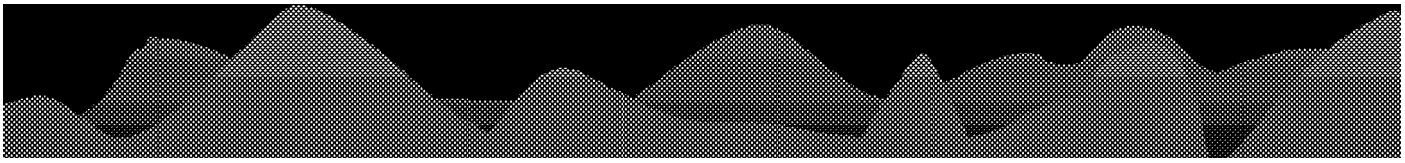

CONTROLLED FLIGHT INTO TERRAIN, PART II: FMS/GPS NONPRECISION APPROACH OPERATIONS—

The Distance To Go

By Steve Bergner

When destination weather is at or near published minimums, the NDB, VOR, or VOR/DME approach can be the most demanding procedure to fly to a safe landing.

Now that global positioning system/global navigation satellite system (GPS/GNSS) has been introduced to the flight management system (FMS) sensor array, the pilot's hope for improved lateral and vertical guidance is almost at hand. New GPS and GPS-overlay procedures have been published, and approach-certified FMS can be found in the cockpits of many jets.

Unfortunately for the flight crew, using FMS/GPS for conducting nonprecision procedures—particularly GPS overlay procedures—currently presents almost as many new problems as it solves. This may surprise operators who haven't yet taken a critical look at the interface of the components comprising the system that pilots will use during approach operations using FMS/GPS.

The pilot flying the FMS/GPS-overlay approach works with three fundamental components:

- the printed approach chart,
- the FMS and its database, and
- the cockpit display.

Each of these components was designed *independently from the others*, but all three are used simultaneously, as a *system*. To safely manage the approach operation, the humans in the cockpit have to interpret and integrate information from all three of these components.

If the total system is to effectively *serve the flight crew*, then all three of its components must function well *together*. They must together provide consistent, straightforward, and unambiguous approach guidance. At present, they do not. Two significant areas of potential confusion in using these components as a system are

- the lack of consistency between the cockpit displays and printed approach charts, and
- the database VNAV coding of the final approach segment.

During instrument approaches, the position of the aircraft and "intent" of the FMS may not be intuitive or self-evident to the crew. Some EFIS displays show the projected aircraft track better than other displays while the FMS is flying procedure turns, holding patterns, and DME arcs. And of course, flight crews of "FMS + steam gauge" airplanes may be flying FMS/GPS approaches *without* EFIS map displays!

While modern FMS and EFIS cockpit displays do a fine job of showing course and distance to an active waypoint, that information may not be useful or even relevant when the pilots try to use the FMS as primary guidance for an overlay approach procedure.

The opportunity for confusion in the cockpit is largely caused by inconsistencies between the electronic version and the printed instrument approach procedure (IAP), and the frequent conflict between FMS/GPS distance and DME fixes. In some Phase 2 GPS overlay procedures, e.g., "VOR/DME or GPS Runway ##," FMS may provide a *lower* level of position awareness for the crew than the old "raw data" course/distance from the procedure-specified navaid.

The designer of the original IAP—i.e., the IAP for the "raw data" procedure on which the overlay IAP is predicated—never constructed or intended the approach to be used solely by a crew of an FMS/GPS-equipped transport. To the contrary, each "underlay" IAP was originally designed to be flown using only the procedure-

