

# A NEW APPROACH

AS SPACE-BASED NAVIGATION SYSTEMS ARE PHASED IN, THEY WILL PROVIDE MORE ACCURATE DATA FOR INSTRUMENT PROCEDURES.

BY JOHN AINSWORTH

Space-based navigation systems have revolutionized all aspects of navigation. In aviation, the technology has cut the cost of implementing instrument procedures dramatically, while providing that capability to sites which would not otherwise be suitable even for ground-based navigation aids.

With the global positioning system (GPS) or global navigation satellite system (GNSS), new procedures have been developed that provide the same capability as ground-based, non-precision nav aids such as non-directional beacons (NDBs) and VHF omnidirectional radio range (VORs), but with greater flexibility. Now, with the introduction of the wide area augmentation system (WAAS), this space-based augmentation system can provide instrument landing system (ILS) performance. This article looks at the design of these new procedures and how airports and aircraft operators will benefit.

All instrument procedures, including approaches, standard instrument departures (SIDs), standard terminal arrival routes (STARs), etc., are designed in accordance with an approved set of criteria, which define every aspect of the procedure, including obstacle clearances, turn radii, and climb and descent gradients. There are only two sources for the base criteria: FAA Order 8260, referred to as TERPS; and ICAO Procedures for Air Navigation Services Aircraft Operations (PANS-OPS). Each nation state is responsible for adopting, adapting (in some cases), approving and maintaining these criteria for their own territory. Canada has chosen the FAA TERPS criteria as the basis for all Canadian instrument procedures. Canada uses a document called Criteria for the Development of Instrument Procedures (TP308) which is almost identical to FAA TERPS.

The first GPS-based criteria were promulgated in the FAA's Order 8260.38 and Transport Canada's TP308 in 1996. Both of these documents were released before the availability of the FAA's WAAS. The lateral navigation (LNAV) procedures designed at that time had a height above touchdown (HAT) no lower than 250 ft., but the obstacle identification surface footprint was quite large, which potentially increased the minimum descent altitude (MDA) due to more obstacles being evaluated.

In 2002, the FAA released 8260.50, which introduced localizer performance with vertical guidance (LPV) GPS criteria that allowed for HAT minimums as low as 250 ft., assuming suitable terrain free of obstacles and an appropriate airport environment (lighting, runway markings, etc.), but now with vertical guidance and an obstacle identification surface footprint the same as for ILS CAT 1. Transport Canada allowed the approval of LPV procedures by releasing an Advisory Circular that permitted the use of the criteria as published in 8260.50, but very few LPV designs were implemented in Canada. Since then, the FAA has released 8260.54A which allows LPV procedures with minimums as low as 200 ft., identical to CAT I ILS procedures. Transport Canada has now published TP308 Change 5.3 that will include 54A and allow similar minimums in Canada.

While flying an LPV approach is no more involved than flying a typical ILS, the development of the LPV procedure is extremely complex. As an illustration, 8260.50, detailing earlier LPV criteria, was about 70 pages, while 8260.54A is close to 350 pages. In the past, it was both possible and practical to develop a procedure manually. It was tedious, taking about a week of trial and error working with large-scale topographic maps and

