Federal Aviation Administration Implantation of RNAV Procedures and "Q" Routes March, 2004

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ABSTRACT

The FAA in an effort to increase the efficiency of the National Airspace System (NAS) has begun implementation of additional en-route, terminal, departure and approach procedures. These additions utilize a mix of new technology, (GPS, WAAS) and resources that exist (DME) in the NAS. This paper shall describe the tools, techniques, procedures and policies put in place to accomplish this effort. These include the use of RNAV-PRO™ a specialized program designed and implemented to provide modeling of NAS infrastructure to ensure sufficient NAS resources are available to support the projected procedure. The upgrades to the AVN flight inspection system used to verify the assumptions made by the modeling system and the policies, tolerances, and reporting in place to support the commissioning of these new procedures. The paper shall reference and describe several industry and academic studies conducted in an effort to standardized avionic equipment performance levels and define NAS infrastructure requirements.

PURPOSE

To provide an overview of the preliminary and ongoing work conducted by AVN and other FAA organizations in pursuit of broadening the available navigational and procedural resources to the flying public.

BACKGROUND

The acronym RNAV (area Navigation) has been in the aviation industry for decades. Early RNAV systems integrated the available ground based navigational resources along with on aircraft sensors to produce a best-known position. These systems where generally limited to large transport class aircraft being used in the intercontinental segment of the aviation business. Several factors, availability of ground navaid resources, air traffic control limitations, and cost of aircraft equipment limited early utilization of these integrated systems. With the advent of reduced aircraft systems costs, where significant improvements in the air traffic and navigation aid infrastructures RNAV capabilities can now become a major component in the U.S. airspace system. Providing increased air traffic flexibility and safety.

With the implementation of Required Navigation Performance (RNP) route widths (i.e., RNP 1.0 or less), the DME ground infrastructure will require additional attention to insure that ground facility infrastructure is adequate to support the required accuracy and integrity. ICAO Annex 10 and FAA Order 8200.1A have established the DME facility tolerances; however, many other issues are involved. Some of the issues raised are DME facility Operational Service Volume (OSV), survey accuracy, survey requirements in conjunction with the relocation of a DME facility, the ability of an FMS to reject (blackball) a facility which does not meet signal requirements, interference encountered when operating outside a facilities frequency protected service volume, NOTAMS, and tools for assessing the DME infrastructure used to support a procedure.

SUBJECT

1. RNAV Procedures Development

The development of RNAV, Q Route, Standard Instrument Departures (SID), and Standard Terminal Arrivals (STAR) procedures involves several FAA organizations, this paper will provide an overview of the process starting with orders covering criteria produced by FAA Flight Standard Services AFS-400, Submission of proposed procedures by FAA Field Procedure Offices (FPO), implantation of these criteria into approach and Departure procedures by AVN-100 using the IAPA development system and flight inspection procedures for commissioning prior to publication.

a. RNAV Route Criteria

The FAA order 8260.44a establishes the guidance and provides the departure construction criteria for the development of RNAV SID procedures. FAA order 7900.09D establishes the guidance and provides the Arrival construction criteria for the development of RNAV STAR procedures.

b. RNAV DME/DME Design

The design of RNAV procedures are supported by multiple DME facilities providing a computed position for operation in a Required Navigational Performance (RNP)

environment. The procedure is developed under FAA Order 8260.44A to Level 1, 2 or Level 3 criteria. Each of these levels corresponds to an RNP value: 1.0, 2.0, and 0.3 respectively.

The viability of an intended procedure is initially determined through the use of modelling software such as RNAV-PRO™ where the intended route is used to derive the available DME ground facilities that will support the procedure. The intent is that the RNAV-PRO™ evaluation tool will be available to the FPO's on a Web based server. The model uses geometric, facility restriction, service volume, and geodetic qualifiers. The model applies the performance criteria established for RNAV DME/DME systems as defined in FAA AC 90-USRNAV appendix 1 for Type A procedures and appendix 2 for Type B procedures. The model also excludes DME facilities associated with ILS, non-U.S. NAS and DOD TACAN facilities. The ILS exclusion is due to the potential alteration of ranging data to provide correlation with runway threshold distances. The TACAN exclusion is due to the status of these facilities as it relates to the US National Airspace System (NAS). Foreign facilities are initially excluded until such time as the compliance with ICAO standards can be determined. Mitigation for the exclusion of DOD facilities can be achieved by inter-agency maintenance agreements. ILS DME usage will be permitted only when insufficient en-route DME infrastructure is determined and only in the departure procedure route structure. The DME facilities identified by the model are provided to flight inspection operations as part of the commissioning procedure package. The anticipated DME's are provided to the flight inspection system in the form of a Comma Separated Variable (CSV) file. Along with the DME identifiers information concerning the criticality, Expanded service volume, and comments on selected DME's are included. The intended route is also defined, with transition points, waypoint names, and geodetic positions are provided.

