NORTHROP REVIEW OF MIL-F-8785B

PROPOSED REVISIONS

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INTRODUCTION

The AFFDL package of proposed revisions to MIL-F-8785B, the Military Specification for Flying Qualities of Piloted Aircraft (Ref. 1), was received by Northrop's Aircraft Group in mid-March 1978. A review was requested with comments to be returned to the government at a symposium and workshop to be conducted in September. The revision package was distributed to appropriate organizations within Northrop. As a result of the initial review, certain topics were identified for which Northrop had as yet unpublished data which would be valuable to the specification activity. Figure 1 shows those paragraphs for which specific contributions have been made. This paper gives a summary of each area along with example data to illustrate the nature of the results.

LEVELS OF FLYING QUALITIES (1.5)

The current version of MIL-F-8785B (Ref. 2) defines levels of flying qualities using one paragraph descriptions which are consistent with levels as defined by the Cooper-Harper rating scale (Ref. 3). Although it is not explicitly stated in the specification, Level 1 corresponds to pilot ratings (PR) less than 3.5, Level 2 to PR's between 3.5 and 6.5, and Level 3 to PR's between 6.5 and 9.5. See Figure 2.

●	1.0	SCOPE AND CLARIFICATION		3.3.1	LAT.-DIR. DYNAMICS
	3.1	GENERAL REQUIREMENTS	●	3.3.4	ROLL CONTROL EFFECTIVENESS
●	3.2.1	LONG. STAB. WITH RESPECT TO SPEED		3.4.11	CONTROL MARGIN
●	3.2.2.1	LONG. SHORT PERIOD		3.5	CHARACTERISTICS OF PRIMARY FCS
●	3.2.2.2	CONTROL FEEL AND STAB. IN MANEUVERING		3.6	CHARACTERISTICS OF SECONDARY FCS
●	3.2.2.3	COMPATIBILITY OF MAN. FORCES AND PITCH SENS.	●	3.7	ATMOSPHERIC DISTURBANCES
●	3.2.2.4	PIO		6.1	INTENDED USE

NOTE: ● SYMBOL IDENTIFIES THOSE PARAGRAPHS REVIEWED

FIGURE 1. PARAGRAPHS REVIEWED IN DETAIL BY NORTHROP

	8785B DEFINITIONS		COOPER HARPER RATINGS
LEVEL 1	FLYING QUALITIES CLEARLY ADEQUATE FOR THE MISSION FLIGHT PHASE	=	< 3.5
LEVEL 2	FLYING QUALITIES ADEQUATE TO ACCOMPLISH THE MISSION FLIGHT PHASE, BUT SOME INCREASE IN PILOT WORKLOAD OR DEGRADATION IN MISSION EFFECTIVENESS, OR BOTH, EXISTS	=	3.5 – 6.5
LEVEL 3	FLYING QUALITIES SUCH THAT THE AIRPLANE CAN BE CONTROLLED SAFELY, BUT PILOT WORKLOAD IS EXCESSIVE OR MISSION EFFECTIVENESS IS INADEQUATE, OR BOTH. CATEGORY A FLIGHT PHASES CAN BE TERMINATED SAFELY, AND CATEGORY B AND C FLIGHT PHASES CAN BE COMPLETED	=	6.5 – 9.5

FIGURE 2. CURRENT SPECIFICATION DEFINITION OF LEVELS OF FLYING QUALITIES

The proposed revision modifies the definition of Levels as shown by Figure 3. The objective is to explicitly recognize the effect of atmospheric disturbances on flying qualities. Sufficient data are available to show that aircraft control and/or pilot work-load can be significantly degraded while operating in moderate to severe environments (Ref. 4, etc.). It is recommended however that this should not change the definition of Levels. The definition of Levels corresponding to the Cooper-Harper Scale should be maintained. Figure 4 shows that there are three primary factors which influence a flying qualities evaluation. These are the system (the airplane in a normal or failure state condition, the flight condition (where in the flight envelope), and the environmental definition (atmospheric condition). When these three factors are defined and a task evaluation is conducted a certain task performance and pilot work-load results which correspond to a pilot rating and therefore a Level.

	ATMOSPHERIC DISTURBANCES		
	LIGHT	MODERATE	SEVERE
LEVEL 1	COOPER-HARPER LEVEL 1 DEFINITION	COOPER-HARPER LEVEL 2 DEFINITION	COOPER-HARPER LEVEL 3 DEFINITION
LEVEL 2	COOPER-HARPER LEVEL 2 DEFINITION	COOPER-HARPER LEVEL 3 DEFINITION	COOPER-HARPER LEVEL 3 WITH NEW TASK DEF
LEVEL 3	COOPER-HARPER LEVEL 3 DEFINITION	COOPER-HARPER LEVEL 3 WITH NEW TASK DEF	NO REQUIREMENT

FIGURE 3. PROPOSED REVISION TO THE DEFINITION OF LEVELS OF FLYING QUALITIES

MIL-F-8785B recognizes the effect of failures and flight condition on flying qualities in paragraph 3.1.10 of the specification by allowing degraded flying qualities for Failure Status and for operation outside the Operational Envelope. It is recom-mended that a better way to accommodate the effect of atmospheric disturbances is to include it in paragraph 3.1.10 as part of a three dimensional space which calls out the required Level of flying qualities as a function of the three primary factors that influence flying qualities. Figure 5 shows the form of this three dimensional space. The Levels assigned to each element of this space are those taken from the specifi-cation and the proposed revisions. This framework also makes it clear that the procuring activity can change the required Level of flying qualities for a specific

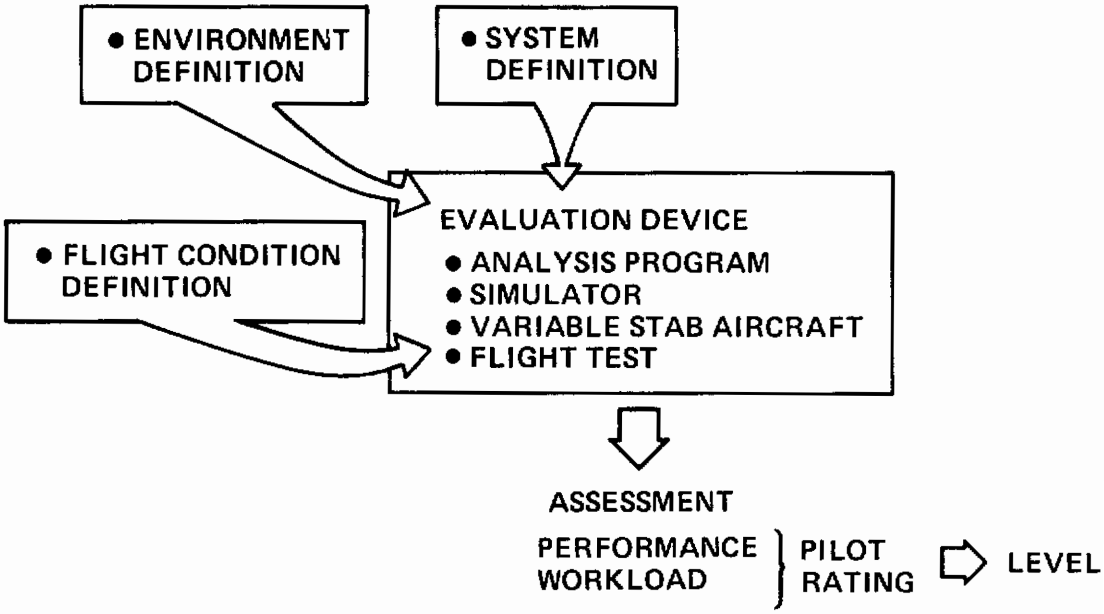

FIGURE 4. THREE FACTORS THAT INFLUENCE THE FLYING QUALITIES ASSESSMENT OF AN AIRCRAFT

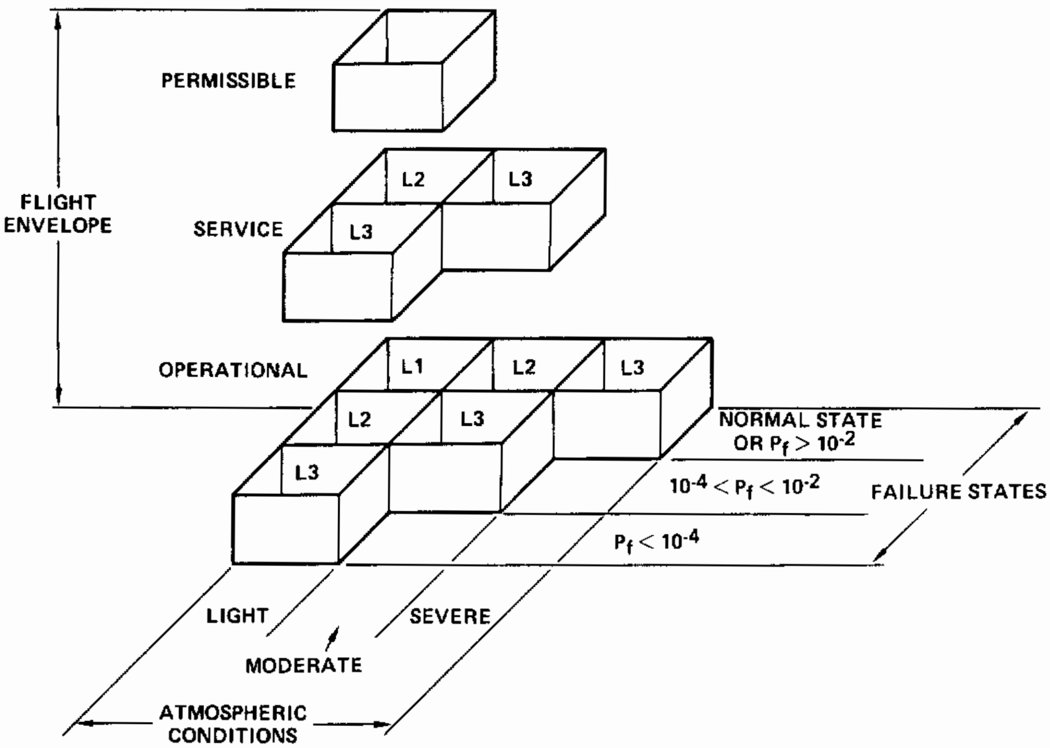

FIGURE 5. ALLOWABLE DEGRADATIONS IN THE LEVEL OF FLYING QUALITIES

new aircraft simply by changing the Level assigned to any element of the space. For instance, an all-weather aircraft might require Level 1 flying qualities in Moderate disturbances and Level 2 in Severe conditions. It is therefore recommended that the effect of atmospheric disturbances be handled in this way and that the definition of Levels remain unchanged.

