TRANSPORT AIRCRAFT FLYING QUALITIES ACTIVITIES

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ABSTRACT

Three research efforts of interest to transport airplane designers are reviewed. The first study is one in which the optimal-control model for pilot-vehicle systems was used to develop a methodology for predicting pilot ratings for commercial transports. The method was tested by applying it to a family of transport configurations previously evaluated by the Douglas Aircraft Company on their motion-base simulator, and for which subjective pilot ratings were obtained.

The second study is an extension of the first in which specific attention will be given to the development of the simulator program and procedures so as to yield objective and subjective performance data useful for a critical evaluation of the analytical method. This study was started in September 1980

The third activity is a proposed program for investigating the influence of flexible modes on transport aircraft flying qualities. This activity will include control system design, analysis of vehicle dynamics (open and closed loop), motion-base simulator studies, and variable-stability airplane tests.

AIRPLANE LONGITUDINAL STABILITY CHARACTERISTICS

The pilot rating prediction method was tested by applying it to a number of subsonic transport configurations evaluated by Douglas Aircraft Company on a motion-base simulator and for which pilot opinion data had been reported in NASA TM X-73. The configurations typified airplanes with varying degrees of longitudinal stability, and the short-period modal characteristics vary from the conventional oscillatory and well-damped mode to two aperiodic modes with varying divergence rates. Flight path stability, $d\gamma/dV$, ranged from stable (negative) values to divergent values, and the mean pilot ratings varied from satisfactory (2.5) to unacceptable (8.3). The mission simulated was an ILS approach with cockpit motion and turbulence and with constant, satisfactory lateral-directional characteristics.

V = 140 knots W = 1 560 000 N

CONFIG. NUMBER	ω_{sp}	ξ_{sp}	n/α	$d\gamma/dV$	PILOT RATING
1	0.846	0.628	3.80	-0.040	2.5
3	(-0.633)	(-0.307)	4.14	-0.049	4.3
4	(-0.811)	(+0.090)	4.20	-0.051	4.2
5	(-0.909)	(+0.158)	4.24	-0.053	5.3
8	0.811	0.662	4.04	+0.339	8.3
15	(-0.991)	(+0.225)	4.29	-0.055	6.7
16	(-1.061)	(+0.291)	4.35	-0.057	7.7
21	0.441	0.665	1.05	+0.285	6.2

CONSTANT, SATISFACTORY LATERAL-DIRECTIONAL CHARACTERISTICS

ILS TRACKING TASK

COCKPIT MOTION AND TURBULENCE

PARENTHESES SIGNIFY FIRST-ORDER FACTOR

Figure 1

PROCEDURE FOR PREDICTING PILOT RATING

There are five basic elements in the methodology for predicting pilot rating. Task definition requires specification of aircraft configuration, mission, such as landing approach, and atmospheric environment. Subtasks are those elements of the task which may be independently analyzed and evaluated by the pilot and for this study included altitude station keeping, glide slope capture, and glide slope tracking. Definition of performance criteria involves the specification of terms to be included in the quadratic performance index as well as the weighting constants. Performance is then predicted as a function of workload which in this method is defined as mental workload and is synonomous with attention. Several candidate pilot rating expressions for linear combinations of performance and workload were evaluated through comparison with the simulation results.