d. Sample Procedures

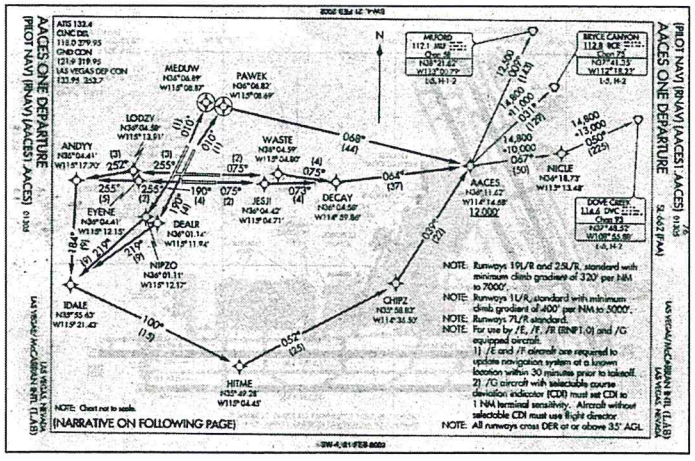

Figure 1: RNAV Departure Procedure

2. Flight Inspection System.

The FAA Flight Inspection fleet contains several different aircraft types (B300 King Air, Lear 60, Bae 800-125, Challenger Cl601) these aircraft perform the AVN flight inspection mission both domestically and internationally. Although these aircraft have diverse performance and flight endurance capabilities, the flight Inspection system configuration and capability are consistent. The flight inspection system uses a combination of real-time Global Positioning System (GPS)/Inertial Reference Unit (IRU) hybrid position, DME/DME, pseudo-time IRU velocity measurement, and DGPS as the truth system during flight inspection. The RNAV inspection mode is comprised of a WAAS precision approach mode and a DME/DME sub-mode.

a. RNAV DME/DME

The Flight Inspection System (FIS) configuration for DME/DME RNAV inspection utilizes the real-time IRU hybrid position as the truth system, the flight inspection systems digital TACAN and the multiple facility capability of a transport grade DME-900 transponder. In the DME/DME mode the flight inspection system is restricted to GPS/IRU hybrid positioning due to the extensive use of the single flight inspection DME unit and the accuracy provided by the IRU hybrid position.

The flight inspection systems digital TACAN is used to measure the multiple DME facilities signal strength. The system supports en-route "Q", SID'S, STAR's, and approach procedures conducting analysis of up to five DME facilities simultaneously. The flight inspection system receives flight plan waypoint identifiers from the Flight Management System (FMS) or directly from the uploaded CSV file, after designation by the system operator of the start waypoint and end waypoint the system uses the segment data elements in the CSV file to incrementally select the intended DME's. For segments containing less than five DME's a search of the flight inspection system database is initiated based on the geodetic position of the aircraft in an attempt to acquire additional DME's. The operator can edit the provided list of DME facilities if required to insure that the facilities under inspection match those selected for the procedure.

The FIS computer configures the FI DME for directed frequency mode tuning each of the five available slots to one of the selected DME's. While in the directed frequency mode the DME will continually acquire and track each station for a period of 100ms. This provides updated distance data at a minimum rate of 2 Hz when 5 facilities are tuned. The FIS digital TACAN is also tuned to each facility under inspection reporting the facilities signal strength for a 5 second period then re-tuning each facility in a round robin routine.