Also, returning to the proposed revision as shown in Figure 3, there are two elements of that matrix which require that "Flying qualities be such that control can be maintained long enough to fly out of the disturbance." This is interpreted as Level 3 flying qualities with an unusual task definition. This will require that one then define the geographic extent of typical atmospheric conditions. This information is not available in paragraph 3.7. Visualizing the subject in the form as shown in Figure 5 raises additional questions. What are the required flying qualities in the Permissible Envelope? MIL-F-8785B states that operation there be "........ allowable and possible." Does that mean Level 3? Also what about the remainder of this three dimensional space of Figure 5? Figure 3 states "no requirement" for Level 3 in severe atmospheric conditions. Does this mean that loss of the aircraft is allowable under these conditions? And, when viewed in the form of Figure 5, is loss of the aircraft allowable in the entire undefined position of the three dimensional space?

LONGITUDINAL STABILITY WITH RESPECT TO SPEED (3.2.1)

The proposed revision modifies the requirement for longitudinal static stability to allow for the existence of aircraft with a statically unstable basic airframe for which augmentation is used to provide effective stability. As a worst case, Level 3 condition, reference 1 allows a time-to-double-amplitude of 6 seconds. If one must be able to operate the aircraft without augmentation this requirement will set a limit on the most aft allowable center-of-gravity (c.g.) position.

YF-17 LANDING APPROACH

For typical aircraft the nature of the airframe stability change with increasing aft movement of the c.g. is demonstrated by Figure 6. The short-period and phugoid roots become real, one Phugoid root will move into the right-half-plane, and a new "third mode" will form. For the Northrop YF-17 the sequence of events was first the short period roots would become real. The Phugoid roots would become real,

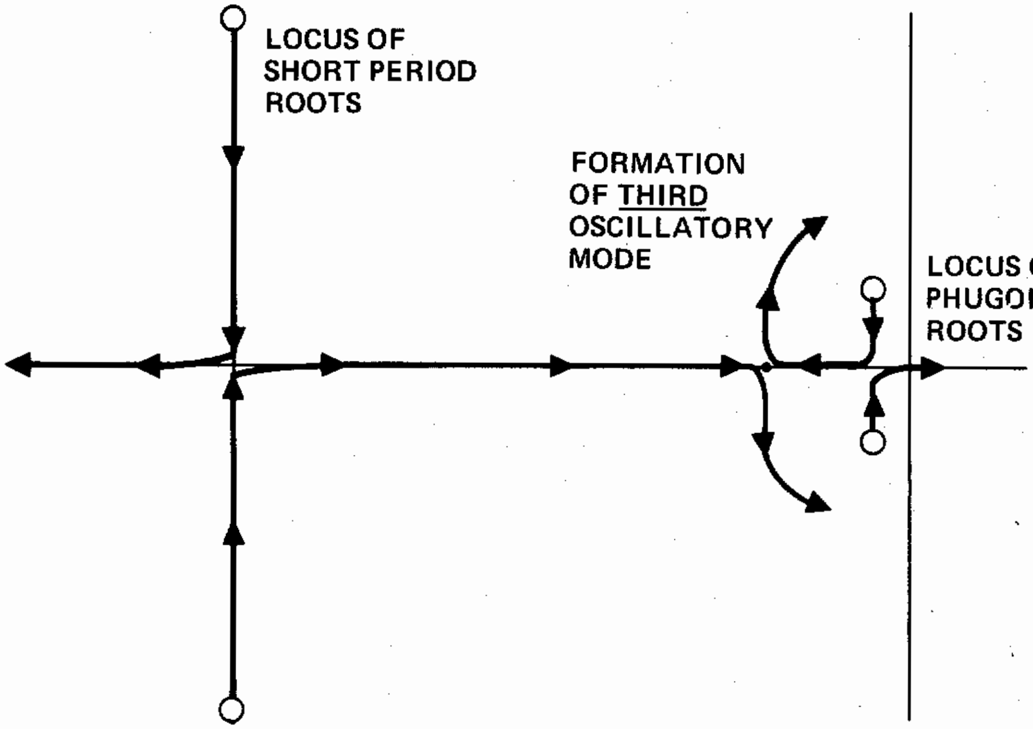

FIGURE 6. TYPICAL MIGRATION OF THE ROOTS OF THE LONGITUDINAL CHARACTERISTIC EQUATION WITH INCREASING AFT MOVEMENT OF THE CENTER OF GRAVITY

the one root would become unstable, then the third mode would form. Figure 7 shows the effect of c.g. location on the longitudinal stability of the YF-17 in the landing approach phase. The aircraft is stable for c.g. positions forward of about 28.5% mac and statically unstable for more aft c.g.'s. Based upon extensive piloted flight simulations, Northrop established a minimum safe time-to-double-amplitude of 4 seconds. The proposed specification revision of 6 seconds is considered to be in agreement with the Northrop value. The 6 second number is based upon in-flight simulation where the additional task realism normally results in more conservatism.

It is interesting to note the sensitivity of the modal changes with c.g. position. With a one percent change in c.g., static stability can change significantly. It has long been known that the sensitivity of time-to-double-amplitude in the pitch axis is largely determined by the stability derivative C_{m_u} (or M_u). See Figure 8. This parameter is currently paid little attention in airplane design and is very difficult to predict accurately.

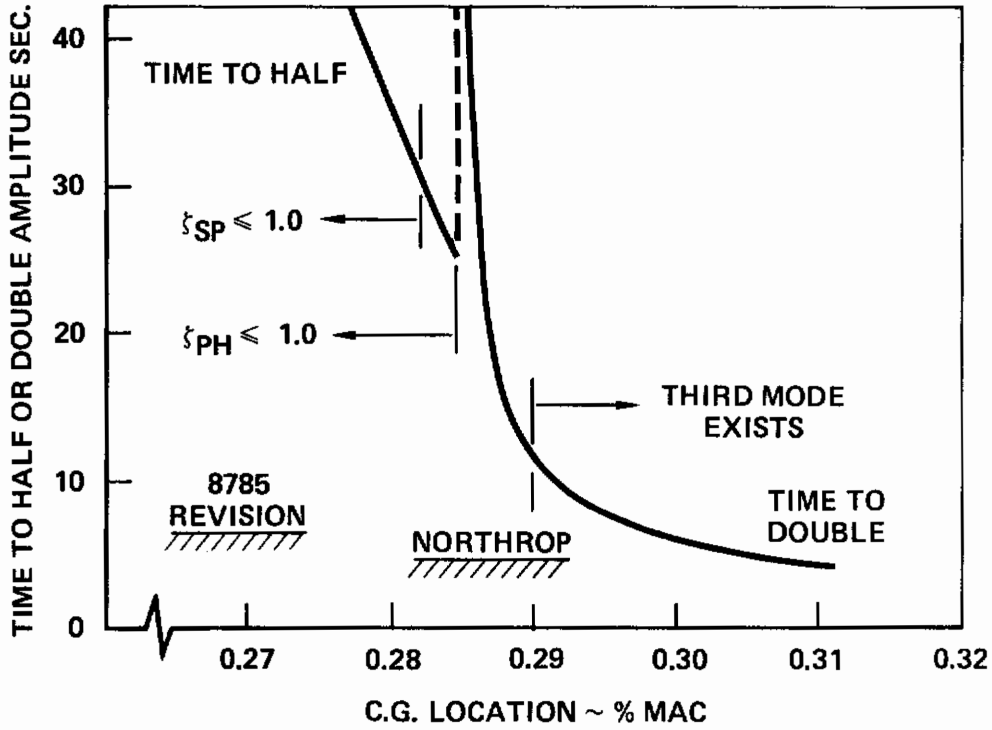

FIGURE 7. VARIATION IN YF-17 LONGITUDINAL STABILITY WITH CENTER OF GRAVITY POSITION FOR LANDING APPROACH

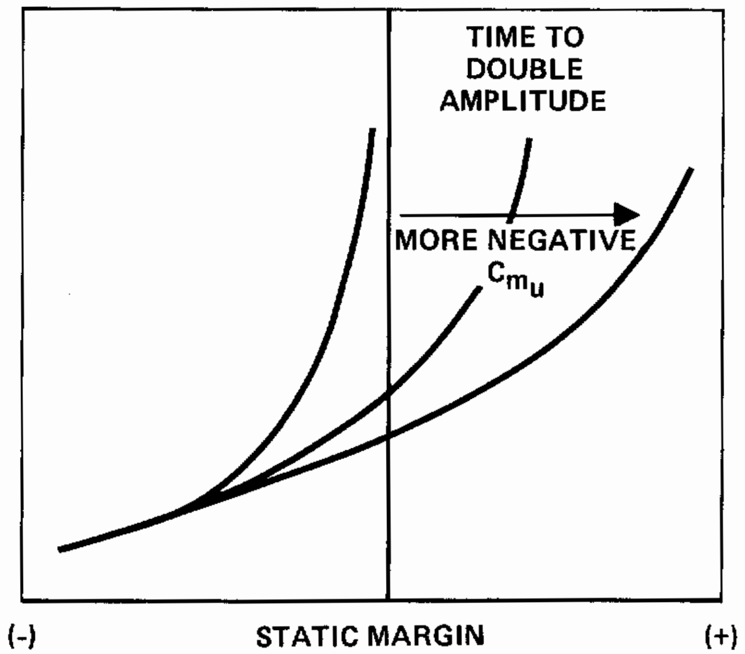

FIGURE 8. THE STABILITY DERIVATIVE, CHANGE IN PITCHING MOMENT WITH SPEED, DETERMINES THE SENSITIVITY OF STATIC STABILITY TO C. G. POSITION

YF-17 TRANSONIC

The effect of failure transients and control following the failure was extensively tested in the YF-17 program. "Failure Modes and Effects" piloted simulations were conducted in which selected critical failures were simulated in both typical flight conditions and in conditions chosen to be most critical for each particular Failure State. For longitudinal control the Pitch Control Augmentation System (PCAS) failure was most critical at aft c.g.'s. For the YF-17 at 0.85 M the elastic neutral point is at 29% of the mean aerodynamic chord (mac) and the elastic maneuver point is at 32% mac. Figures 9 and 10 are typical data from those simulation tests. Transient and peak load factor values are shown for each test condition as the c.g. is moved further and further aft. Pilot ratings were also taken for each task which was to maintain control during and after the failure. Based upon the composite of these simulation tests, the flying qualities correlated most readily with maneuver margin and stick force gradient as shown by the solid lines on Figure 11. These simulation trends were verified by a limited number of flight test points. These data indicate that a minimum maneuver margin of about 1.5% mac and a minimum stick force gradient of about 2 lbs/g are reasonable Level 3 design conditions.