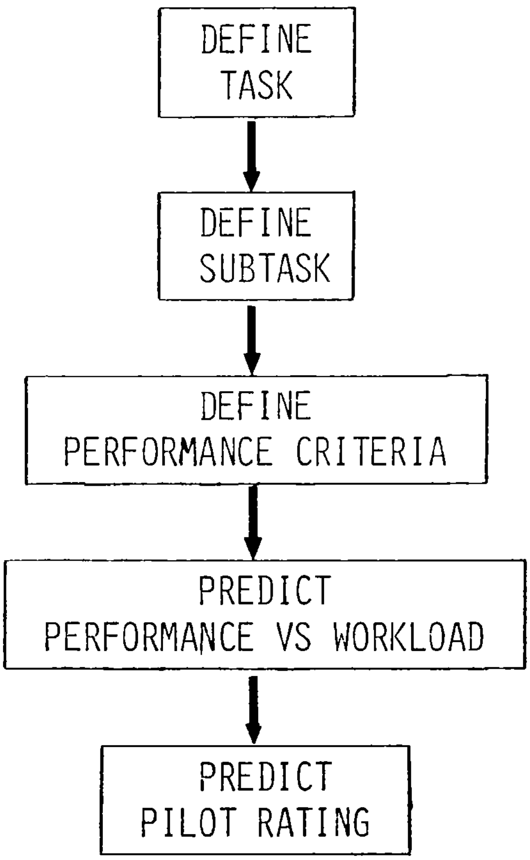

Figure 2

COMPARISON OF PREDICTED AND EXPERIMENTAL RATINGS

Experimental mean pilot ratings and their standard deviations are presented for the test configurations along with predicted values. For most of the test configurations the agreement between the mean experimental rating and the predicted rating is less than one rating number which is certainly good for subjective results. The standard deviations of experimental ratings are unfortunately large for many of the configurations as a result of a small data set and render some obscurity to the comparisons. No explanation is available for the apparent large discrepancy in the data for configuration 8 in which the pilot rating exceeded the predicted value by about 2 1/2 units.

