ATTACHMENT 18
Flight Safety Foundation Study

"Enhancing Safety in the 21st Century":
US Airways RNAV / VNAV Initiative
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The Global Baseline

At the 51st Annual International Air Safety Seminar in Cape Town, South Africa, the Flight Safety Foundation (FSF) Approach-and-Landing Accident Reduction (ALAR) Task Force presented its final working group reports. To no one's surprise, approach and landing accidents and controlled flight into terrain (CFIT) were clearly identified as primary causes of most fatal airline crashes worldwide. According to the FSF report, even though the approach-and-landing phase of flight comprises, on average, only 16% of total flight time, approximately 56% of the world's jet fleet accidents to date have occurred in these flight phases. The ALAR working groups consistently noted that non-precision instrument approaches were often associated with CFIT accidents, and that a lack of vertical-position awareness was a significant factor leading to CFIT.

The Data Acquisition and Analysis Working Group (DAAWG) reported on their high-level analyses of 287 fatal approach and landing accidents between 1980 and 1996. One particularly sobering conclusion that emerged from their analysis was that, "among occurrences where data were available, three-fourths of the accidents happened where a precision-approach aid was not available or was not used." The working group also conducted detailed case studies of 76 accidents and serious incidents that occurred between 1984 – 1997, and concluded that "lack of positional awareness" -- which generally implied lack of vertical-position awareness -- was the fourth most frequent causal factor for these accidents. A key recommendation from the ALAR Task Force was that ***"the implementation of certified constant-angle, stabilized-approach procedures for non-precision approaches should be expedited globally."***

The U.S. Situation

Within the same timeframe, the FAA conducted its own internal review of the causes of aviation accidents. In mid-1998, a high-level U.S. team that included Vice President Al Gore, Transportation Secretary Rodney Slater, and FAA Administrator Jane Garvey, unveiled to the American public a new safety program entitled: ***Safer Skies – A Focused Agenda.*** The goal of *Safer Skies* is to bring about a five-fold reduction in fatal accidents over the next decade. In partnership with industry, *Safer Skies* uses the latest technology to analyze U.S. and global data to find root causes of accidents and determine the best actions to break the chain of events that lead to accidents. "The steps we are announcing … will make the safest skies in the world even safer," Vice President Gore said. "By targeting and preventing the leading causes of fatalities and injuries… we will significantly reduce the number of plane crashes and save hundreds and

hundreds of lives."

Because *Safer Skies* is intended to be a roadmap for a focused priority safety agenda, it allows FAA to focus resources on a limited number of safety areas that hold the most potential. The three focus areas include commercial aviation, general aviation, and cabin safety. Specifically, the commercial aviation initiative focuses on controlled flight into terrain (CFIT), loss of control, uncontained engine failures, runway incursions, approach and landing, and weather.

A Joint Safety Implementation Team (JSIT), comprised of a varied cross-section of government and industry representatives, was convened to develop a set of recommendations that will define the agenda and timeline for the commercial aviation initiative. While the JSIT's report has not yet been released, one of its key recommendations is expected to mirror that of the ALAR: ***"the implementation of certified constant-angle, stabilized-approach procedures for non-precision approaches should be expedited."*** Specifically, RNAV/VNAV (area navigation with vertical navigation guidance) procedures are likely to be endorsed in lieu of traditional non-precision procedures.

A New Paradigm

US Airways made a corporate decision in January 1998 to jump-start national implementation of RNAV/VNAV procedures in the United States, and contracted with Crown Consulting, Inc. to complete obstacle assessments for all domestic airports that are either part of the US Airways route network or a divert airfield. When this initiative is complete in early 2000, US Airways will be able to fly RNAV/VNAV approaches to more than 400 domestic and Caribbean runways.

In January 1999, US Airways became the first major carrier to routinely use the sophisticated capabilities of the Airbus Flight Management System (FMS) to provide an alternative to traditional non-precision approaches. US Airways was the first carrier to discontinue use of non-precision approaches by an entire fleet of aircraft when the FAA's Flight Standards Service granted operational approval to super-impose RNAV procedures over existing instrument landing system (ILS) approaches. The US Airways initiative uses combined RNP 0.3 lateral navigation (LNAV) guidance with barometric vertical navigation (BARO VNAV) guidance to provide a backup approach procedure with vertical guidance at all ILS runways. It also establishes RNP 0.3 approaches for all runways with existing non-precision localizer, localizer back course, and localizer directional approaches (LDA). The new procedures overlay the ILS localizer and use the FMS for vertical guidance, providing a constant angle descent to the runway.