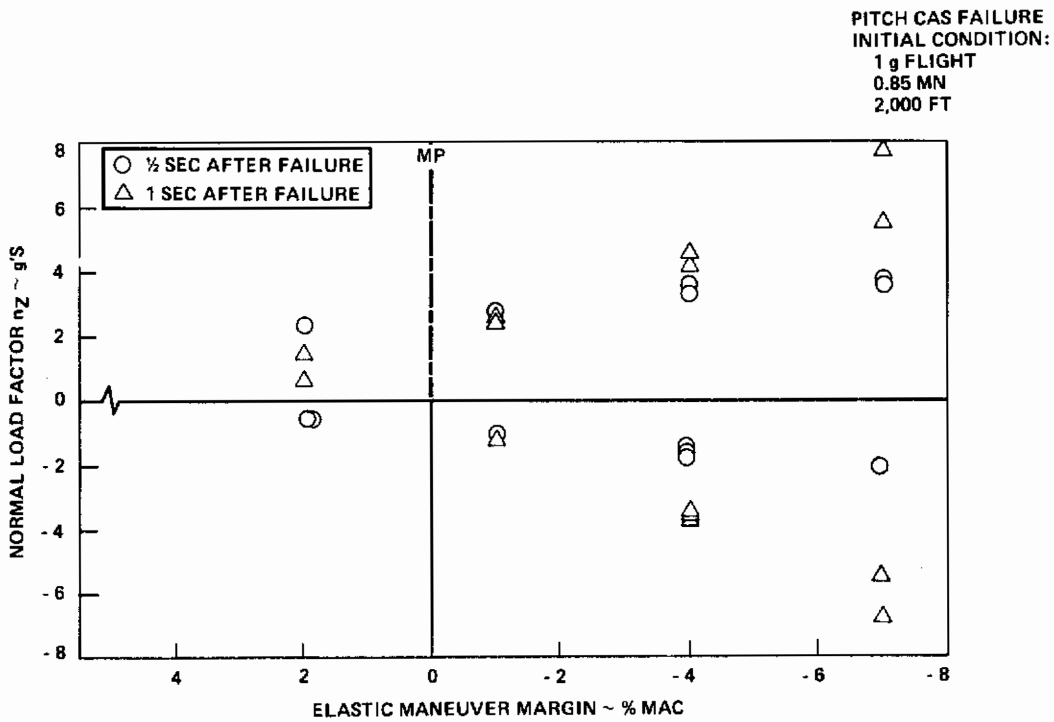

FIGURE 9. EFFECT OF MANEUVER MARGIN ON NORMAL LOAD FACTOR TRANSIENTS FOLLOWING A PITCH CAS FAILURE

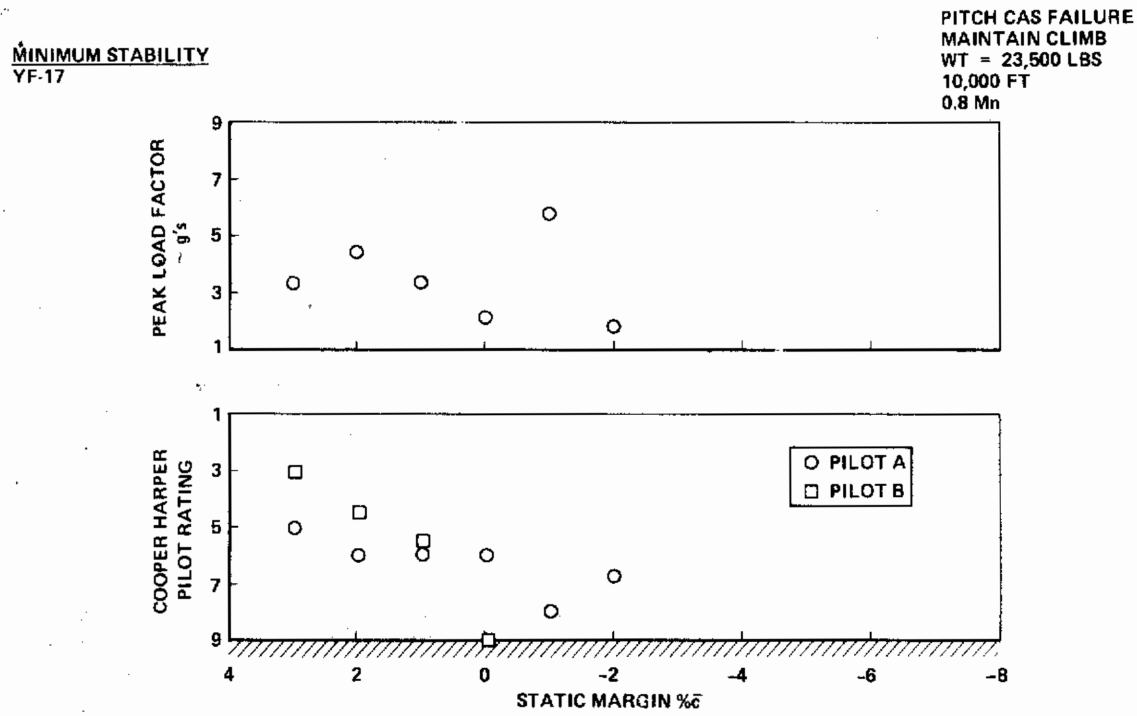

FIGURE 10. EFFECT OF STATIC MARGIN ON LONGITUDINAL CONTROL FOLLOWING A PITCH CAS FAILURE

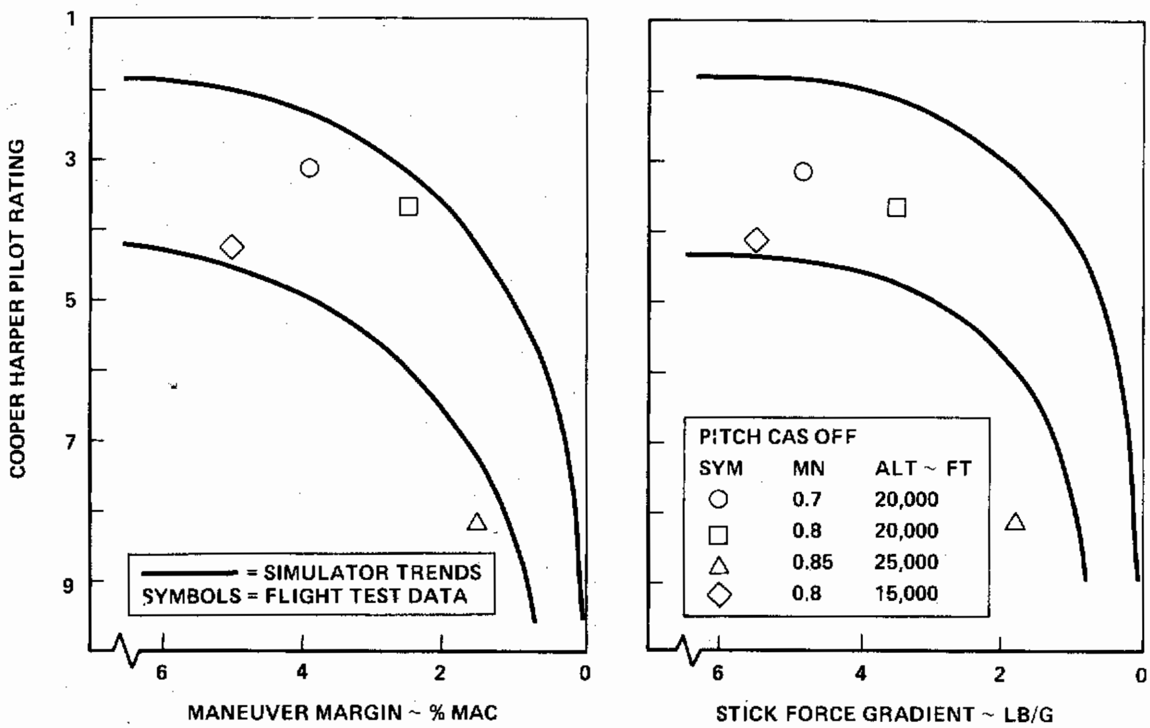

FIGURE 11. FLYING QUALITIES CORRELATE WITH MANEUVER MARGIN AND STICK FORCE GRADIENT

LONGITUDINAL SHORT PERIOD RESPONSE (3.2.2.1)

One of the primary motivations for revising 8785B at this time is to insure that it will accommodate highly augmented aircraft for which the resulting dynamics are far removed from those of the basic airframe. Figure 12 lists the typical problems that occur when attempting to compare such aircraft with the current specification. MIL-F-8785B longitudinal short period response requirements are now stated in terms of classical modal parameters which are difficult to identify for highly augmented aircraft.

LARGE ORDER SYSTEM

- MANY ROOTS ON ROOT LOCUS
- MANY TERMS IN TRANSFER FUNCTION

NON-LINEAR SYSTEM

- PROBLEM FOR ANY LINEAR METHOD

NON-CLASSICAL MODES

- LIMITED SYSTEMATIC DATA BASE

FIGURE 12. HIGHLY AUGMENTED AIRCRAFT PRESENT MANY PROBLEMS FOR THE CURRENT SPECIFICATION CRITERIA

Northrop is currently using a variety of alternate criteria as design guides for highly augmented aircraft. Figure 13 lists those approaches which are currently being used. Northrop's experience and methodologies for pilot-in-the-loop analyses are well documented in a recent contract publication, reference 5.