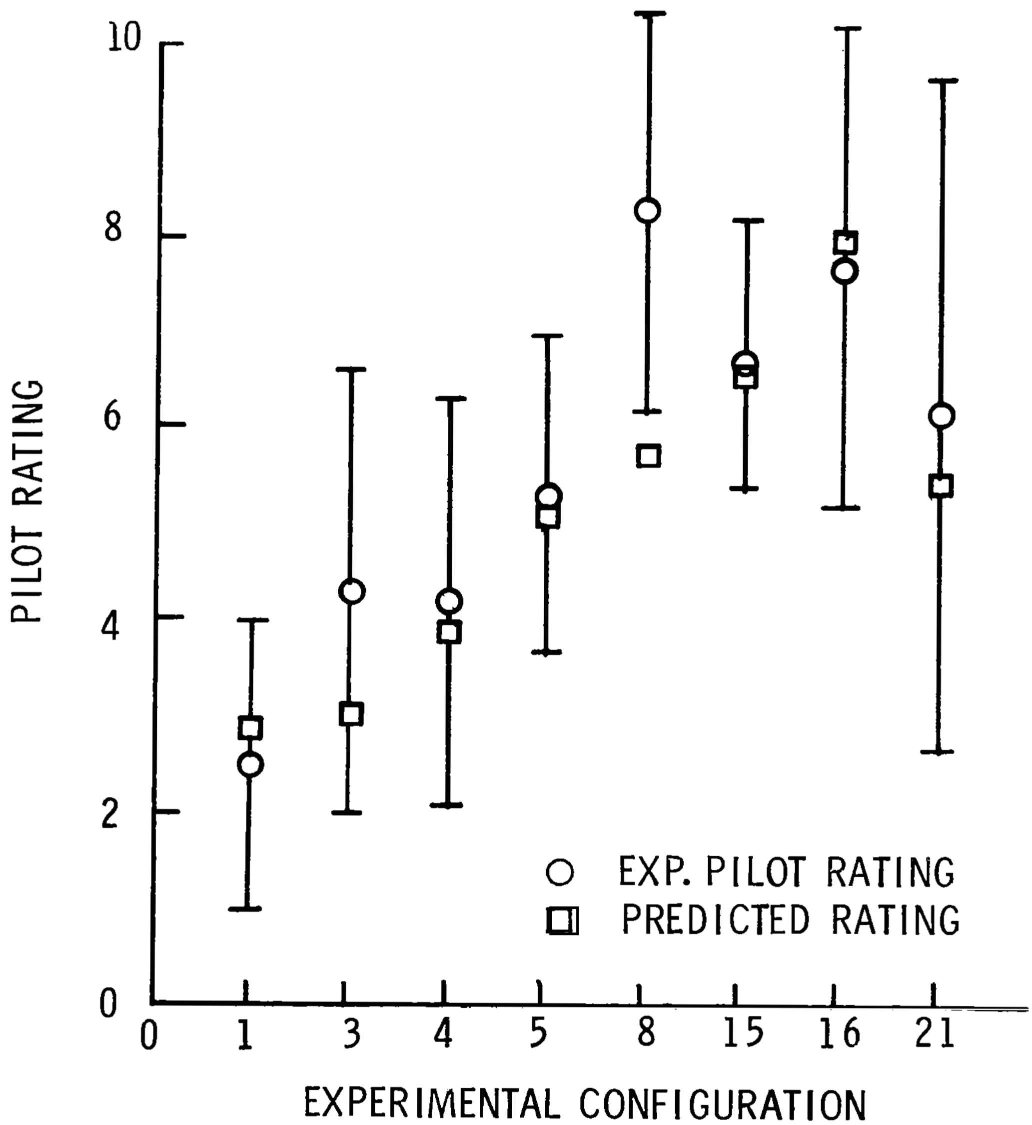

Figure 3

BOLT BERANEK AND NEWMAN/DOUGLAS AIRCRAFT CO. PHASE II STUDY

The results obtained in comparing the pilot rating prediction method with the subjective pilot opinion data from the Douglas study were encouraging and have prompted a follow-on effort in which simulator test procedures will be designed to produce both objective and subjective results in a form compatible to the analytical method. Subtasks will be selected for rating by the pilots, and an attempt will be made to standardize the test maneuvers and the method used in arriving at a composite rating. Performance criteria, or expectations, will be obtained from pilot questionnaires and interviews, and efforts will be made to arrive at a common set of criteria. In all this effort, a significant test pilot participation is essential. A major addition to this program will be the acquisition of quantitative data, which will provide another basis on which to test the analytical method.

<u>EXPERIMENT DESIGN</u>

SUBTASKS

PERFORMANCE CRITERIA

PILOT ROLE

<u>DATA OUTPUT</u>

TIME HISTORIES OF AIRPLANE MOTIONS, CONTROLLER INPUTS

MEAN AND STANDARD DEVIATIONS OF PERTINENT VARIABLES

Figure 4

INFLUENCE OF FLEXIBLE MODES ON TRANSPORT AIRCRAFT FLYING QUALITIES, RIDE QUALITIES, AND PILOT OPINION

Within the Advanced Controls RTOP a program has been initiated to investigate the flying qualities and ride qualities of flexible transport airplanes. This activity will include control system design, analysis of vehicle dynamics (open and closed loop), motion-base simulator studies, and variable-stability airplane tests. The initial effort will be a study of flexible vehicle dynamics for advanced transports to identify flexible and rigid body modes; to ascertain which structural modes influence flying qualities, ride qualities, and control; to determine reduced-order math models of vehicle dynamics for use in piloted simulator studies; and to evaluate capability or limitations of motion-base simulators to replicate vehicle motions. The entire effort is expected to extend over about four years.

MILESTONES:

- ANALYSIS OF VEHICLE DYNAMICS AND PRELIMINARY FLYING QUALITIES CRITERIA, FY 81-82
- DEVELOPMENT OF MOTION-BASE SIMULATOR MATH MODEL, FY 81-82
- CONDUCT MOTION-BASE SIMULATION PROGRAM, FY 82
- DEVELOPMENT OF CANDIDATE CONTROL LAWS FOR FLEXIBLE TRANSPORT, FY 82-83
- CONDUCT IN-HOUSE MOTION-BASE SIMULATOR STUDY TO VALIDATE CRITERIA, FY 83-84
- FSAA OR VARIABLE-STABILITY AIRPLANE TESTS OF FLYING QUALITIES, FY 84-85

Figure 5