Handling Qualities Effects on Precision Weapons Delivery

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Theme

WEAPONS delivery accuracy depends on precise target tracking and meeting a set of release conditions favorable to accurate weapons impact. The ability to accomplish this task is a function of the dynamics of the pilot-airplane-flight control system combination and atmospheric disturbances. Since tactical-aircraft weapons delivery missions play a significant role in modern warfare and are expected to do so in the future, continual research is required to provide a better understanding of the causes of poor weapons delivery accuracy. In addition, the rising costs of modern weapons systems increase the importance of an early evaluation of their mission effectiveness, thus allowing required changes to be incorporated during the design and prototype stages of development. The flight test program presented in Ref. 1 provided specific design guidance to the USAF A-X close air support aircraft development and produced results of a general nature from the effort made to identify those handling qualities parameters which have the largest effect on tracking and impact accuracy.

Contents

This Synoptic presents the principal results and conclusions of the investigation in which Calspan Corporation used the Air Force Flight Dynamics Lab. variable stability T-33 (Fig. 1) to simulate the characteristics of the Northrop A-9A and Fairchild A-10A (as they were known to exist six months prior to first flight) and to study the effects of various combinations of aircraft dynamics, modes of control and flight control systems for free-fall weapons delivery with a fixed-reticle gunsight. The flight test conditions were chosen to duplicate realistic operational profiles and to match two of those which were to be used in the actual A-F flyoff.

The T-33 variable stability airplane is an in-flight simulator capable of reproducing with a high degree of fidelity the dynamic response and control system characteristics of an entirely different airplane.

The simulation was unique with regard to technique and detail. The basic variable stability system of the T-33 was used to simulate the unaugmented stability and control parameters of the two prototype A-X airplanes, and additional feedback loops were designed and installed which duplicated the proposed augmentation schemes for each airplane (Fig. 2). The gain controls for these feedback paths were also located in the rear cockpit. This meant that the safety pilot essentially had independent control of the gains of the proposed stability augmentation systems and could vary them in flight. The A-X feel system characteristics, including force gradients, hysteresis, breakout and friction characteristics as well as any expected nonlinearities, were duplicated.

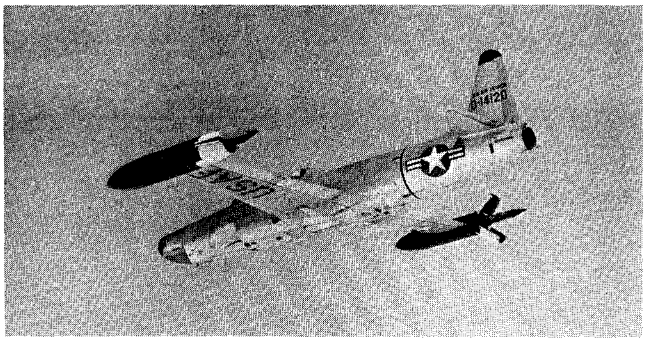

Fig. 1 USAF variable stability T-33.

The A-9A prototype had direct side force control capability. This is accomplished by balancing the yawing moment resulting from deflecting the rudder with an asymmetric deflection of split aileron drag devices located on each wing. The result is a side force applied to the airplane which is a function of the lift generated by and proportional to the rudder deflection. The variable stability T-33 achieved direct side force control in the same manner but used the drag produced by variable petals mounted on its tip tanks to balance the yawing moment of the rudder. The direct side force system was operated by the pilot through the rudder pedals and could be selected "on" or "off" in flight. The system was designed to allow the pilot to control side force to obtain a wings level, steady yaw rate response.

The flight test conditions were chosen to duplicate realistic operational profiles and to match two of those which were to be used in the actual A-X competitive flyoff. A 25° dive-bombing maneuver was flown at a stabilized

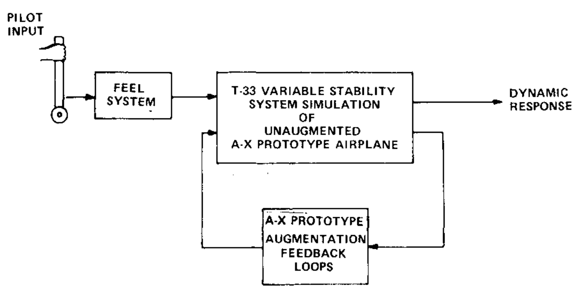

Fig. 2 Simulation technique.

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Index categories: Aircraft Handling, Stability, and Control; Aircraft Configuration Design.