Figure 14 shows the pitch response criteria to which the YF-17 was designed. The total augmented frequency response of pitch rate to stick force was required to fall within the shaded region. These bounds are based primarily upon the Neal-Smith data base of reference 6. This criteria can be used regardless of the order of the subject airplane system. Non-linear effects can be accommodated if one tests for the input amplitude dependent nature of the frequency response. Unacceptable airplanes are most conspicuous on this criteria by the increased phase lag at moderate frequencies as shown in Figure 15.

APPROACHES

- FREQUENCY DOMAIN (BODE) BOUNDARIES
- TIME RESPONSE BOUNDARIES
- EQUIVALENT SYSTEM PARAMETERS
- PILOT-IN-THE-LOOP ANALYSIS

FIGURE 13. APPROACHES TO FLYING QUALITIES CRITERIA FOR HIGHLY AUGMENTED AIRCRAFT

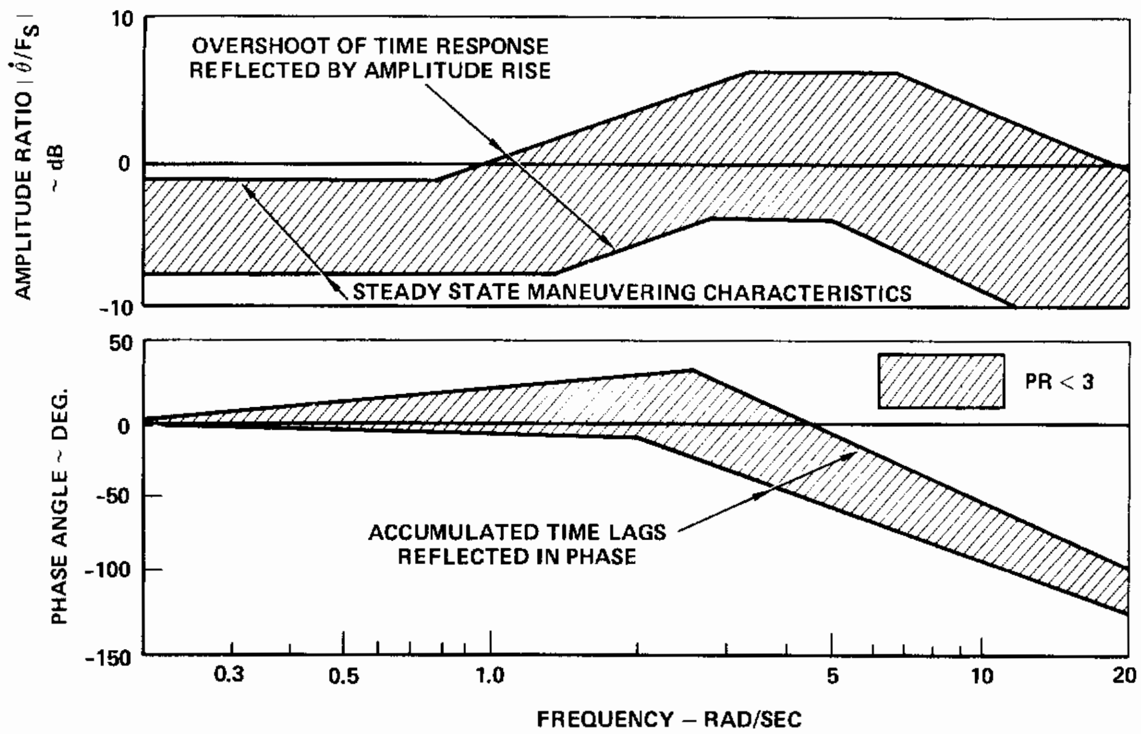

FIGURE 14. LEVEL 1 FREQUENCY RESPONSE REGION FOR LONGITUDINAL CONTROL

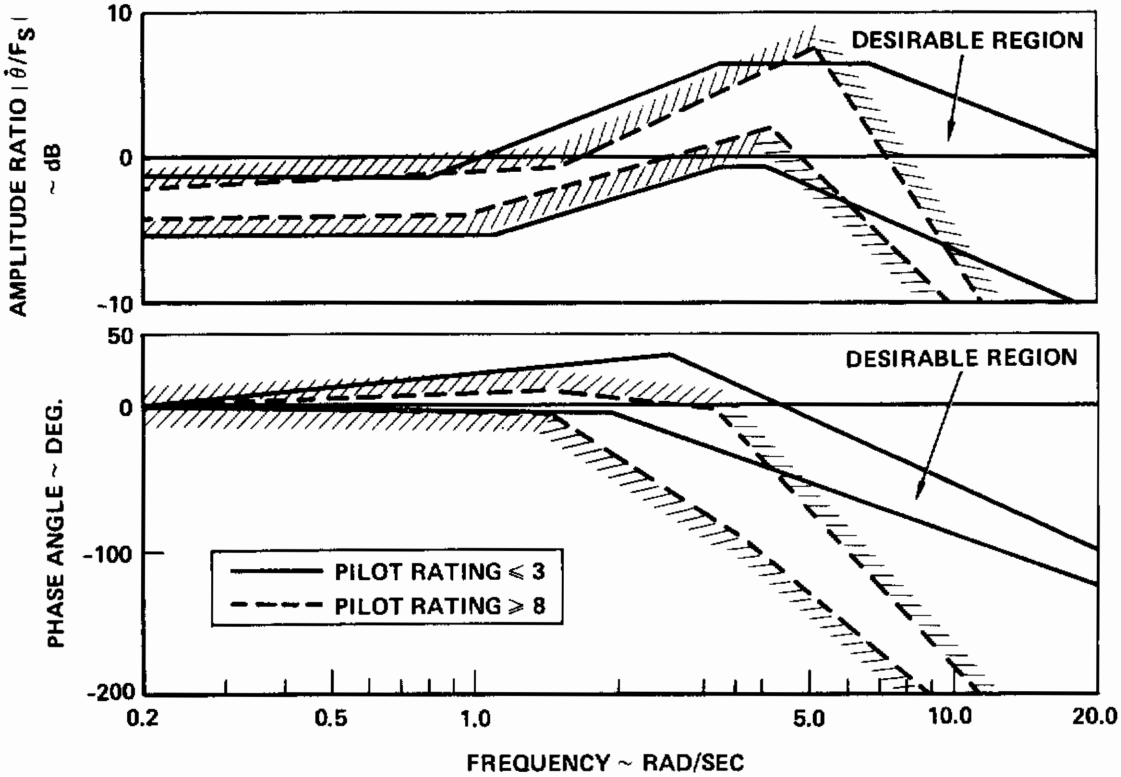

FIGURE 15. DEGRADED FLYING QUALITIES AS THEY APPEAR IN THE FREQUENCY DOMAIN

An equally satisfactory and possibly more direct means of accomplishing flight control system and flying qualities design is to operate directly in the time domain. This approach allows for the effect of plant nonlinearities, allows one to use non-linear elements in the design of the control system itself, and encourages the use of direct digital design of control system software. An example of the non-linearities present in a typical advanced fighter design are shown in Figure 16, taken from reference 7. Figure 17 shows time history responses taken for this system and demonstrates that very well behaved responses can be obtained even for highly unstable airframes. From such time histories classical modal parameters can be estimated using techniques historically used for flight test data reduction. Figure 18 shows the flying qualities of the subject airplane compared to the boundaries of 8785B. In general these results have been varified by piloted flight simulation.

The purpose here is to demonstrate alternatives to the equivalent system approach as stated in reference 1. It is hoped that such methods will be given due consideration in the final selection of a short period response requirement, but regardless of the format of the requirement, it is recommended that the revision