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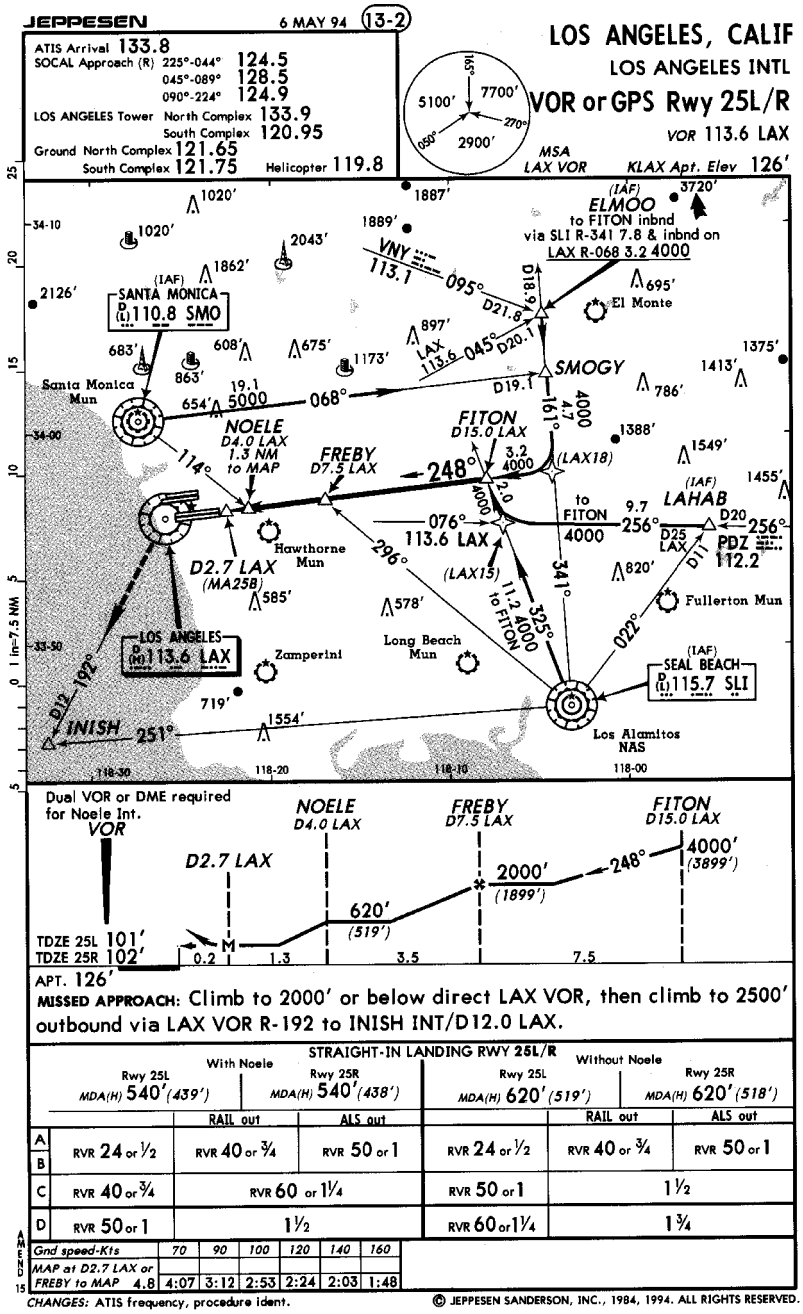
Governments should be urged to rapidly develop and certify these standalone procedures. The old "dive and fly level" style of flying nonprecision approaches should be retired as soon as possible.

Figure 1



This instrument approach chart for Runway 25L/R at Los Angeles International Airport contains several examples of the potential for confusion in the cockpit of an FMS/GPS-equipped transport. This chart, reproduced with the permission of Jeppesen Sanderson, Inc., © 1994, is shown for illustration only, not to be used for navigation.

specified ground-based navaid(s); i.e., VOR, VOR/DME, NDB, etc. The designers subsequently gave tacit approval to the use of FMS/GPS equipment "after the fact."

Several examples of the potential for confusion in the cockpit can be found in the VOR or GPS approach to Runway 25L/R at Los Angeles International Airport (Figure 1). If the ELMOO transition is selected for the approach, the CDU display of database waypoints would appear as in Figure 2 (opposite).

If the pilots study and compare the waypoints listed on the CDU to the fixes on the printed chart, they will find that two waypoints are missing:

- SMOGY, on the appr oach segment from ELMOO to FITON, and
- NOELE, a step-down fix in the final approach segment, identified by D4.0 from LAX.

The pilots might not be too concerned with the fact that SMOGY isn't in the database—the minimum instrument altitude remains 4,000 feet while passing this fix. In the final approach segment, however, the pilots *are* responsible for the minimum altitude of 620 feet until passing NOELE—yet this important fix isn't in the database, nor can the pilots readily identify it from the cockpit.

