NASA/DFRC EVALUATION OF DIGITAL FLIGHT CONTROL SYSTEM DELAYS USING THE DFCS F-8 AIRPLANE

by

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One problem unique to digital flight control systems is the introduction of a pure transport delay due to the sampling and computation cycle. In order to provide information to validate criteria that might be useful for these types of systems, a program was conducted on the DFRC F-8 digital flybywire airplane where the transport lag could be easily varied. Two landing tasks were evaluated: tightly controlled landings where the pilot attempted to touchdown accurately at a given spot; and loosely controlled landings where the pilot accepted large variations in the touchdown point.

The approaches were made at 180 knots with idle power to simulate low L/D approach conditions. The longitudinal control system consisted of a C* command augmentation system. However, it was not optimized for these flight conditions and provided only nominally satisfactory longitudinal handling qualities. Pure transport lag ranging from 0 to 100 milliseconds was added between the pilot and the control system. The results are shown in figure 1 for the two landing tasks. The longitudinal ratings for the loose control task degrade slightly with increasing delay time. The ratings for the more difficult tight control landing task show a significant degradation with increasing delay time in addition to the degradation due to the task.

One promising criterion for correlating these results is the Neal-Smith criterion of reference 1. In this criterion, the pilot is modeled as a lead-lag network and the pilot gain and phase are adjusted to provide good closed-loop response over a given bandwidth. The unknown in the formulation is the relationship between the bandwidth requirement and the task. It is certainly reasonable to assume that the bandwidth requirements will increase as the task becomes more difficult and demanding.

The pilot ratings from figure 1 are compared to the Neal-Smith criterion in figure 2. Two bandwidths were selected which provide a reasonable correlation with the criterion. For the loosely controlled landing task, a bandwidth of 2.5 rad/sec was used and the criterion shows a good correlation with the pilot rating as a function of transport delay. For the tightly controlled landing task, a bandwidth of 3.0 rad/sec was selected. Again, the trend of pilot rating with transport delay correlates well with the criterion.

The results indicate that the Neal-Smith criterion can provide a means of analyzing the effects of pure transport delay in the flight control system. However, further research is needed to establish the relationship between the bandwidth requirements and the task. For situations where the task/bandwidth relatiohnship is know (such as with an existing flight vehicle and task) the method can provide a reasonable means of predicting the effects of control system modifications.

Reference

1. Neal, T. P.; and Smith, R. E.: An In-Flight Investigation to Develop Control System Design Criteria for Fighter Airplanes. AFFDL-TR-70-74, vol. 1, Air Force Flight Dynamics Lab, Wright Patterson Air Force Base, Dec. 1970.

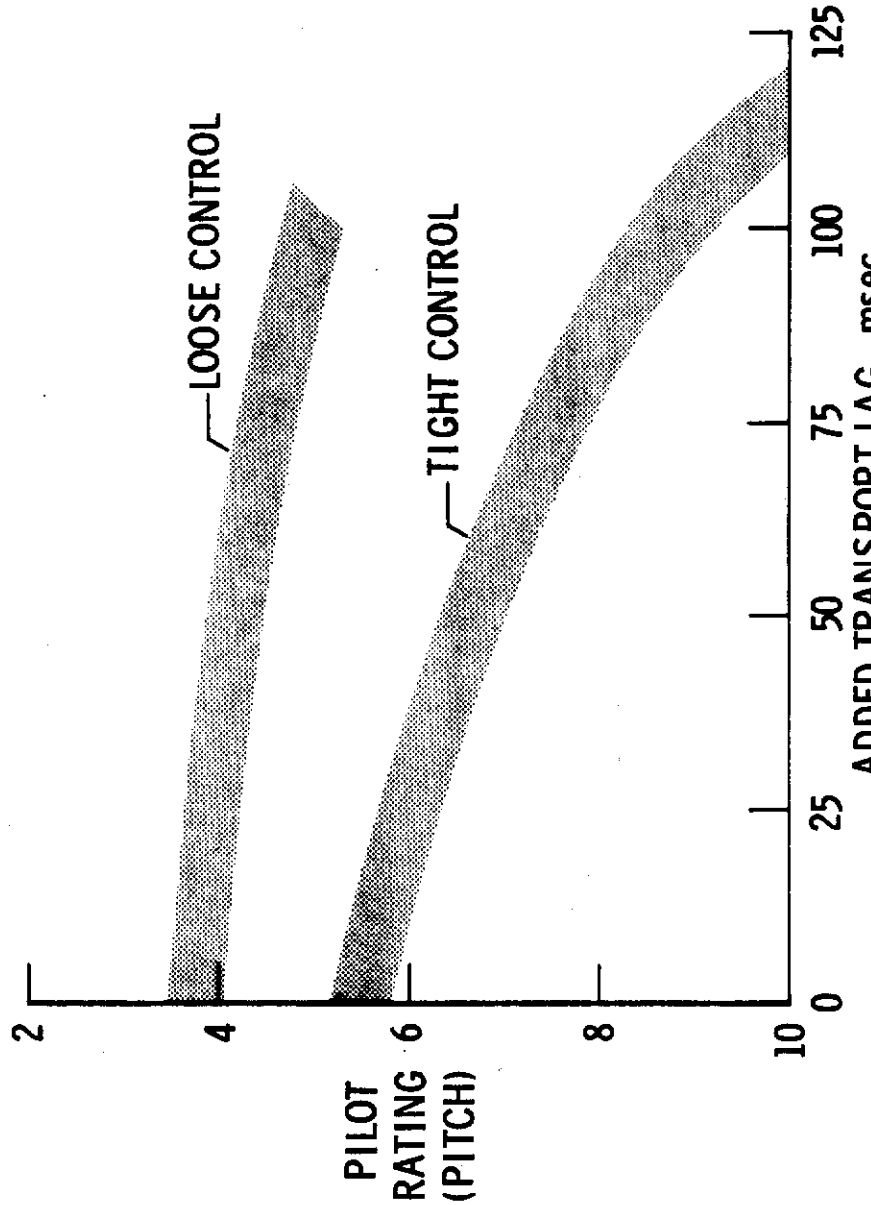

FIGURE 1 - EFFECT OF ADDED TRANSPORT LAG ON F-8 DFBW CONTROL

FIGURE 2 _ F-8 DFBW RESULTS AND NEAL/SMITH CRITERION