Figure 1: Example of Required Calculations

Formula 6-2b1. TIA Length Multi-CG (LNA/LP)	
<b>Math Notion</b>	$TIA_{length} = FSL + \frac{r}{(r+MDA)} + \frac{r}{CG1} \cdot \frac{1852}{0.3048} \cdot \ln\left(\frac{r+CG1_{termalt}}{(r+MDA)}\right) + \frac{r}{CG2} \cdot \frac{1852}{0.3048} \cdot \ln\left(\frac{r+turn_{alt}}{r+CG1_{termalt}}\right)$
<b>Standard Text</b>	$FSL \cdot r / (r+MDA) + r / CG1 \cdot 1852 / 0.3048 \cdot \ln((r+CG1_{termalt}) / (r+MDA)) + r / CG2 \cdot 1852 / 0.3048 \cdot \ln((r+turn_{alt}) / (r+CG1_{termalt}))$
<b>Given Values:</b> CG1 <sub>termalt</sub> = Initial CG termination altitude r = Earth Radius (20890537 ft) MDA = Aircraft Final MDA CG1 = Initial Climb Gradient (≥ Standard 200) CG2 = Second Climb Gradient (Standard 200)	
Formula 6-2b2. TIA Length SINGLE-CG (LNAV/LP)	
<b>Math Notion</b>	$TIA_{length} = FSL \cdot \frac{r}{(r+MDA)} + \frac{r}{CG} \cdot \frac{1852}{0.3048} \cdot \ln\left(\frac{r+turn_{alt}}{r+MDA}\right)$
<b>Standard Text</b>	$FSL \cdot r / (r+MDA) + r / CG \cdot 1852 / 0.3048 \cdot \ln((r+turn_{alt}) / (r+MDA))$
<b>Given Values:</b> Turn <sub>alt</sub> = Required turn altitude r = Earth Radius (20890537 ft) DA = Aircraft Final DA CG = Climb Gradient (Standard 200)	
Formula 6-2c1. TIA Length Multi-CG (LNAV/VNAV)	
<b>Math Notion</b>	$TIA_{length} = FSL + \frac{r}{(r+DA)} + \frac{r}{CG1} \cdot \frac{1852}{0.3048} \cdot \ln\left(\frac{r+CG1_{termalt}}{(r+DA)}\right) + \frac{r}{CG2} \cdot \frac{1852}{0.3048} \cdot \ln\left(\frac{r+turn_{alt}}{r+CG1_{termalt}}\right)$
<b>Standard Text</b>	$FSL \cdot r / (r+MDA) + r / CG1 \cdot 1852 / 0.3048 \cdot \ln((r+CG1_{termalt}) / (r+MDA)) + r / CG2 \cdot 1852 / 0.3048 \cdot \ln((r+turn_{alt}) / (r+CG1_{termalt}))$
<b>Given Values:</b> CG1 <sub>termalt</sub> = Initial CG termination altitude r = Earth Radius (20890537 ft) DA = Aircraft Final DA CG1 = Initial Climb Gradient (≥ Standard 200) CG2 = Second Climb Gradient (Standard 200)	

transparent overlays; but it was, originally, the only way to do it. Now, with the increased complexity, it is no longer practical to use manual methods. Underscoring this, Figure 1 shows a small sampling of the calculations required. Note that these calculations define, in part, a complex, three-dimensional surface (in this case, the length of the turn initiation area (TIA) for given climb gradients on the missed approach segment), that must then be searched, using terrain and obstruction databases, to see if there are any penetrations. Specialized, computer-based tools are available to automate the process; but, owing to the extensive development and limited market, there are only three currently on the market (one each from Italy, France and Canada).

There are a few existing LPV procedures in Canada, notably Waterloo (CYKF) and Sioux Lookout (CYXL), but they are limited to a HAT minimum of no lower than 250 ft. and designed to 8260.50. Other considerations, like terrain, approach lighting and obstacle clearance requirements, may raise the HAT minimum even higher. Airport authorities can now have a typical GNSS LPV procedure, giving the same or better utility as an ILS, without the need to install equipment costing millions of dollars.

The first procedure with TP308 Change 5.3 will be a procedure for Runway 08 at CYTZ, Toronto's Billy Bishop Airport (see Figure 2). Unfortunately, owing to the lack of approach lights, the HAT minimum can be no better than 250 ft. To illustrate the advantages of the new criteria, the existing GNSS LNAV procedure (designed in accordance with TP308, Change 5.2) has a HAT minimum of 469 ft. and even the ILS/DME procedure has a HAT minimum of 309 ft..

The main reason for the improved minimums is, of course, the better accuracy provided by a WAAS GPS navigation system, resulting in a smaller obstacle identification surface footprint. For example, the width of the terrain and obstruction search area at six nautical miles (NM) from the missed approach point (MAP) is 6.2 NM for an LNAV procedure (pre-change 5.3), and only 3.5 NM for an LPV. This is illustrated in Figure 3. The red

