AN EVALUATION OF HEAD-UP DISPLAYS IN CIVIL TRANSPORT OPERATIONS

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SUMMARY

As part of a joint NASA/FAA program to determine the advantages and disadvantages of Head-Up Displays (HUD) in civil transport approach and landing operations, an operational evaluation was conducted on the Flight Simulator for Advanced Aircraft at Ames. Two HUD concepts were evaluated during this study: (a) a non-conformal HUD which contained raw data and Flight Director command information; and (b) a conformal, flight path HUD. Both HUD concepts were designed to permit terminal area maneuvering, intercept, final approach, flare, and landing operations. Twelve B-727 line pilots (Captains) flew a series of precision and non-precision approaches under a variety of environmental and operational conditions, including wind shear, turbulence and low ceilings and visibilities. A preliminary comparison of various system and pilot performance measures as a function of display type (Flight Director HUD, Flight Path HUD, or No HUD) has indicated improvements in precision and accuracy of aircraft flight path control when using the HUDs. The results also demonstrated some potentially unique advantages of a flight path HUD during non-precision approaches.

INTRODUCTION

The experiment reported in this paper is one of a series of studies conducted under a joint agreement between the FAA and NASA. The program was organized into four major phases: Phase I, for which the FAA had major responsibility, was a review of the relevant literature, and an analysis of the major issues surrounding HUD; Phase II, conducted at Ames Research Center, focussed upon fundamental human factors issues related to HUD and upon the development of candidate HUD concepts to be further evaluated in Phase III, which focussed upon the major operational issues associated with HUD and which is the subject of this report. Phase IV of the program consists of flight tests conducted in an FAA aircraft; this part of the program is currently underway, and will be reported in a future report. The following is an overview of the Phase III operational evaluation only. No attempt has been made here to summarize the entire Phase III study, and for complete details, the reader is referred to the final report for that project (ref. 1).

OBJECTIVES

The primary objectives of this study were to determine the benefits of HUDs during manually flown, visually referenced approaches and landings, and to determine potential problems associated with their use. Secondary objectives

included a preliminary evaluation of various ancillary issues, including flight crew operating procedures and flight crew training requirements associated with the use of HUD in jet transport operations.

APPROACH

Two candidate HUDs were developed for use in the Phase III evaluation: (1) a flight path HUD, described in the paper appearing elsewhere in these proceedings by Bray and Scott (ref. 2); and (2) a flight director display, described in reference 3. Both of these HUDs were designed to be capable for use during precision and non-precision approaches. In addition, both displays were designed so that limited terminal area maneuvering and intercept of the final approach guidance could be accomplished using only information on the HUD.

Ten line qualified B-727 captains served as subject pilots for this experiment. Following completion of a comprehensive training program which consisted of handout material, lecture and 35 mm slides, video tapes and simulator training, subject pilots flew a series of precision and non-precision approaches under a variety of environmental and operational conditions, including head-, cross- and quartering tail-winds, ceilings and visibilities near the appropriate minima for the approach type, and various other conditions, including wind shear, variable visibilities and simulated runway incursions. An identical series of approaches was flown for each of the three display conditions (flight path HUD, flight director HUD, and no HUD). In addition to objective measures of aircraft flight path and airspeed control, subject pilots were asked to complete several questionnaires and rating scales during the course of the experiment.

RESULTS

Objective performance measures were analyzed by phase of approach and display type. Statistically significant differences in performance as a function of display type were observed for 23 variables at various stages of the approach and landing. All were measures of either airspeed, lateral flight path, or vertical flight path control. Generally, performance using either of the two HUDs showed improved precision and accuracy when compared to normal, no-HUD approach and landing operations. Significant improvements in vertical flight path control were particularly noticeable for non-precision approaches conducted using the flight path HUD.

Pilot opinion and rating data show strong preferences for the flight path display compared to conventional panel instruments. Opinion was divided with respect to the flight director HUD.

CONCLUSIONS

The preliminary results of the study have indicated that the use of a HUD can result in improvements in the precision and accuracy of flight path control under a variety of circumstances. These benefits were particularly noticeable for the flight path display during non-precision approaches. Other observations and conclusions were made regarding HUD design, training requirements, and operational procedures.

REFERENCES

1. Lauber, J. K.; Bray, R. S.; Harrison, R. L.; Hemingway, J. C.; and Scott, B. C.: An Operational Evaluation of Head-Up Displays For Civil Transport Operations: NASA/FAA Phase III Final Report. NASA TP-1815, 1981.

2. Bray, Richard S.; and Scott, Barry C.: A Head-Up Display Format For Transport Aircraft Approach and Landing. 1980 Aircraft Safety and Operating Problems, NASA CP-2170, 1981. (Paper 9 of this compilation.)

3. Naish, J. M.: A Review of Some Head-Up Display Formats. NASA TP-1499, 1979.