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Agenda Item 4: PANS-OPS Implementation

CFIT-Procedure Design Considerations

Use of VNAV on Conventional

Non-Precision Approach Procedures

WORKING PAPER

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SUMMARY

This paper identifies safety concerns regarding the use of the aircraft modern technology capability of VNAV while flying conventionally designed non-precision approaches.

BACKGROUND

As the computer technology of aircraft navigation systems became more and more sophisticated, aircraft and avionics manufacturers attempt to exploit this computer capability in aircraft operations. One of the most profound capabilities being exploited recently is the aircraft's capability of navigating vertically on an instrument approach without reference to an external electronic guidance signal such as an ILS glideslope or MLS elevation signal. This mode of operation is called "VNAV".

The vertical guidance is usually based on barometric altimetry augmented with information from a mix of navigation sensors. Vertical command information may be retrieved from the aircraft's aeronautical information database or from the pilot's input into the Flight Management System (FMS). Vertical command information while conducting VNAV on a conventional non-precision approach is normally retrieved entirely from the aircraft's aeronautical database.

CFIT

Operators of these new technology aircraft have been using the VNAV features for determining the Top-of-Descent (TOD) in order to gain the most economical benefit of operating the aircraft in the descent and approach for landing. In addition, however, pilots have been utilizing the VNAV capability of a large air carrier type aircraft to establish a stabilized descent profile while conducting a non-precision approach. Traditionally, aircraft had descended in steps to level at the Minimum Descent Altitude (MDA) during the conduct of a non-precision approach. This "de-stabilized" method of flying an instrument approach procedure is considered by many to be a major contributing factor in Controlled Flight Into Terrain (CFIT) accidents.

Much has been written concerning CFIT while conducting an instrument approach procedure. In the effort to reduce CFIT accidents during non-precision approaches, VNAV has been touted as the most effective means to manage the vertical component of a non-precision approach procedure by avoiding the necessity of levelling-off at the minimum flight altitude along each of the different segments of the procedure. Some operators have extended the philosophy of VNAV to the point of describing it as an "ILS look-alike." Others have readily accepted the use of VNAV on non-precision approaches as simply another precision approach!

DEVELOPMENT OF APPROACH PROCEDURES

All members of the OCP are acutely aware of the differences in developing non-precision and precision approaches and the associated definitions:

> ***Minimum descent altitude (MDA) or minimum descent height (MDH).*** A specified altitude or height in a non-precision approach or circling approach below which descent must not be made without the required visual reference. (PANS-OPS VOL II)
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> ***Decision altitude (DA) or decision height (DH).*** A specified altitude or height in the precision approach at which a missed approach must be initiated if the required visual reference to continue the approach has not been established. (PANS OPS VOL II)
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> ***Precision approach procedure.*** An instrument approach procedure utilizing azimuth and glide path information provided by ILS or PAR. (PANS OPS VOL II) *NOTE: It has been recognized that other signal-in-space glide paths, such as MLS, is included in this definition.*

It appears, however, that with the introduction of VNAV on non-precision approaches, the differences

between the traditional non-precision approach and precision approach in the minds of some authorities and operators have been clouded and mis-represented. One State's air carrier authority has gone as far as authorizing air carrier operations utilizing VNAV on non-precision approach to permit the pilot to use the MDA as a DH. In other words, the pilot is permitted to fly VNAV vertical guidance information on a non-precision approach and when the barometric altitude reads the MDA value, a missed approach is initiated if the required visual reference is not established. This, of course, allows the aircraft to be below the MDA while transiting to the missed approach on a procedure that was developed requiring no descent below MDA unless the required visual reference is established. No acceptable or unacceptable height loss parameters are identified or stated within this authorization. This situation raises the first safety concern regarding VNAV.

VNAV SAFETY CONCERNS

Descents below MDA without the required visual reference

In all ICAO States' regulations, descents below the traditional non-precision approach MDA is strictly prohibited without the required visual reference. These regulations governing pilot actions regarding MDA are consistent with and support the instrument procedure design criteria of non-precision approach procedures.