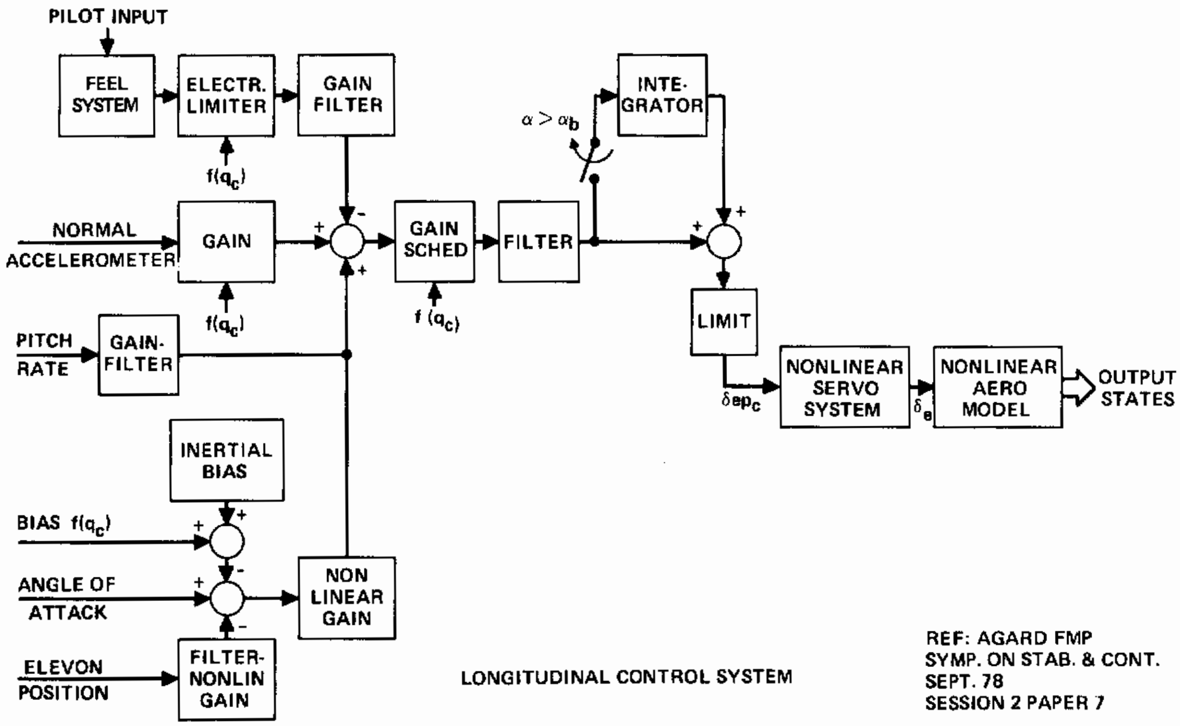

FIGURE 16. TYPICAL ADVANCED FIGHTER LONGITUDINAL FLIGHT CONTROL SYSTEM

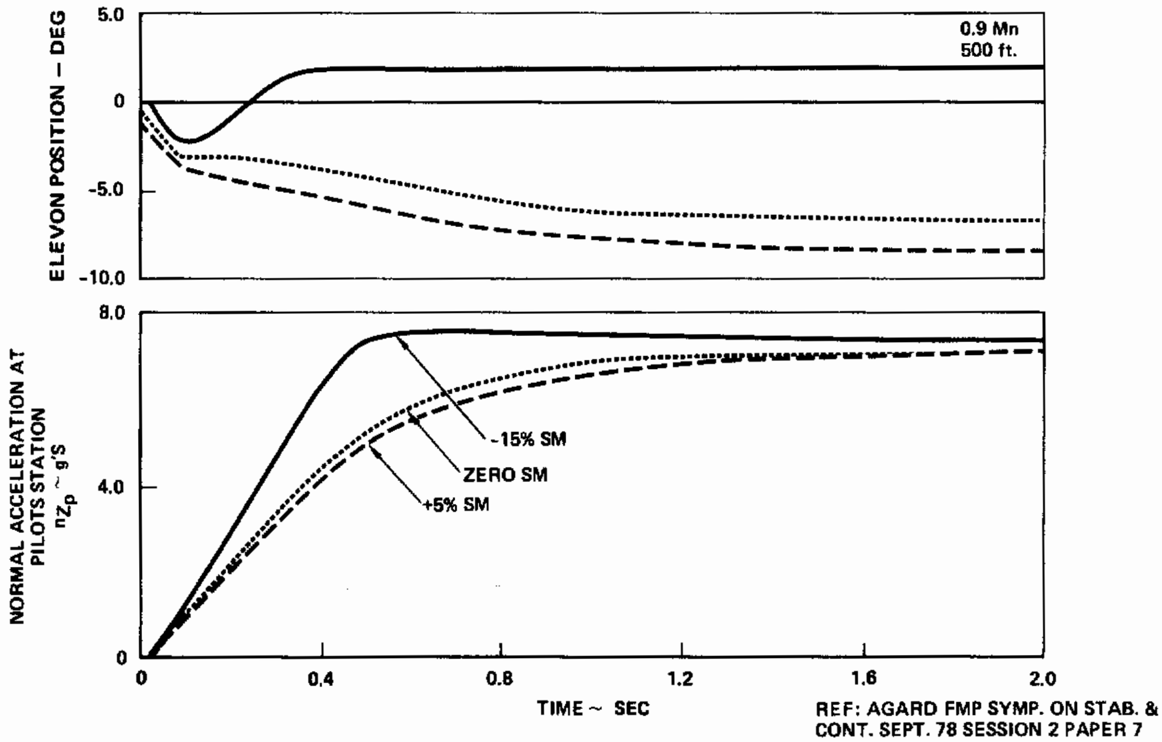

FIGURE 17. TIME RESPONSE EXAMPLE OF HIGHLY AUGMENTED NON-LINEAR AIRCRAFT SYSTEM

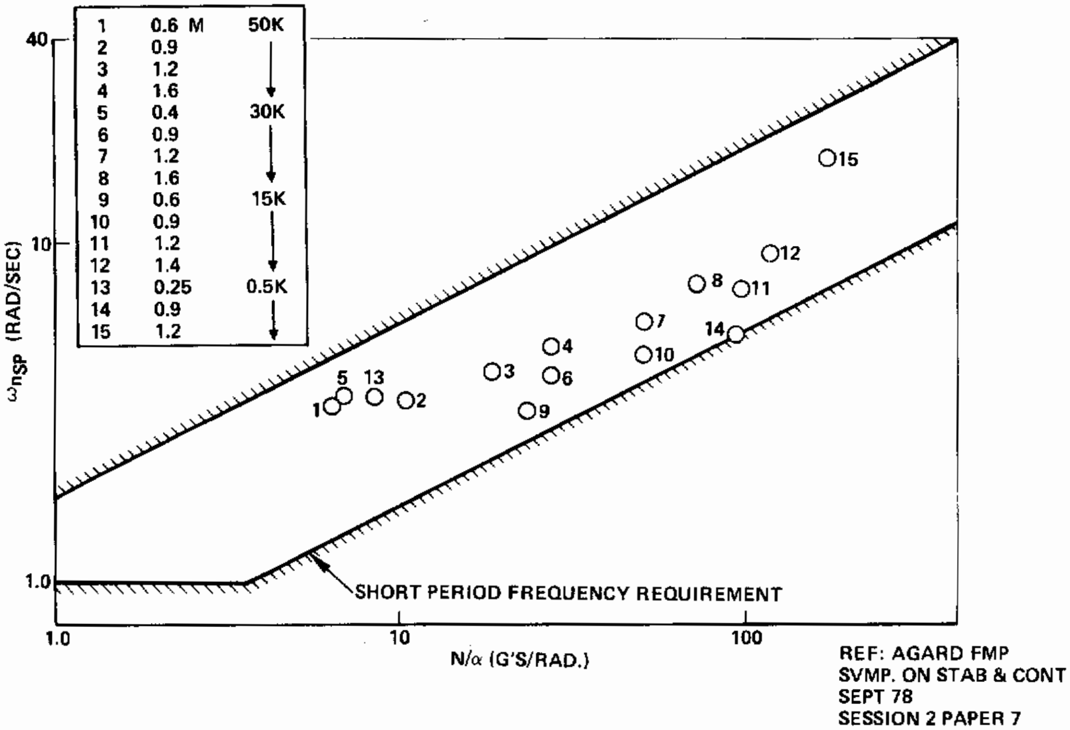

FIGURE 18. HIGHLY AUGMENTED ADVANCED CONFIGURATION COMPARED TO MIL-F-8785B BASED UPON EQUIVALENT CLASSICAL PARAMETERS ESTIMATED FROM SIMULATION TIME HISTORIES

combine the chosen parameters into one criteria. In other words, ζ_{sp} should not be an independent requirement from ω_{sp} vs $n_{z\alpha}$.

CONTROL FEEL IN MANEUVERING FLIGHT (3.2.2.2)

8758B basės it's control requirements on response per pound of stick or pedal force and this is appropriate. However, the specification almost completely ignores the effect of stick position or deflection. Figure 19 shows the effect of arm location relative to the body on the maximum pull capability of a 5th percentile male. These data are from reference 8. They show that one's maximum force capability is not symmetric left and right and varies by about a factor of two for forward and aft stick positions. Figure 20 shows similar data for both pull and push strength as a function of upper arm angle. Here one can see that pull and push strength differ significantly and also that the 5th and 95th percentile male strengths differ by as much as a factor of three.

These data are included here because it is the feeling of the author that their effect is not widely known. It is hypothesized that at least the upper limit of stick