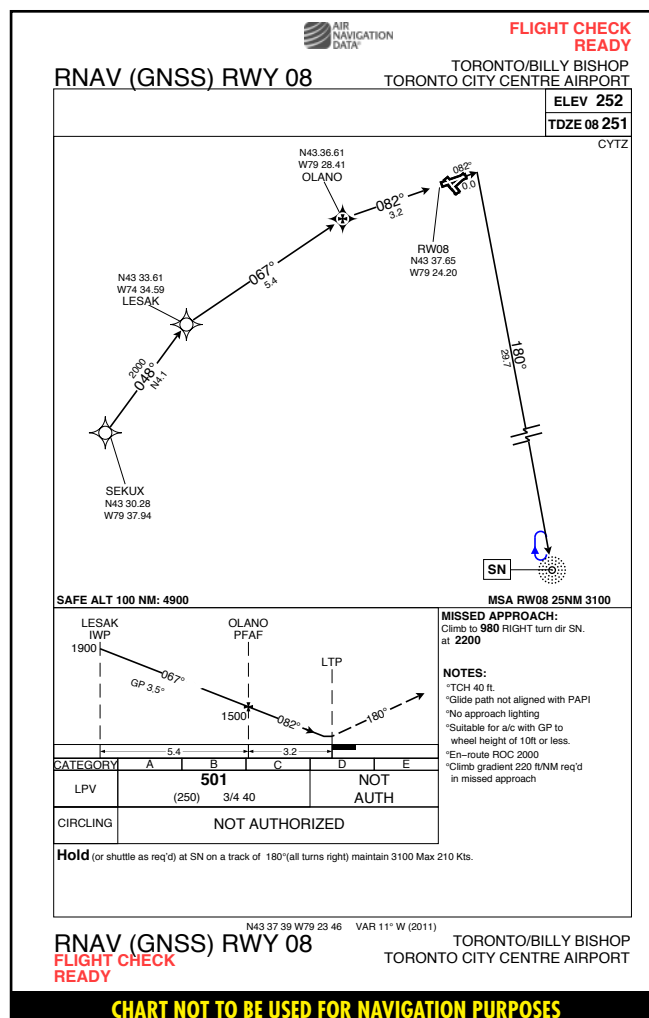


Figure 2: New LPV Approach for Billy Bishop Airport

Figure 3: Comparison of Different Obstacle Search Areas

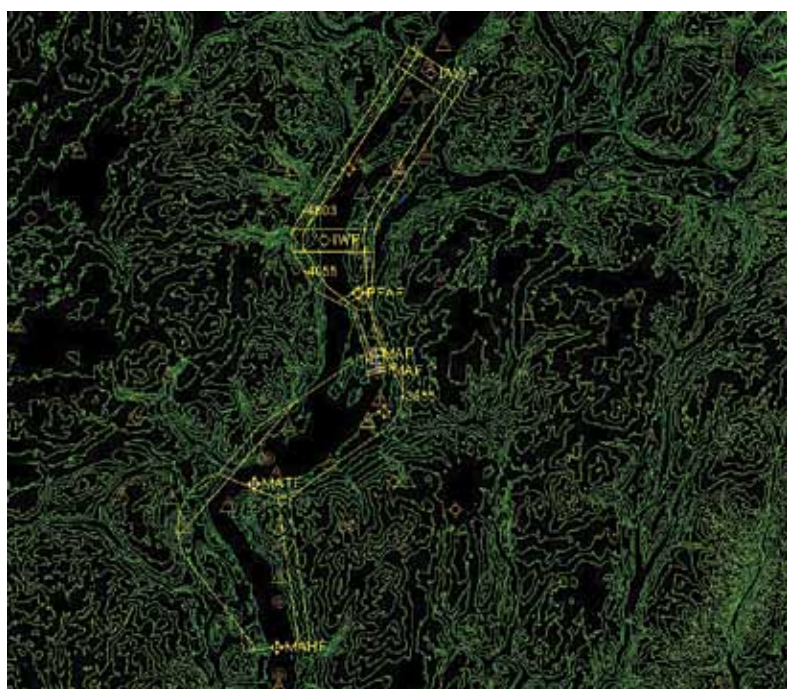
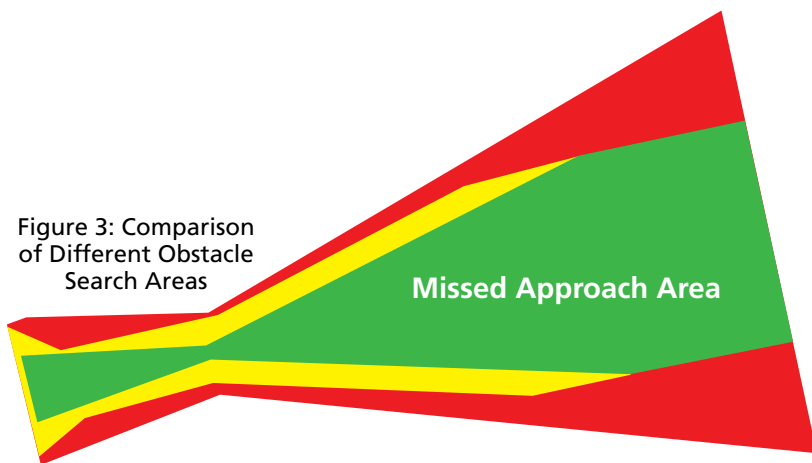


Figure 4: Hypothetical LNAV Approach Using TP308 change 5.3 Vol 6 Doc. 7

area represents the obstacle search area for the older GPS procedure, while the yellow represents LNAV/VNAV and the green represents the search area for LPV procedures.

