Boeing will soon offer a suite of new integrated flight deck navigation options that enhance the proven approach capability of 737-600/-700/-800/-900 airplanes. Available in 2003, these options enable pilots to fly precise three-dimensional paths that smoothly intercept a variety of final approach legs. The Category IIIB Autoland, Global Navigation Satellite System Landing System, Integrated Approach Navigation, and Navigation Performance Scales options work together or separately to improve safety and performance while decreasing operating costs.
Operators will be able to enhance the approach capability of their 737-600/-700/-800/-900 airplanes this year with a suite of new flight deck navigation options: Category IIIB Autoland, the Global Navigation Satellite System (GNSS) Landing System, Integrated Approach Navigation, and Navigation Performance Scales.

Together with the excellent existing approach capabilities of the 737, these options offer a flexible navigation solution for airlines that want to increase their competitive advantage by improving airplane safety and performance, decreasing operating costs, and reducing flight crew training requirements through advanced technology.

The new navigation options work together or separately to enable pilots to fly safe, stable, and precise three-dimensional paths that smoothly intercept a variety of final approach legs.

The options improve landing capability in adverse weather conditions, in areas of difficult terrain, and on existing difficult approach paths. It addition, they will allow crews to take advantage of emerging air traffic control technologies designed to improve airport operations.

To help operators understand these navigation options and their features, this article describes

1. Category IIIB Autoland.
2. GNSS Landing System.

The article also discusses how the options and procedures are compatible with current and emerging approach navigation technologies such as the Instrument Landing System, mixed-mode, and constant-angle nonprecision approaches.

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**CATEGORY IIIB AUTOLAND**

The new 737-700/-800/-900 Category IIIB Autoland option (fig. 1) provides the same all-weather, precision approach autopilot guidance currently available on other Boeing airplane models.

This option, which is in flight test, will be offered with the 737-700/-800/-900 over-under engine format. The over-under format provides the display space necessary for Category IIIB Autoland system messages. (The 737-600 is not currently being certified for Category IIIB operation.)

The initial 737-600/-700/-800/-900 GLS option supports a Category I instrument approach capability and the ability to complete the approach with an automatic landing. This system is being expanded to support full Category IIIB Autoland operations.

Retrofit for the 737-600/-700/-800/-900 GLS requires new multimode receiver (MMR) hardware and software, a navigation control panel with GLS capability, hardware and software upgrades for the enhanced ground...
proximity warning system (EGPWS), flight management computer (FMC) U10.5 software, and common display system (CDS) Block Point 2002 software. A future curved GLS approach capability might require autopilot and CDS software changes.

The U.S. Federal Aviation Administration (FAA) plans to deploy GLS ground stations in Memphis, Chicago O’Hare, Juneau Alaska, Seattle, Phoenix, and Houston to support operational evaluation testing. The program calls for the purchase and deployment of as many as 40 ground stations per year after the initial phase. The FAA projects a total of 160 GBAS ground stations are needed in the United States. Europe also plans to develop and install GBAS ground stations.

Integrated Approach Navigation (IAN) is an approach option designed for airlines that want to use ILS-like pilot procedures, display features, and autopilot control laws for nonprecision (Category I) approaches. This option does not require additional ground facility support.

The FMC transmits IAN deviations to the autopilot and display system. The pilot procedures for IAN are derived from current ILS pilot procedures and are consistent for all approach types:

1. Select the approach on the FMC control display unit, tune the appropriate station, and arm the autopilot approach mode. The IAN function supports the ILS for glideslope inoperative, localizer only, and backcourse approach types.

2. The IAN function will alert the crew to approach selection or tuning inconsistencies. For example, if an ILS station is tuned and an area navigation (RNAV) approach also is selected on the FMC, the flight crew will be alerted and the ILS approach mode will take precedence automatically, with the appropriate display format.

3. While the IAN display (fig. 3) is similar to an ILS display, there are sufficient visual differences to ensure that the crew does not confuse a nonprecision IAN approach for a precision ILS or GLS approach (fig. 4). As on all nonprecision approaches, the altimeter is the primary method of ensuring that altitude constraints are honored.

4. Retrofit of this option involves software updates for the FMC, CDS, flight control computer, and digital flight data acquisition unit (DFDAU) and hardware and software updates for the EGPWS.
Navigation Performance Scales (NPS) is a new display feature that integrates the current lateral navigation (LNAV) and vertical navigation (VNAV) with actual navigation performance (ANP) and required navigation performance (RNP). The primary display format of the NPS (fig. 5) can be interpreted easily, thereby allowing the crew to monitor flight path performance relative to flight phase requirements and airplane system navigation performance.

NPS can be especially valuable for approaches with tight airspace restrictions because of terrain, traffic, or restricted areas. LNAV and VNAV with NPS supports Category I approaches down to 0.10-nmi RNP. NPS also is designed to smoothly transition to an ILS, GLS, or IAN approach. (For a detailed description of NPS, see “Lateral and Vertical Navigation Deviation Displays,” Aero no. 16, Oct. 2001.) Retrofit of this option involves software updates for the FMC, CDS, and DFDAU.