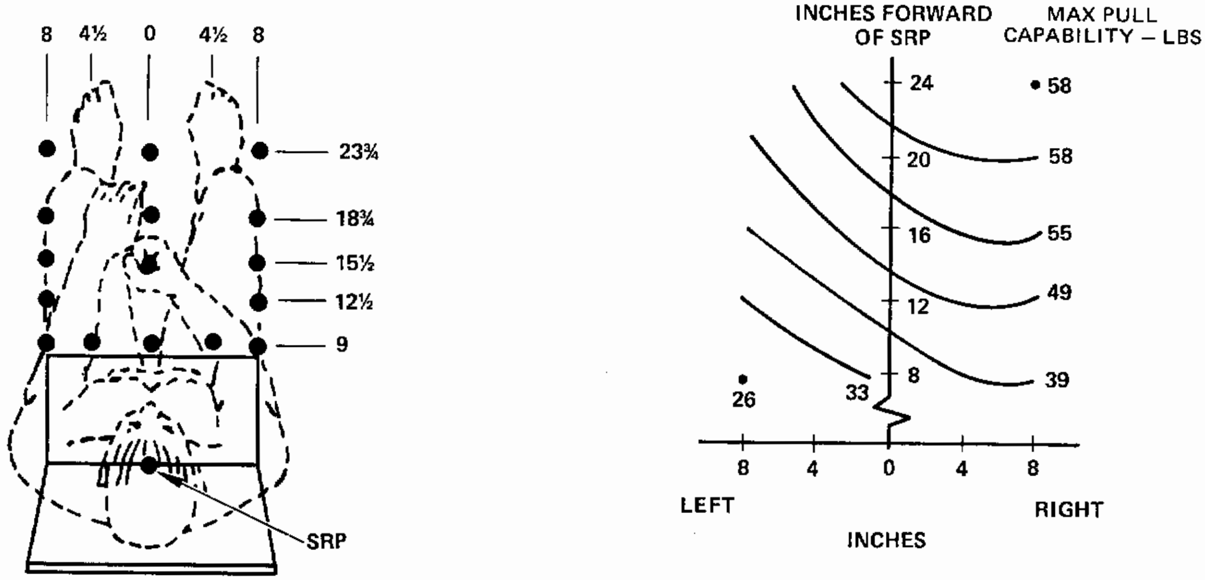

FIGURE 19. EFFECT OF ARM/STICK GEOMETRY ON MAXIMUM PULL CAPABILITY FOR THE 5TH PERCENTILE MALE

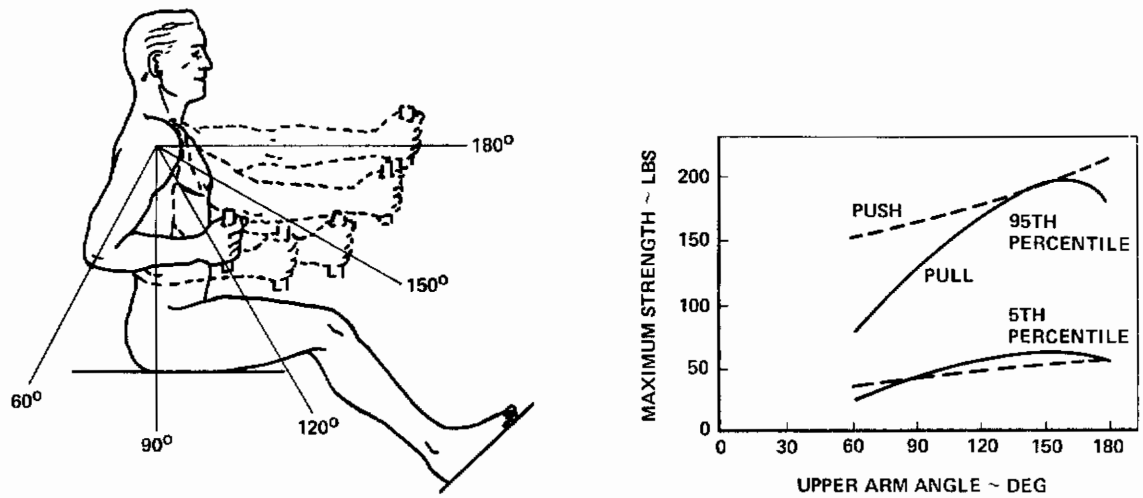

FIGURE 20. EFFECT OF UPPER ARM ANGLE ON PULL AND PUSH STRENGTH FOR THE 5TH AND 95TH PERCENTILE MALE

force should be a function of the percent of pilot effort required and not just of force required at the stick grip. Certainly a given stick force at the grip will feel heavier to the pilot for aft stick positions. Also one must be very careful in correlating the acceptability of stick forces for various aircraft to include the effect of stick location and maximum stick deflection. For instance, the F-5A stick deflection is greater than that of the A-7D by more than a factor of 2. This places the stick in a different location in the cockpit for maximum deflection.

PILOT INDUCED OSCILLATIONS (3.2.2.4)

Northrop's attention was sharply focused on the subject of Pilot Induced Oscillations (PIO) as the result of a very dramatic encounter on the T-38A in 1960. A time history of that incident is shown as Figure 21. Peak load factors ranged between -9 and +8 g's but the aircraft was brought under control and recovered. The incident occurred on a low altitude high-speed run on which the stability augmenter malfunctioned. A limit cycle occurred (not shown in Figure 21) in the pitch SAS and the pilot disengaged the SAS at a peak value of surface command and the aircraft experienced a step input to the stabilizer. This initiated large pilot inputs which coupled with the airplane to form the PIO. See references 9 and 10 for details.

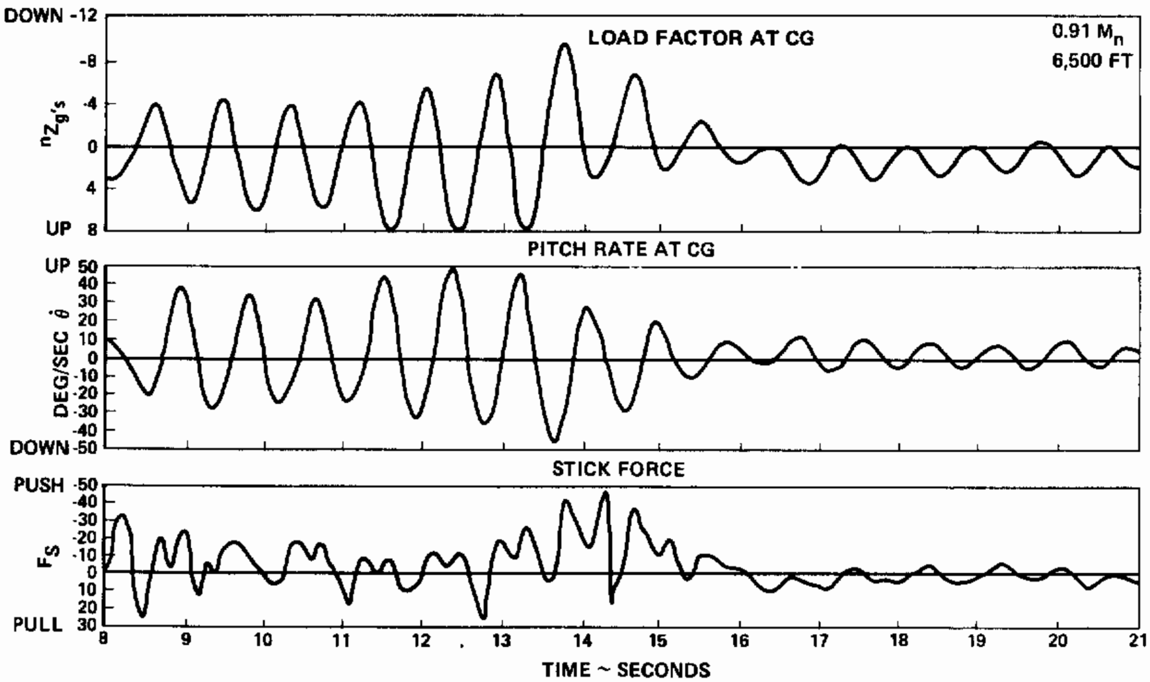

FIGURE 21. A FLIGHT TIME HISTORY OF A T-38A PILOT INDUCED OSCILLATION (JAN. 1960)

The incident was attributed to several factors including the bob-weight, feel-spring, and horizontal tail servo-value. Changes were made to these parameters and the modified versions of the T-38 have been PIO free. The investigation, analysis, and research conducted in support of the T-38 emphasized the importance of the variation in stick force per g versus frequency. This dynamic stick force per g for the T-38 before and after the control system modification is shown in Figure 22. The difficulty is that at least three potentially significant features have changed simultaneously. The

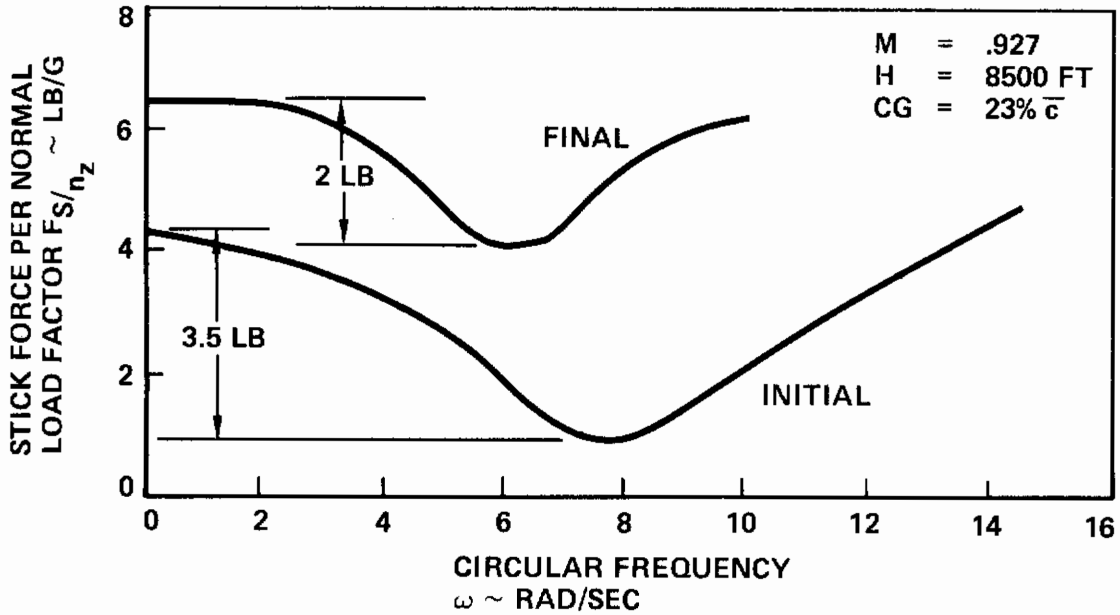

FIGURE 22. DYNAMIC STICK FORCE PER g FOR THE T-38 BEFORE AND AFTER THE CONTROL SYSTEM MODIFICATION

amount of the drop was decreased, the minimum value was increased, and the level at high frequencies (in the vicinity of 10 rad/sec) was increased.

Northrop has since been using the gain margin on the dynamic stick force per g as a criterion parameter. Figure 23 shows the Northrop gain margin criteria requires that Level 1 be greater than 16db, Level 2 be between 10 to 16 db, and Level 3 be between 5 and 10 db. It is now recommended that the minimum drop requirement augment the gain margin criteria and that both should be used.

ROLL PERFORMANCE (3.3.4.1)

The proposed revision to the roll response requirements are intended to account for the inherent reduction in roll response at low and high airspeeds and at elevated load factors while requiring a higher rate of response in the middle of the envelope for one g flight. For the Combat and Ground Attack Flight Phases the requirements are stated in terms of bank-to-bank rolls for any load factor up to $0.8n_L$. The requirement is to change bank angle by 30, 50, 90, or 180 degrees in a time less than or equal to a specified amount.