An LPV procedure can be provided in some environments where an ILS might not be possible due to terrain affecting the ILS signal. Figure 4 shows a hypothetical procedure for Kelowna, B.C., with the initial, intermediate, final and missed approach segments. Notice how the wind spirals, which allow for drift while flying the procedure, enlarge the size of the missed approach segments in the turn.

GPS procedures are flown based on the data in the aircraft's GPS receiver. This data contains the instructions on how the procedure is to be flown. In the case of the LPV, an additional security feature is added in the form of a cyclical redundancy check (CRC). The CRC is generated from the final approach segment data block (FASDB) which contains the elements of the final approach. This CRC provides validation that data has not

been corrupted from the time that the procedure was designed to the time it is being flown.

While there are a number of LNAV/VNAV procedures at this time, the expectation is that they will be phased out and replaced with LPV procedures. The common assumption is that, while not as good as full LPV, LNAV/VNAV procedures provide a greater utility than just LNAV. In many cases, this is not true. A number of LNAV/VNAV procedures have minimums that are considerably higher than the LNAV procedure shown on the same plate. An example, from Harrisburg, Pa., is shown in Figure 5. The minimums for the LNAV procedure are 872 ft. (HAT) and one-half mile visibility, while the minimums for the LNAV/VNAV procedure are 1,264 feet and five miles! The problem is that the missed approach point for an LNAV procedure is usually at the runway threshold, while that for an LNAV/VNAV procedure is further back from the threshold at the decision altitude. If there is an obstruction between the LNAV/VNAV MAP and the LNAV MAP, within the obstacle identification surface footprint, that obstruction will force the HAT minimum higher. This is exactly the case at Harrisburg International Airport.

Looking at the history, LNAV/VNAV was an upgrade from Baro-VNAV which, in turn, was the first stabilized approach to get away from the now out-of-favour "dive 'n' drive" style of executing a non-precision approach. As both the LNAV/VNAV and LPV procedures require the same WAAS-enabled equipment, the need for LNAV/VNAV procedures is diminishing. The sooner these outdated procedures with confusing minimums of questionable value are replaced with LPV procedures, the better.

As of mid-2011, there were some 3,216 non-precision approaches based on traditional nav aids in the U.S., while there were 5,541 GPS and LNAV procedures. Similarly, there were only 1,285 CAT I ILS procedures compared to 5,273 LNAV/VNAV and LPV procedures (including 541 with a HAT minimum of 200 ft.). Looking at the numbers another way, there were a total of 10,979 satellite-based procedures (including GPS, LNAV, LNAV/VNAV, LPV and LP procedures) and only 4,792 ground-based procedures (including CAT I/II/III ILS and various non-precision procedures). Other countries are fielding space-based augmentation systems (SBAS) similar to WAAS, including Europe (EGNOS), Japan (MSAS) and India (GAGAN), all of which are inter-operable.

Hopefully, now that the WAAS system includes Canada and we have the appropriate criteria, there will be a similar rapid implementation of GNSS procedures with ILS minimums here in Canada.

*John Ainsworth is the president of Air Navigation Data (www.AirNavigation.com), an Ottawa, Ont.-based company dedicated to providing services and tools to support instrument procedure design. Ainsworth is a member of the TP308 Working Group, a committee headed by Transport Canada that reviews and updates the Canadian instrument procedure design criteria.*

Figure 5: Harrisburg (KMDT) Approach Minimums

Category		A	B	C	D
LPV	DA	558/24 250 (300-1/2)			
LNAV/VNAV	DA	1 572-5 1264 (1300-5)			
LNAV	MDA	1180/24 872 (900-1/2)	1180/40 872 (900-3/4)	1180-2 872 (900-2)	1180-2 1/4 872 (900-2 1/4)
CIRCLING		1180-1 870 (900-1)	1180-1 1/4 870 (900-1 1/4)	1180-2 1/2 870 (900-2 1/2)	1180-2 3/4 870 (900-2 3/4)