By using the sophisticated capabilities of the Airbus FMS to provide an alternative to non-precision approaches, US Airways has significantly reduced the risk of controlled flight into terrain (CFIT) when ground-based precision landing systems are out-of-service. When the ILS approach is inoperable, the pilot will still be able to fly a near-precision approach that emulates the ILS, using the aircraft FMS. Transition to all 3-D approaches means US Airways Airbus pilots no longer fly conventional non-precision (e.g., VOR, NDB or localizer-only) approaches. The regulatory requirement for back-up approach capability when the ILS is not available is met through near-precision RNAV approaches with 3-D guidance provided by the FMS. This has allowed US Airways to eliminate traditional non-precision approaches from the Airbus training

curriculum.

Regulatory Guidance

The FAA's operational approval is based on several documents, including draft Advisory Circular (AC) 120-29A, FAA Order (FAA) 8260.47, and the US Airways Operations Specifications. These documents provide the guidance for developing and obtaining approval for RNP 0.3 instrument approach procedures as well as training for the aircrew.

LNAV guidance is contained in the Appendix 5 of draft AC 120-29A, Criteria for Approving Category I and Category II Landing Minima for FAR 121 Operators. The lateral area on either side of the approach centerline for RNP airspace is twice the RNP. For RNP 0.3 approaches, this area is defined as 2 x 0.3 nautical miles (NM) or 0.6 NM.

To fly RNP 0.3 approaches, the aircraft must have a qualified LNAV system. The LNAV system must meet a two-dimensional accuracy requirement equal to or less than 0.3NM with 95% probability. The following LNAV systems meet this criterion:

a. GPS certified under AC120-38, Airworthiness Approval of GPS Navigation Equipment for Use as VFR and IFR Supplemental Navigation System.

b. Multimode receivers (MMR) using Inertial Reference Units (IRU) in combination with DME/DME or GPS certified under AC-20-130, Airworthiness Approval of Navigation or Flight Management Systems Integrating Multiple Navigation Sensors.

c. RNP systems approved for RNP 0.3 NM operations or less.

The BARO VNAV guidance comes from FAA Order 8260.47, Barometric Vertical Navigation (VNAV) Instrument Procedures Development. BARO VNAV requires a navigation system which presents computed vertical guidance to the pilot referenced to a specific Vertical Path Angle (VPA). The computer resolved vertical guidance is based on geometric altitude and is either computed as a geometric path between two waypoints or an angle from a single waypoint. Although every effort is made to obtain an optimum VPA of 3.00^{o} the VPA may be established between 2.75^{o} and 3.77^{o}.

To use BARO VNAV, the aircraft's VNAV system must be certified for approach operations under AC 20-129, Airworthiness Approval of Vertical Navigation (VNAV) Systems for Use in the US National Airspace System (NAS) and Alaska. A database contains the waypoints and associated VNAV information including the altitudes and VPA. Once the aircrew selects the procedure, the approach automatically loads into the navigation system flight plan.

Because the barometric altimeter provides input to the system, altimeter errors must be considered. Two sources of altimeter error are remote altimeters and the effects of cold temperatures. Remote altimeters are not authorized for any BARO VNAV approaches.

Using a temperature deviation (T_{DEV}) mitigates the effect of cold weather. The T_{DEV} for each airport uses the mean low temperature of the coldest month of the year for the past five years. After calculating the T_{DEV}, the temperature limitation or T_{LIM} for the airport is also determined. The T_{LIM} provides the minimum temperature that the VNAV approach can be authorized. Rarely, a below average low temperature will prevent operations into an airport.

The BARO VNAV order provides a minimum of 250 feet required obstacle clearance (ROC) above all obstacles. The ROC may be increased based on the T_{DEV} and the height of the obstacle above the airport. Airports with a low T_{DEV} and high obstacles require a higher ROC. In addition to the ROC, the RNP guidance provides for an additional 50-foot buffer in the Decision Altitude (Height) (DA (H)). This buffer accommodates the momentary loss of altitude that occurs as the aircraft commences the missed approach.

For the RNP 0.3 approaches, some modifications to the BARO VNAV criterion are made by RNP guidance. These RNP unique modifications include the requirements for vertical guidance across the entire lateral area, a single-engine missed approach, and a single-engine rejected landing.

This FAA has provided approval and guidance to US Airways through the US Airways Operations Specification (OPS SPEC). Section C089, Terminal RNAV Instrument Approaches Using an Area Navigation System Approved for RNP Operations, describes the aircraft equipment and limitations for conducting the RNP approaches. The provisions for conducting the obstacle assessments and a listing of the approved RNP Approaches are found in Section C090, Terminal RNP Instrument Approach Operations Using Non-Part 97 Obstacle Assessments.

ICAO Document 9613 defines RNP as a statement of the navigation performance accuracy necessary for operation within a defined airspace. In order to conduct RNP operations, the aircraft must be equipped with certified equipment and a properly trained aircrew. Only an aircrew flying a RNP 0.3 capable aircraft may fly the US Airways RNP approach procedures. Before commencing an RNP 0.3 approach, the aircraft's Estimate of Position Uncertainty (EPU) must be less than 0.3. EPU is a measure, based on a defined scale in nautical miles or kilometers, which conveys the current position estimation. EPU is also known as estimated position error (EPE) or actual navigation performance (ANP). If EPU exceeds the RNP at any time during the approach, the aircrew is alerted by a warning message and must terminate the approach.