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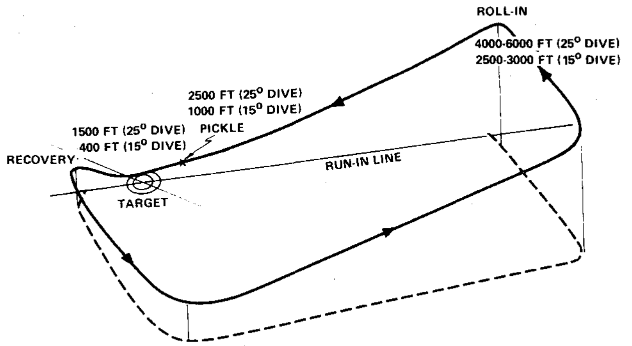

Fig. 3 Typical weapons delivery pattern.

speed of 250 knots IAS with simulated weapons release occurring at approximately 2500 feet AGL. A 15° strafing maneuver was flown at a stabilized speed of 225 knots IAS with simulated firing occurring at approximately 1000 feet AGL. Both maneuvers were flown in a standard left-hand race track pattern (Fig. 3), giving the safety pilot in the rear seat time to set up for the next configuration before the entry position was reached.

Forty-three separate configurations were evaluated by two pilots. These include the simulated A-X prototype airplanes and variations in handling qualities parameters about these two baseline configurations. The independent variables selected to provide information on the effect of handling qualities parameters on precision weapons delivery accuracy were: 1) longitudinal short period frequency, 2) Dutch roll frequency, 3) yaw due to lateral control, 4) roll sensitivity, 5) pitch damping with zero longitudinal static margin, 6) Dutch roll damping ratio, 7) rudder pedal force gradient, 8) rudder pedal breakout and hysteresis, and 9) direct side force control with and without roll stabilization.

Weapons impact points were calculated from the initial conditions determined to exist at weapons release using the weapon delivery model from Ref. 3. The standard deviation of the miss distance was adopted as a measure of performance. Analysis of variance was used to determine if apparent differences in means and standard deviations between configurations were significant. Pilot comments and ratings, using the Cooper-Harper rating scale were used to obtain qualitative evaluations of each test configuration.

The results of the handling qualities variations are summarized as follows: The base A-10A configuration was rated as satisfactory without any improvement required. One consistent complaint, however, was the low roll control sensitivity and correspondingly heavy roll control forces. The base A-9A configuration was considered to be a very maneuverable and responsive airplane. It was rated as satisfactory with no improvement required. However, a well "tuned" side force control system with proper feel characteristics did improve the performance over the base configuration with or without its side force control system. Both pilots felt that the rudder pedal gradients were too light on the base A-9A for the side force control. Increasing the rudder pedal gradient greatly improved the lateral weapons impact but resulted in poorer pilot ratings due to the increased rudder pedal forces required to obtain the desired yaw response. Roll stabilization was investigated as a means to simplify the pilot's tracking task to two axes when the side force control system was being used. Roll stabilization does not, however, appear to benefit delivery accuracy and was not particularly liked by the pilots. Large variations in yaw due to aileron control, in either the adverse or proverse sense, significantly degraded the pilot's ability to control lateral impact. Increasing the Dutch roll frequency showed little significant change in pilot rating or performance. The high-frequency configuration, however, was more susceptible to turbulence, and small oscillations resulted while tracking. It appears that high Dutch roll damping ratio is not required and in fact may be detrimental to impact accuracy. Increasing the short period frequency caused a slight but not significant decrease in performance. The low frequencies were reported to be more easily controlled in turbulence, but the high frequencies resulted in more precise speed and dive angle control. The zero static margin configurations resulted in noticeable control difficulties during the roll-in and dive recovery maneuvers.

The following conclusions were drawn from this flight test program:

1) An in-flight simulator or variable stability airplane can be beneficially used in realistic mission effectiveness evaluations to measure both performance and pilot evaluations and to indicate the relative merits of competing flight control system concepts.

2) This program demonstrates that release conditions can be measured and effectively used to analytically calculate bomb trajectories and resulting impact points. Although it eliminates some of the uncontrolled variables such as separation problems and erratic flight trajectories, it introduces random variations through release condition measurement errors.

3) Pilot rating was not necessarily a good indicator of weapons delivery accuracy in that some configurations with degraded pilot ratings showed significantly improved impact accuracies. This does not mean, however, that pilot rating is not important—only that task performance measures as well as pilot evaluation must be considered.

4) Changes in handling qualities parameters that resulted in improvements in the lateral-directional performance measures were generally accompanied by attendant improvements in longitudinal accuracy. It was concluded that improving the lateral task allows the pilot to concentrate on the longitudinal task, which is the main source of over-all error.

5) Some handling characteristics that were acceptable for target tracking were considered unacceptable for the maneuvering portions of the task. It was concluded that some form of multimode control may be desirable to provide a more optimum attack aircraft in the over-all mission.

6) Direct side force control can improve weapons impact dispersion, but careful control system design is required.

7) Variations in airplane handling qualities parameters do produce statistically significant differences in the performance measures for the weapons impact dispersions and weapons release parameters.

References

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