The chart publisher does indeed print the 1.3 nm distance to the MAP in very small print in the *plan* view, but pilots tend to look at the *profile* view for the altitude information in the final approach segment. NOELE is identified in the profile view only as D4.0 LAX, even though the pilots can fly the IAP by referring solely to FMS/GPS.

If the pilots mistakenly apply 4.0 *FMS* distance (from the EFIS display) instead of 4.0 *DME*, they might descend 2.7 miles too soon. Anytime pilots use FMS as the primary navigation display during an overlay approach, similar, or more serious,

discrepancies will very likely be found between the FMS distance to an active waypoint and the charted DME distance value to the same fix. In fact, the respective distance displays may even "count" in *opposite* directions.

Although the pilots could find and use the 1.3 FMS/GPS distance from the MA25B fix to identify NOELE, to expect them to do so—without error—in dark, turbulent flight conditions is not reasonable.

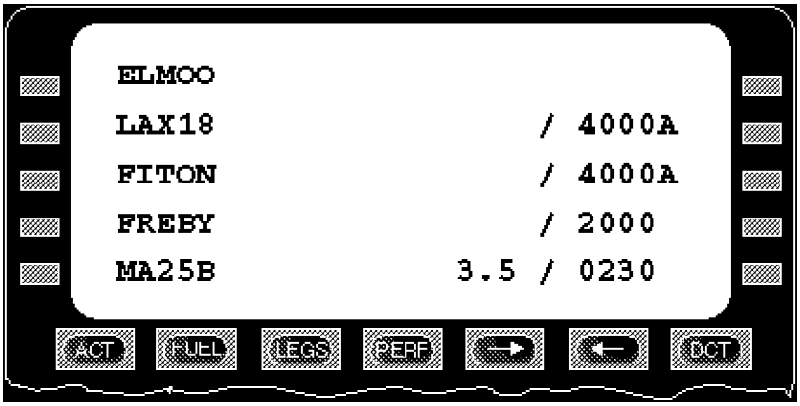
Problems in the VNAV component of FMS/GPS overlay approaches are just as serious, and perhaps even more complex. In this example, VNAV provides reasonably good vertical guidance. The database VPATH will clear the NOELE step-down fix—although the flight crew cannot easily determine this from the chart or CDU.

On many other overlay approaches, however, database VNAV coding can be confusing and inconsistent. Some VPATHs lead to a descent to MDA earlier than necessary; others don't arrive at the MDA until reaching the missed approach point—often far too late for a stabilized descent to landing. Careful study of the FMS CDU is required to evaluate each selected approach. The use of VNAV guidance may not be appropriate for many overlay approaches.

Are procedures like this one safe? Are they the best we can do for the flight crew? Perhaps not.

Criticizing the airline industry and the federal government would be unfair without first giving them credit for recognizing the problems of using FMS/GPS in the approach environment. At this writing, ARINC's 424 Committee is working to revise the specifications of the database coding of overlay approaches. The federal government, airline pilots, and the aviation industry are also reviewing charting. All are to be encouraged to carefully complete the task of resolving the remaining issues.

Figure 2



Flight management system database waypoints appear in sequence in the left column. The database VNAV angles (if any) and database altitudes appear at the right side of the CDU—for example, FMS VNAV altitude for FREBY fix is 2,000 feet, and FMS VNAV angle of 3.5 degrees is coded to an altitude of 230 feet at the MA25B fix.

The important point to be made is that the GPS standalone approach has by far the most potential of the FMS/GPS IAP selections.

The standalone procedure and its chart can be designed to perfectly match cockpit equipment and displays.

Step-down fixes, identified by FMS distance to the runway threshold, could be used as a backup to a barometric FMS VPATH.

The FMS/GPS standalone procedure can be designed with excellent course alignment to the runway threshold and provide for continuous, uninterrupted descent to minimums. Governments should be urged to rapidly develop and certify these standalone procedures. The old "dive and fly level" style of flying nonprecision approaches should be retired as soon as possible.

Meanwhile, operators should be advised to be skeptical and cautious as FMS/GPS technology is applied to overlay IFR approaches.