Obstacle Assessments

Several differences exist in the construction of the RNAV/VNAV (or RNP 0.3) approaches. These differences include the sensitivity of the approach, the dimensions of the lateral obstacle clearance area (OCA), and the application of the vertical guidance. RNP approach criteria differs significantly from the FAA's Terminal Instrument Procedures (TERPS) criteria normally applied to instrument approach procedure development. Because other instrument approaches are based on ground-based navigational equipment, trapezoids with primary and secondary areas are used as OCA. These OCAs of the angular trapezoids decrease in size as the accuracy increases near the navigational facility. Unlike the ILS, the RNP 0.3 approach is linear instead of angular; the

RNP 0.3 navigation system remains constant as the aircraft approaches the runway. Vertical position accuracy is a function of the aircraft's equipment and the height of the aircraft above the ground. Aircraft using RNP guidance also receive positive course guidance throughout the missed approach.

Why a Commercial Solution?

Development of instrument procedures is an inherent government responsibility. No airline wants to be in the procedures development business over the long-term. However, US Airways selected a commercial path to implementation as the most expedient means to an end. To ensure that an adequate number of procedures were in place to support the introduction of the Airbus fleet into revenue service, and to ensure that the pace of procedures development kept pace with the rapid expansion of the Airbus route network, the only viable alternative was to award a contract to a well qualified vendor with extensive procedure development expertise.

Pursuit of a commercial solution (at least as an interim step) probably accelerated the timeline for implementing a national network of RNAV/VNAV procedures in the United States by at least three years. US Airways considered the safety and training benefits important enough to justify the financial investment. Key benefits are summarized below:

- Air carriers are required to provide aircrews with training for each type of approach authorized by the FAA. This typically includes both precision and non-precision approaches. Because the RNP 0.3 approach display and procedures are virtually identical to the ILS approach, US Airways has received authorization from the FAA to delete training for traditional non-precision approaches.
- The elimination of the non-precision approach simplifies pilot training and enhances safety by virtue of the operational and procedural similarities of the RNAV and ILS approaches. The complexity of learning five or more approach types is now reduced to only one approach type - and it is the safest one, providing both horizontal and vertical guidance.
- Eliminating non-precision approaches increases safety by reducing or eliminating unstabilized approaches that can lead to controlled flight into terrain (CFIT) accidents. Both the Korean Air accident at Guam and the recent Thai Airways accident in Thailand might have been averted if an alternative precision approach capability had been available when the ILS was out-of-service.
- Because commercial aircrews rarely fly non-precision approaches, the potential for errors in crew coordination is high. Repeating the same crew coordination and using the same techniques for each precision ILS or RNAV/VNAV approach decreases the potential for human error. The chance of error is further reduced because the RNAV/VNAV approaches are accessed through the FMS database, which means that the crew does not have to manually input a navigational frequency or course into the FMS.
- The likelihood of diversions is reduced. By flying an approach using a constant angle, stabilized descent, the aircrew remains well clear of obstacles, is placed in the optimum position for acquiring the runway environment, and reduces the requirement to maneuver in close proximity to the ground.

It's also important to note that introduction of these procedures was virtually transparent to the controller work force. Because the US Airways' RNP approaches overlay the localizer approaches, the RNAV/VNAV approach being flown by the pilot looks exactly like an ILS approach to the air traffic controller. The only difference is that the controller now clears the pilot for an "RNAV approach." For this reason, the amount of air traffic control training required before the RNP approaches may be instituted is minimal.

Next Steps

Despite the fact that the obstacle assessments of the RNP containment area were conducted by a commercial vendor, the US Airways RNAV/VNAV initiative has been a model of government – industry partnership. The collaborative effort between the airline, the FAA's Flight Standards Service and the Air Traffic community enabled these procedures to be introduced quickly, efficiently – and with no adverse impacts either on the flight deck or at the controller work station. US Airways Airbus crews fly these procedures daily.

The more than 300 RNAV/VNAV procedures produced thus far are currently identified as "specials" for US Airways. However, with FAA approval they could also be flown by other airlines and by high-end corporate or general aviation operators. Several other carriers have expressed interest in using these procedures with their RNP-certified new technology aircraft. Because this initiative is such an important component of CFIT risk reduction, US Airways has offered to work with the FAA to transfer responsibility for maintenance of these procedures to the Aviation System Standards (AVN) organization so that the procedures may be used by any operator with suitable equipage.

Working together, US Airways and the FAA are closing out the old millennium with a dramatic step toward the Flight Safety Foundation's goal of reducing controlled flight into terrain accidents. It would be very appropriate to usher in the new millennium by beginning the process to migrate that capability throughout the rest of the world.