Descents below MDA on instrument approach procedures that have not been assessed for obstacles for IMC descents below the published MDA

One of the reasons that the required obstacle clearance for a precision approach (ILS) procedure is less than that of a non-precision approach is that on a precision approach, the vertical guidance is provided by a signal-in-space ground-based transmitter. This signal-in-space glide path is not affected by altimeter errors associated with VNAV and is monitored and flight checked to ensure compliance with the standards. The instrument procedure development criteria recognizes this and appropriately applies a reducing obstacle clearance requirement in the final segment as compared to a non-precision approach flat required obstacle clearance.

Non-precision approach minimum altitudes are designed without recognition of any vertical guidance, VNAV or otherwise. A controlling obstacle within the final approach segment may be located anywhere along the segment and any descent below MDA in IMC could place the aircraft in direct conflict with that obstacle. The lowest required obstacle clearance (ROC) on a non-precision approach (LOC and VOR with FAF) is 250 feet above the controlling obstacle within the final approach segment. This 250-foot ROC is guaranteed only when the conditions under which the procedure is flown are ISA. Under normal operating conditions, the ROC may be more and can be less than the 250 feet.

MDAs are recognized world-wide as a "do not descend below" altitude under IMC. This recognition is consistent with all non-precision approach procedure design.

If descents below MDA in IMC are permitted, what is the minimum acceptable height loss below MDA?

FMS and NMS computed non-precision approach descent paths that ignore step-down fix altitude restrictions and which, in some cases, cause premature descent below these step-down fix altitudes resulting in loss of designed obstacle protection

All database instrument approach procedure minimum altitudes are encoded by a commercial vendor without any certification process to ensure correctness or integrity of the data. Many errors have been

found in current aircraft approach databases - some errors were minor and not safety related; others were major and seriously affected the safety of flight. A recent case in point resulted in the following service bulletin alert:

> *"Certain FMSs and NMSs compute an NPA glidepath, or pseudo-glideslope, as a straight line between the Final Approach Fix (FAF) and the Missed Approach Point (MAP) altitudes as coded in the Jeppesen approach database. During NPA operations, vertical deviation guidance is provided to this path.*
>
> *A problem has been noted in that some charted approaches include step-down fixes with altitude restriction which penetrates this computed glidepath, and therefore the vertical guidance provided by the FMS/NMS will cause premature descent below these step-down fix altitudes, thus resulting in the loss of some obstacle protection. These step-down fixes are not currently coded as part of the approach procedure database included in the FMS/NMS.*
>
> *If the published approach procedure contains one or more step-down fixes between the Final Approach Fix and the Missed Approach Point, DO NOT USE vertical guidance provided by the Flight/Navigation Management Systems. Fly Non-Precision Approach procedures based on the Pilot's Altimeter and the applicable published approach procedures."*

VNAV operations conducted on non-precision approaches do not address the issue of database errors and how to mitigate these hazards.

Flight crew confidence of flying VNAV and its association with an "ILS-look-alike"

Much has been written and said about computer generated vertical guidance being an "ILS-look-alike." In actual fact, VNAV and its presentation to the pilot in the cockpit does look like an ILS. While this kind of presentation may be desirable, it introduces human factor issues that the cockpit display design engineers may not have considered.

Witnessing a number of modern aircraft cockpit procedures while the crews were operating the VNAV capabilities of the aircraft, it became evident in these cases that the crew were flying the VNAV with the confidence and comfort of an ILS glidepath presentation. While this may be harmless and, indeed, desirable at altitudes that are not associated with obstacle clearance, it is this same confidence that may be detrimental to the safe operation of the aircraft on a non-precision approach flown with VNAV.

VNAV is not the same, in any way, shape or form, as an ILS (or MLS) glidepath yet cockpit procedures do not address or recognize this difference. ILS (and MLS) glidepath is a signal-in-space; VNAV is not. ILS procedures are obstacle protected for descents below published DH; flying VNAV on non-precision approaches and using MDA as a DH are not protected. ILS precision approach procedures do not have step-down fixes in the final segment; non-precision approaches do and VNAV does not address these step-down fixes. The integrity of the ILS glidepath is checked and monitored; database derived VNAV does not have any integrity.

It is apparent that flight crews do not appreciate the limitations of VNAV and do not address these limitations when briefing for an approach using VNAV.

VNAV Database Minimum Flight Altitudes

VNAV information is retrieved from the aircraft's database or, in some cases, from a VNAV command input into the Flight Management System made by the flight crew. Extending the VNAV capability of

the modern aircraft avionics to the approach phase of flight raises a number of database issues that have not been resolved as yet.