There are several factors which should be clarified in the context of this requirement. First, "bank-to-bank" generally refers to symmetric maneuvers; for instance, 60 degrees bank-to-bank is from 30 degrees left wing down to 30 degrees

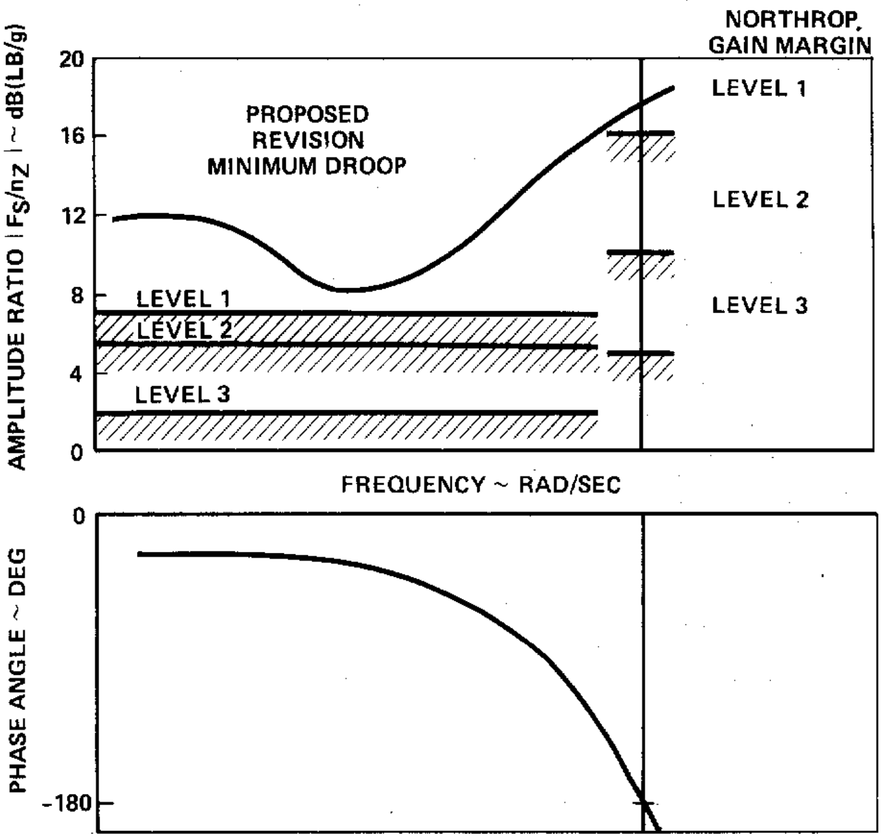

FIGURE 23. DYNAMIC STICK FORCE PER g CRITERIA

right wing down. It is assumed for the purposes of this paper that for the elevated load factor conditions the required change is from the trimmed bank angle for that load factor through whatever change in bank angle is required. See Figure 24. For example, when trimmed at 1.15 g's the change in bank angle of 90 degrees would be from approximately 30 degrees left wing down to 60 degrees right wing down. In addition, especially when considering steep clumbing or diving trajectories or high angle-of-attack conditions, one must be concerned about the definition of bank angle and the axis system in which it is defined. A standard practice is to use the integral of the body axis roll rate. The specification requires that the roll angle be measured in the Y-Z plane between the y-axis and the horizon but is not clear if this is a body or stability axis coordinate system.

The required roll performance is stated for four separate speed ranges from very low (VL) to High (H). These speed ranges were calculated for the F-5E in the Combat (CO) and Ground Attack (GA) Flight Phases. For the speed ranges as defined in reference 1 certain of the speed ranges collapsed to a single value. As shown in

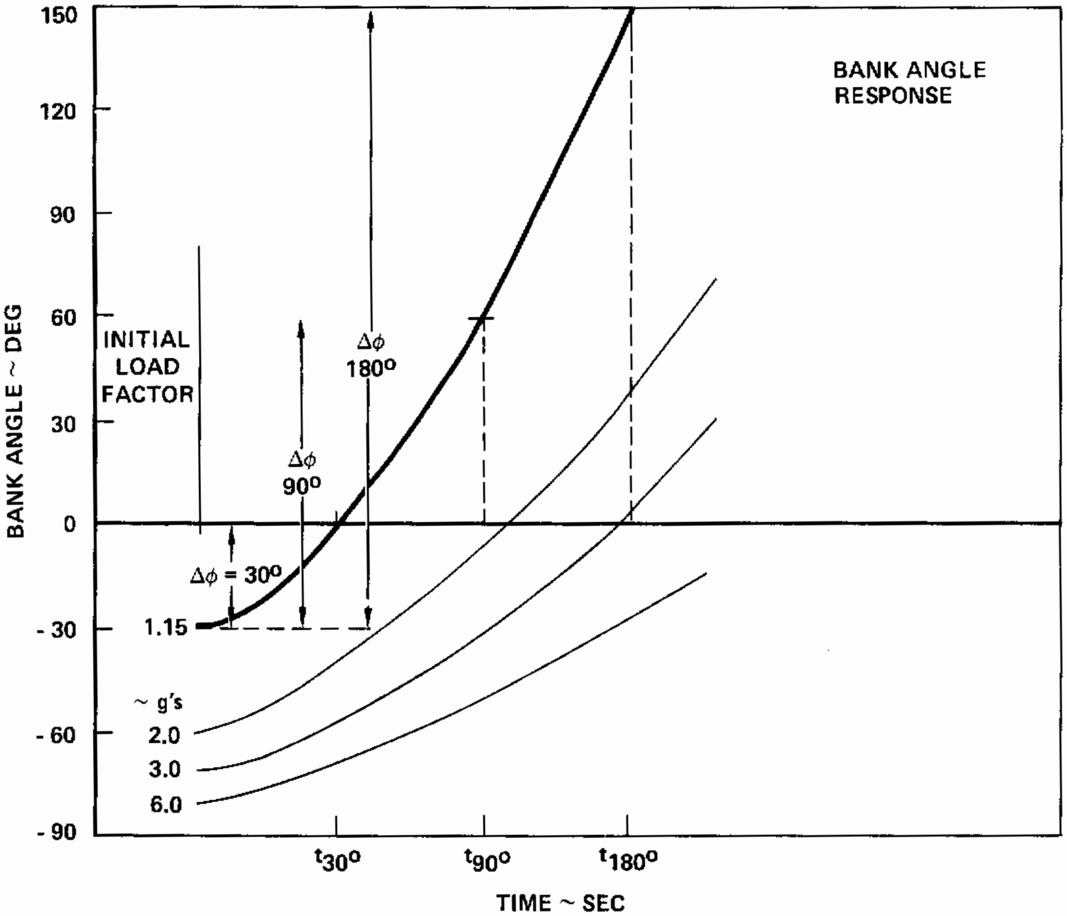

FIGURE 24. ROLL PERFORMANCE FLIGHT RESPONSE MEASUREMENTS

Figure 25 for the CO Flight Phase the VL range collapse and for the GA Flight Phase both the VL and M (Medium) ranges collapsed.

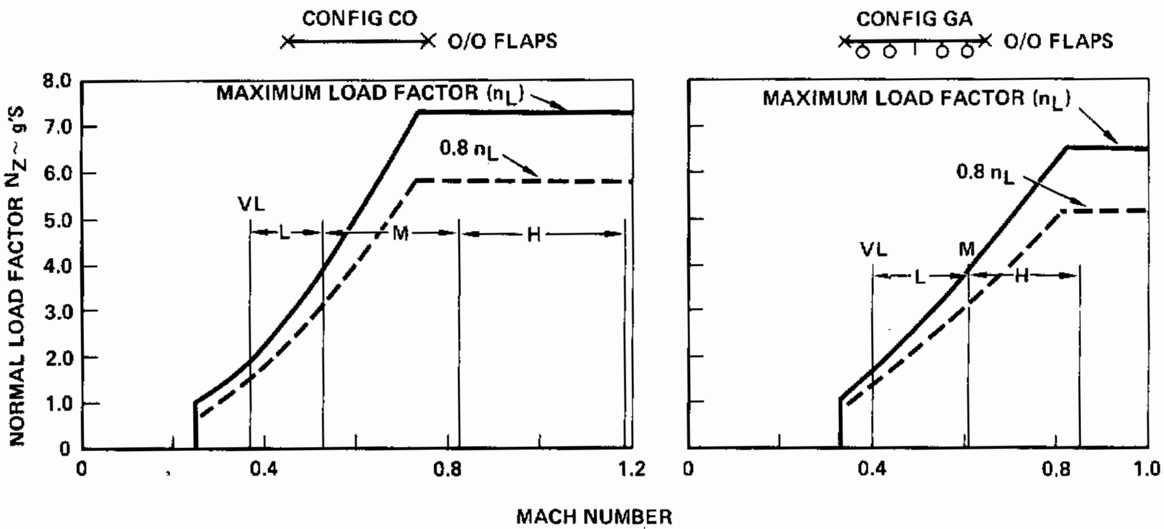

FIGURE 25. F-5E SERVICE LOAD FACTORS AT 15000 FT
SHOWING THE ROLL PERFORMANCE SPEED RANGES

It is recommended that the speed ranges be redefined in such a way that this collapsing of ranges does not occur. Figure 26 shows the speed range definitions as stated in the proposed revisions (reference 1) and the Northrop recommended definitions. It is recommended the speed ranges be defined as a percentage of the entire operational speed range. The lower 10% is VL, the next 30% is L, the next 30% is M, and the remaining 30% is H. With these definitions all aircraft are treated equally with the ranges being an "elastic" fit to the particular total speed range.

8785B PROPOSED REVISION

SPEED RANGE SYMBOL	EQUIVALENT AIRSPEED RANGE
VL	V_o MIN $\leq V < V_{MIN}$ + 20 KTS
L	V_{MIN} + 20 KTS $\leq V <$ 2VS
M	$2V_S \leq V < 0.7\, V_{MAX}$
H	$0.7\, V_{MAX} \leq V \leq V_o$ MAX

NORTHROP RECOMMENDATION

SPEED RANGE SYMBOL	EQUIVALENT AIRSPEED RANGE
VL	V_o MIN $\leq V < V_o$ MIN + 0.1 ΔV
L	V_o MIN + 0.1 $\Delta V \leq V < V_o$ MIN + 0.4 ΔV
M	V_o MIN + 0.4 $\Delta V \leq V < V_o$ MIN + 0.7 ΔV
H	V_o MIN + 0.7 $\Delta V \leq V \leq V_o$ MAX
WHERE $\Delta V = V_o$ MAX - V_o MIN	

FIGURE 26. RECOMMENDED SPEED RANGE DEFINITIONS FOR THE ROLL PERFORMANCE REQUIREMENTS

An example of the F-5E roll performance is shown in Figure 27 which plots time to bank versus Mach number for maximum rolls at 0.8 n_L. The data includes time to roll 30 degrees, 50 degrees, and 90 degrees. The solid symbols show the required maximum time allowable for the bank angle change for each speed range. If the speed ranges are defined as in reference 1 and as shown on the left half of Figure 27, the F-5E does not, in general, meet the requirement. If the speed ranges are defined as recommended by Northrop and as shown in the right half of Figure 27, then the requirements are satisfied for most conditions although not universally. Since the F-5E roll performance is found very satisfactory in operational use, it is recommended that the speed ranges be redefined. The performance levels are then approximately satisfied.

