the case of LAAS, sends corrections directly to the aircraft. This not only provides greater integrity but also much quicker alerting.

## Other Minima Lines

The GNSS Landing System (GLS) decision altitude was a place holder for ongoing upgrades to WAAS and for LAAS. (Refer to Figure 5). It has been replaced by LPV on the RNAV(GPS) charts. The acronym GLS is now associated with the LAAS minima and will be published on a separate chart when LAAS ap-

proaches become available.

## Still Confused?

Perhaps this summary will make it easier. Every IFR-certified and installed GPS unit allows the pilot to descend to LNAV (or Straight-in) and circling approaches. Baro-VNAV-equipped GPS systems can also descend to LNAV/VNAV minima. WAAS receivers can descend to LNAV, LNAV/VNAV, and LPV minima. Need another hint? Look for the DA designation versus the Minimum Descent Altitude (MDA) abbreviation on the minima line. Only procedures with vertical guidance have DAs. (See Figure 7) A descent angle may be provided on procedures which have only LNAV minima, to aid in a stabilized descent, but the MDA must still be respected.

## Need More Information?

You can find a condensed version of the information in this article on page A1 of each *U.S. Terminal Procedures Flight Information Publication* and the *Aeronautical Information Manual* (AIM) paragraph 5-4-5, j. More GPS and WAAS information is available in the AIM paragraphs 1-1-19 and 1-1-20.

See the following Web sites for additional background information on GPS approaches:

- FAA Satellite Navigation: <<http://gps.faa.gov/>>
- Aeronautical Information

*Manual*: <<http://www.faa.gov/at-pubs/AIM/AIM.pdf>>

- *Instrument Procedures Handbook*; Chapter 5 at <[http://www.faa.gov/library/manuals/aviation/instrument\\_procedures\\_handbook/](http://www.faa.gov/library/manuals/aviation/instrument_procedures_handbook/)>
- FAA National Aeronautical Charting Office (NACO) Introduction to IFR Symbols at <[http://www.naco.faa.gov/content/naco/online/pdf\\_files/7th\\_IAP\\_Intro.pdf](http://www.naco.faa.gov/content/naco/online/pdf_files/7th_IAP_Intro.pdf)>
- AOPA's technology Webpage link at: <[http://www.aopa.org/asf/safety\\_topics.html#technology](http://www.aopa.org/asf/safety_topics.html#technology)>

The following advisory circulars can be accessed through: <[http://faa.gov/regulations\\_policies/](http://faa.gov/regulations_policies/)>

- AC 90-94, *Guidelines for using Global Positioning System Equipment for IFR En Route and Terminal Operations and for Nonprecision Instrument Approaches in the U.S. National Airspace System*
- AC 90-97, *Use of Barometric Vertical Navigation (VNAV) for Instrument Approach Operations Using Decision Altitude*.
- AC 90-100, *U.S. Terminal and En Route Area Navigation (RNAV) Operations*.



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Types of GPS equipment req'd	CATEGORY	A	B	C	D	E
WAAS	LPV DA		296/40	250	(300 - 3/4)	
WAAS, Baro-GPS	LNAV/ VNAV DA		500/50 454 (500 - 1)			
WAAS or Baro-RNAV (GPS) or GPS	LNAV MDA	640/40	594 (600 - 3/4)	640/50 594 (600 - 1)	640/60 594 (600 - 1 1/4)	640 - 1 1/2 594 (600 - 1 1/2)
" " " "	CIRCLING	640-1 1/2 594 (600 - 1 1/2)			640-2 594 (600-2)	740/2 1/2 694 (700 - 2 1/2)

**(Figure 7 - Approach Minimum Equipment Comparison)**

\* IFR, Approach Certified Equipment