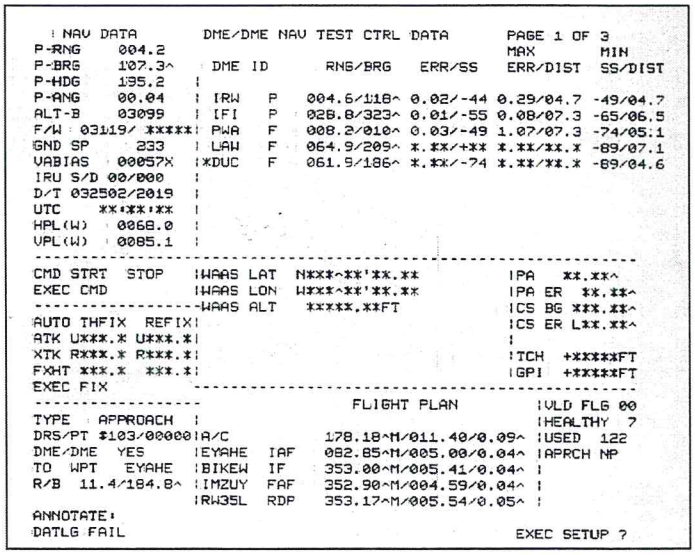

Figure 2: DME/DME Inspection page

The system provides a station "HOLD" functions allowing constant monitoring of an individual facility interrupting the signal strength scan. The system also decodes and verifies that the tuned stations are transmitting the proper Ident. code. The DME/DME inspection page provides the operator with real-time range/bearing to the facility, current error and signal strength. The maximum distance error and minimum signal strength are recorded at the distance from the selected Facility.

The five facilities under inspection have corresponding plots for Distance Error, Signal Strength, and Status. The plot also contains a FI range mark representing the distance from the selected waypoint leg pair in .1nm increments, with 1nm-enhanced marks. The DME status trace for each of the five DME facilities provides an indication of the flight inspection DME receivers state during the entire scan cycle. Reported states indicate normal operation, Coast, or No Computed Data (NCD). The Status trace when reporting normal operation underlies the DME error trace providing an easily recognizable zero error baselines.

The AFIS monitors the parameters and applies the following tolerances and will generate an operator alert when tolerances are exceeded.

DME Parameter	Alert Level
Distance Error	> 0.1 nm
Signal Strength	< -80 dbm
Facility Ident.	No Ident. > 45 sec.

Table 1: DME/DME Tolerences

The system utilizes data from the input CSV file pertaining to the performance (ESV request) and criticality of selected DME's. DME's designated as critical must remain locked on for the entire segment. DME's requested for ESV are monitored for performance with required ESV reporting data being generated. The ESV data is used in the post mission analysis to approve the ESV request from spectrum management.

During each leg the system uses the guidance from AC 90-USRNAV and RTCA/DO-236A Minimum Aviation System Performance Standards Required Navigation Performance for Area Navigation, to compute a Position Estimated Error (PEE) and verify the DME infrastructure can support the computation of a valid position based on the minimum and advanced FMS performance criteria. The system produces a "Leg Summary report" containing Critical DME status, ESV reporting data, Minimum and advanced FMS performance status, and PEE summary. The RNP level of the procedure determines the FMS performance and PEE limits.

The system digitally records all position and inspection information to a removable media for post mission analysis when required.

b. AFIS RNAV-Pro output

The AFIS produces an output CSV file for feedback to the RNAV-Pro program. This file will be used if the flight inspection shows that projections of NAS infrastructure by RNAV-Pro will not support the intended procedure. The data will be used to re-evaluate the models used and make adjustments to the prospective procedure to improve its performance.

CONCLUSIONS

The incorporation of additional procedures into the U.S. National Airspace System (NAS) will provide additional resources for the air transport and private aviation communities. The merge of both conventional and space based navigation resources in the RNAV environment posses' challenges to both the flight inspection and regulatory branches of all aviation authorities. With the ever increasing use of integrated navigation solutions, where aircraft systems manage and utilize ground based, aircraft autonomous and spaced based navigational resources the certification and regulatory side of the aviation industry must remain ever vigilant. The increased use of RNP criteria on terminal airspace, air routes, and approach procedures will increase airspace efficiency and safety.

REFERENCES

[1] FAA Order 8260.48, Area Navigation Approach construction Criteria.

[2] TM3500-071 AFIS System Description Manual, Parker Haniffin Corp.

[3] TI4040.55 FAA AFIS Technitions User Manual

[4] TI4040.56 FAA AFIS Pilots Guide

[5] FAA 8200.1A, Flight Inspection Manual

[6] Draft FAA 8200.1° Paragraph 209.32.e (9)

[7] FAA Order 8260.44, Area Navigation Departure criteria

[8] FAA AC 90-RNP RNAV, Operational aproval for Required Navigational Performance Area Navigation (RNP RNAV)

[9] FAA AC 90-USRNAV, US Terminal and Enroute AREA Navigation (RNAV) Operations.

[10] RTCA/DO-236°, Minimum Aviation System Performance Standards: Required Navigation Performance for Area Navigation.