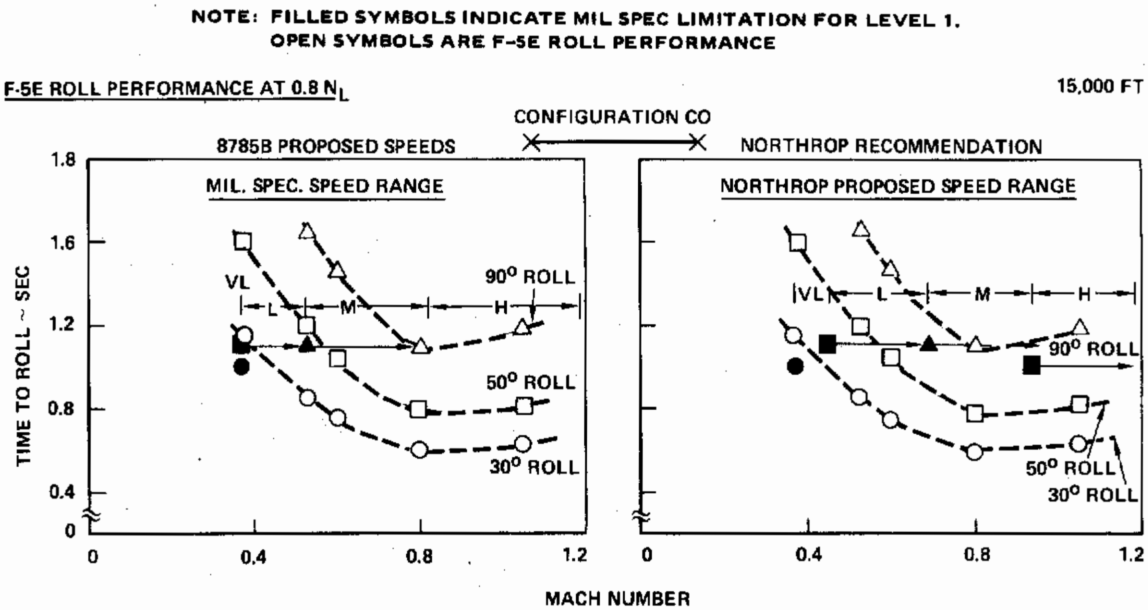

FIGURE 27. F-5E ROLL PERFORMANCE

ATMOSPHERIC DISTURBANCES (3.7)

Northrop has extensive experience in the modeling and use of atmospheric disturbances in both analysis methods and in piloted simulations. See references 4 and 11. The most recent experience has been with respect to Gaussian vs. non-Gaussian turbulence models (ref. 12). The non-Gaussian model employed is known as the Tomlinson (or Jones) Model. The so-called Tomlinson model is featured as being more representative of the true time varying or intermittent properties of the real atmosphere. Figure 28 shows that the Tomlinson model has fewer changes of intermediate velocity with a "greater-than-Gaussian" probability that there will be either very small velocity increments or extremely large velocity changes. Figure 29 shows a comparison of representative Tomlinson and Dryden forms.

Reference 12 presents the results of an analytical and piloted simulation investigation of a ride improvement mode system for the YF-17 in low altitude high speed flight. Both Gaussian and non-Gaussian turbulence models were used. Since reference 12 is available in the open literature one is referred there for details. It was concluded there however that the performance of the flight control system design may be influenced by the choice of turbulence model and that this aspect may need to be reflected in the appropriate military specification.

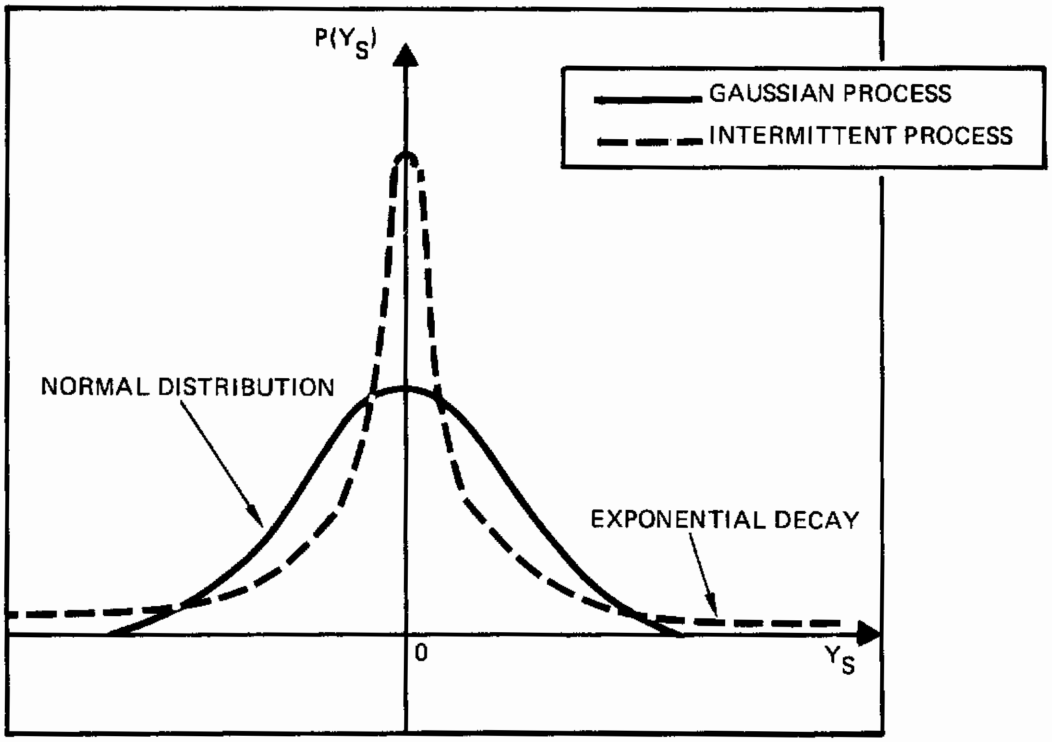

FIGURE 28. PROBABILITY DENSITY OF VELOCITY INCREMENTS (SCHEMATIC)

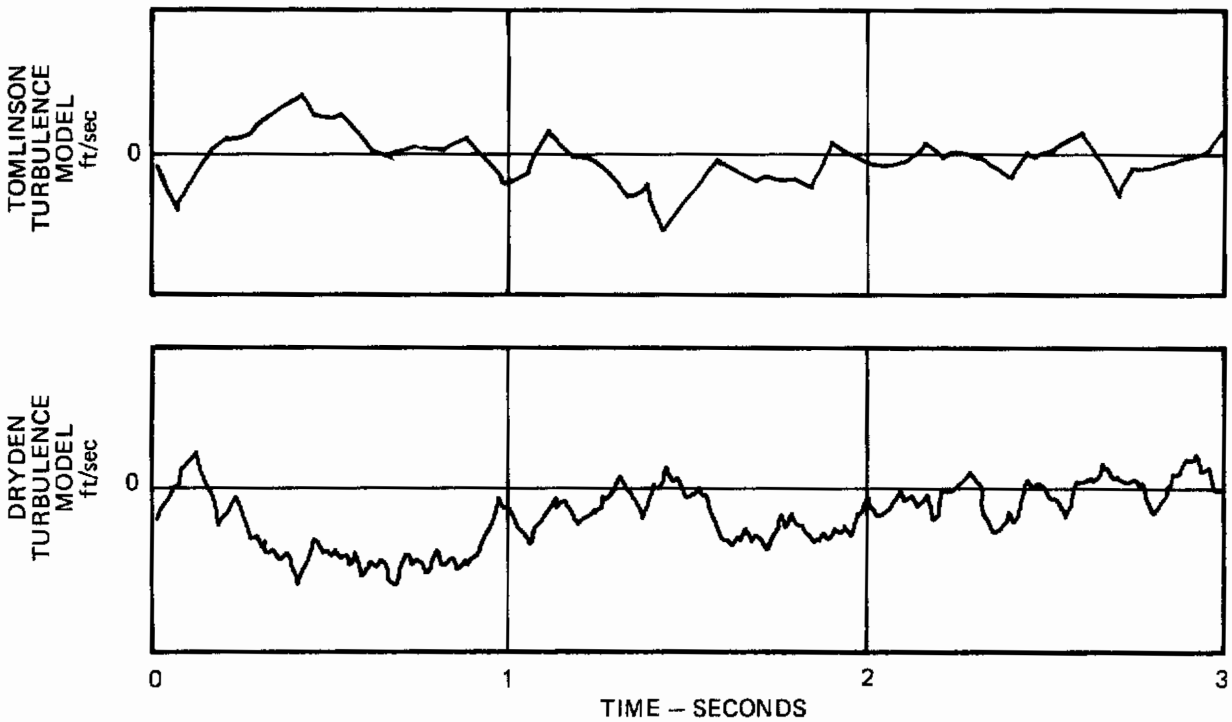

FIGURE 29. W – GUST TIME HISTORIES FOR THE TWO TURBULENCE MODELS

In addition, there is a lack of flying qualities requirements, criteria, and even rough design guidance for aircraft response to, and control in atmospheric disturbances. This is true of both discrete and continuous upsets. The models are reasonably well defined but means of identifying levels of acceptance are relatively non-existent. It is recommended that additional studies similiar to that of reference 12 be conducted to fill this void.

SUMMARY

Selected sections of the proposed revisions to the Flying Qualities Specification, MIL-F-8785B have been reviewed by a team of aerodynamic and controls personnel at Northrop's Aircraft Group. The results for the paragraphs reviewed are discussed above. This paper is an edited and condensed version of a Northrop internal report reference 13 which will be furnished to the tri-service 8785 team. In general, the revisions were found to be satisfactory with minor disagreements and recommendations covered separately above. It is noted however that the desire to couch requirements in terms of engineering parameters of the system itself is leading to an increasingly complex and cumbersome specification. As a philosophical recommendation for future revisions, it is suggested that stating the requirements in terms of the desired output performance should simplify the specification, better insure satisfactory operational systems, and provide the contractor with greater engineering design freedom. System simulations are available sufficiently early in the design process today to check output performance that this approach should not provide the procuring agency with any unusual problems in following specification compliance in the early stages of development. If this approach is used it is also recommended that a "Backup Document" or "Military Handbook" be formulated to contain the current systems design engineering knowledge on how to obtain good flying qualities. This document should contain methodologies and a collection of useful criteria for each performance requirement area. This document would have to be continually revised to remain current as new knowledge is obtained.

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