All database minimum flight altitudes are encoded by database vendors based upon the State source aeronautical information for a particular procedure. All instrument approach procedures are developed to provided the MINIMUM flight altitude for each segment of a procedure. Database suppliers encoded this minimum flight altitude into the aircraft's database. This, of course, does not mean that the aircraft must be flown at these minimum IFR altitudes. In fact, correction factors are assumed to be applied. PANS-OPS VOL I states, in part, "*3.5.4.5.2. It is assumed that the aircraft altimeter reading on crossing the fix is correlated with the published altitude, allowing for altitude error and altimeter tolerances.*" Table III-3-3 in PANS-OPS VOL I details values to be added by the pilot to published altitudes in feet.

Since the database reflects only published altitudes, operating an aircraft in a VNAV capacity on a non-precision approach will mislead the pilot unless the pilot takes some corrective action to add values to the database altitudes. Adding a correction value to published altitudes in a conventional operation of aircraft, i.e., without VNAV, is a fairly easy matter - not so when dealing with VNAV and databases.

Remote Altimeter Sources

Instrument approach procedures may be developed based upon local and/or remote altimeter sources. A database minimum flight altitude problem occurs when the procedure is based upon a part-time local altimeter and a remote altimeter source at other times. Database suppliers will encode only those altitudes that are published on the instrument procedure chart, therefore if the procedure is to be flown based on a remote altimeter source, the procedure database altitudes presented to the pilot are in error and no message is transmitted to the pilot that will alert him/her of the database error.

Cold Temperature Corrections

Minimum flight altitudes within an aircraft database are accurate only under ISA conditions. PANS-OPS VOL I & II clearly state the corrections needed to the altimeter under non-ISA conditions. These corrections are easily applied to the conventional, non-VNAV, aircraft by simply adding the correction value to the published altitude and flying the result on the barometric altimeter.

Adding a correction factor to the aircraft VNAV database is not that easily accomplished or, in fact, desirable. The computer calculation of VNAV is based upon the altitudes encoded within the database. Therefore, the VNAV presentation to the pilot will be incorrect in all cases should a correction factor be needed on the procedure. Having the crew manipulate the aircraft database within the terminal area at a time when pilot workload is already high is undesirable.

A method of accounting for correction factors to the aircraft minimum flight altitude database must be developed.

RECOMMENDATIONS

In the spirit of reducing CFIT related accidents, the conduct of VNAV operations on conventional non-precision approaches must be introduced and conducted with care and full knowledge of the capabilities and limitations of the aircraft VNAV system. Furthermore, flight crews must respect all minimum flight altitudes associated with the non-precision approach, no matter what vertical guidance information may or may not be present. It becomes quite obvious that aircraft technology has surpassed the concepts under which most non-precision approach procedures have been developed.

I solicit the support of the Working Group in addressing CFIT and instrument procedure design to put forward to the ANC the following recommendations:

1. In order to comply with the intent and spirit of aviation regulations and non-precision approach procedure design, non-precision approach VNAV operations must be conducted in such a manner so as not to violate the minimum descent altitude unless the required visual reference has been established. This will necessitate adding a factor to the MDA that equals the height loss during the conduct of a missed approach procedure. This will permit the aircraft to execute a stabilized approach, and under all weather conditions where the ceiling is above the MDA, no penalty is placed on the operation. There is a trade-off between flying a stabilized approach and accepting a missed approach under weather conditions that equal the MDA. This approach to VNAV operations is consistent with State regulations, the non-precision approach procedure design philosophy and international application of MDA.

2. Flight crew cockpit VNAV approach procedures must include, in the approach briefing, limitations and cautions associated with flying VNAV non-precision approaches. Limitations and cautions should include but not be limited to:

    a. effects of temperature corrections;
    b. remote altimeter setting application, if required;
    c. step-down fix altitude restrictions;
    d. height loss factor and application to MDA; and
    e. database altitude confirmation and its correctness related to the published instrument approach chart.

3. Request aircraft and avionics manufacturers to provide data on the design of VNAV in order to facilitate development of instrument procedure criteria that will accommodate VNAV capability. This VNAV data should include the accuracy, integrity and continuity that is common to other navigation aids and the associated instrument procedure.

4. OCP to develop obstacle clearance criteria specifically for VNAV approaches.