This year, operators will be able to enhance the approach capability of their 737-600/-700/-800/-900 airplanes through a suite of new flight deck navigation options: Category IIIB Autoland, GLS, IAN, and NPS. These options enable pilots to fly paths that smoothly intercept various final approach legs. This integrated, flexible approach navigation solution improves safety and performance and decreases operating costs. The options are designed to meet the current and future approach requirements of Boeing customers worldwide.
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## New Navigation Approach Options Complement Instrument Landing System Capability

<table>
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<tr>
<th>Approach option/capability</th>
<th>Description</th>
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| Category IIIB Autoland      | - All-weather, autoland capability  
- Matches Category IIIB capability available on other Boeing airplane models  
- Not currently offered for 737-600 |
| GNSS Landing System        | - New augmented satellite landing system  
- Does not require a dedicated ground station for each runway  
- Proposed as potential follow-on to current ILS stations  
- Supports Category I operation in initial implementation  
- Retrofit requires MMR and EGPWS hardware and software, FMC and CDS software, and a new navigation control panel |
| Integrated Approach Navigation | - Nonprecision Category I capability with display similar to current ILS  
- FMC-generated glidepath and final approach course  
- Integrates with ILS localizer and backcourse approaches  
- Retrofit requires EGPWS hardware and software and FMC, CDS, flight control computer, and DFDAU software |
| Navigation Performance Scales | - Supports RNAV Category I procedures  
- Integrates ANP and RNP capability with current LNAV and VNAV capability  
- Supports curved approaches  
- Integrates with ILS, GLS, or IAN final approach capabilities  
- Retrofit requires only software changes |
| Instrument Landing System  | - Currently available on 737-600/-700/-800/-900  
- Well-established procedures  
- Supports Category I and II operations  
- Integrates with IAN  
- Many ILS ground stations may be deactivated in the future |

## FMC Enhancements to Improve LNAV and VNAV Operations

Additional FMC enhancements are being studied or developed to further improve LNAV and VNAV approach operations, including:

- LNAV missed approaches, which enable the crew to arm and engage an LNAV missed approach by pressing the takeoff/go-around button. This option reduces crew workload during a busy period in the flight deck.

- Branching missed approaches, which allow one of several preplanned missed approach procedures to be engaged for the applicable approach leg.
Safety Benefits of Stabilized Approaches

The safety benefits of stabilized final approaches, both nonprecision and precision (fig. A), have been recognized for years. The Global Positioning System makes stabilized approaches possible at many airports around the world. NPS, IAN, and GLS all take advantage of this technology to provide consistent, intuitive displays and associated procedures that support stabilized approaches.

The following excerpt (source: The Boeing Company, copyright 1997) is from Controlled Flight Into Terrain Education and Training Aid, section 3:

Unstable approaches contribute to many incidents/accidents. Pilots should establish a stabilized approach profile for all instrument and visual approaches. A stabilized approach has the following characteristics:

- A constant rate of descent along an approximate 3-deg approach path that intersects the landing runway approximately 1,000 ft beyond the approach end and begins not later than the final approach fix or equivalent position.
- Flight from an established height above touchdown should be in a landing configuration with appropriate and stable airspeed, power setting, trim, and constant rate of descent and on the defined descent profile.
- Normally, a stabilized approach configuration should be achieved no later than 1,000 ft AGL in IMC. However, in all cases if a stabilized approach is not achieved by 500 ft AGL, an immediate missed approach shall be initiated.
Displays and Procedures Are Similar to ILS

The current ILS remains the basic approach capability. To minimize training requirements, new 737-600/-700/-800/-900 approach options use displays and pilot procedures that are similar to those used with the ILS (fig. B). For example, the new options involve the established fly-to convention, where a lateral pointer on the right of the center scale reference indicates a lateral path to the right of the current aircraft position (fig. C).

The 737-600/-700/-800/-900 displays include an explicit annunciation at the top of the attitude indicator that clearly defines the source of the displayed deviation scales and pointers. The approach data block, which includes the selected station and course and distance measuring equipment distance, is retained in the GLS and IAN approaches although modified to support their unique characteristics.

The 737-600/-700/-800/-900 procedures have been human engineered to ensure that, although their appearance and operation are consistent with an ILS, aircrews easily can differentiate among approach types (fig. 4, p. 16).
Mixed-Mode Approaches

Under certain circumstances, pilots may choose to mix modes (fig. D). For example, figure E shows an Instrument Landing System localizer (ILS LOC) approach with vertical navigation path (VNAV PTH) vertical guidance. The procedures for mixed-mode approaches are straightforward, and the display formats are consistent and easy to interpret.

Constant-Angle Nonprecision Approaches

Many airlines are moving away from the traditional “dive and drive” step-down procedures and are introducing new constant-angle nonprecision approaches (CANPA). In conjunction with the autopilot, lateral navigation, and vertical navigation, CANPAs decrease workload during approach by allowing the flight crew to load most required data before beginning the approach.

The new 737-600/-700/-800/-900 navigation displays allow the flight crew to easily and intuitively evaluate the status of the entire approach against an objective flight technical error scale and pointer. Flight technical error is a measure of the accuracy with which the airplane is being controlled relative to the defined flight path. Deviations can be caused by the autopilot, crew response to the flight directors, or external environmental conditions such as a wind gradient or turbulence.