SECTION V

SESSION 3: THE PROPOSED REVISION TO MIL-F-8785B, AND COMMENTS

A SUMMARY OF VALIDATION REPORTS FOR MIL-F-8785B

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Introduction:

In the early 1970's, through a series of contracted efforts we examined the validity and completeness of the new Military Specification for Flying Qualities of Piloted Airplanes MIL-F-8785B (ASG) by application to existing airplanes. (Note: the F-4 was compared with 8785A, which was essentially the same.) The efforts consisted of paragraph-by-paragraph comparisons of 8785B requirements with the documented characteristics of aircraft currently flown by the U.S. military and its allies and with the available pilot comments and ratings. Aircraft selected for the study were chosen based upon the following criteria:

i) a well documented history with a sufficient amount of data to perform quantitative analysis

ii) a sufficient number of operational flight hours

iii) aircraft representative of a specific class

Based upon these criteria the following aircraft were chosen:

Ref.	Airplane	Class	AFFDL TR
1.	F-4(B,C,D,E,J) Phantom	IV	70-155
2.	F-5(A,B)/T-38A Talon	IV	71-134
3.	P-3B Orion	III	72-141
4.	C-5A Galaxy	III	75-3

The author will summarize but will not comment on the validity of any recommendations proposed in the reports. In order to assess validity it is suggested that the reader consult the background discussions in the reports cited.

Evaluation of Requirements

This section presents the comparisons of the four airplanes to the requirements of the Flying Qualities Specification (Refs. 5 & 6). Specification paragraphs of Sections 1 and 3 for which recommendations have been suggested will be annotated in the following manner:

** - addressed by the proposed 1978 revision (Ref 7) to 8785B

* - "Significant" items that warrant consideration but have not been addressed by the present proposed revision

Significant recommendations are considered to be those:

1) resulting from marked inconsistency of pilot ratings and comments and the requirements.
2) for which two or more airplanes have similar discrepancies in the requirements.

If conflicting recommendations have been proposed for two airplanes in the same class, the author chose not to present the recommendations. All recommendations have been substantiated through pilot ratings/comments, data, or both. Background discussion or aircraft identification will be given where it is considered necessary or helpful for clarification. Notes will be made where a proposed revision conflicts with or does not incorporate the recommendations proposed by the reports.

Requirements and Recommendations

1. - SCOPE AND CLASSIFICATION

1.1 - Scope*: It is necessary to recognize and deal with the need for coordination between MIL-F-8785B and MIL-F-83300, the V/STOL flying qualities specification (Ref. 3).

1.2 - Application**: The wording of the requirement implies that deviations from the specification are allowable. It should suggest that special requirements, whether additional or alternate, may be specified by the procuring activity (Ref. 2).

1.4 - Flight Phase Category: Missions of specific airplanes differ enough to make any listing of discrete flight phases possibly ambiguous, incomplete, or superfluous. Rewrite 1.4 and expand the background document in support of 1.4 to include the Flight phases which are considered in each category (Ref. 3).

1.5 - Levels of flying qualities**: The verbal discussion for the various levels of flying qualities should be placed in the background document (Ref. 3). (Note: a major rewrite has been proposed for Section 1 in 1978 revision.)

Section 3 - Requirements

3.1 - General requirements

3.1.1 - Operational missions**: A good, clear and concise mission definition is lacking (Ref. 1,3,4). Special maneuvering requirements should be addressed and the spectrum of usage should further be defined (Ref. 1).

3.1.2 - Loadings: The requirement to define loadings that will exist for each flight phase is not realistic for certain aircraft with a wide spectrum of operational missions and with possible variations of profiles within a mission (i.e. Ref. 3 on ASW). The Contractor should define the envelopes of c.g. and corresponding weights that will exist throughout the operational mission (Ref. 3). Also, clarification is needed on the data to be used to define the critical loading for corresponding normal and failure states.

3.1.6.1 - Airplane Normal States: The procedure for selecting critical values of such items as gross weight, c.g. and moment of inertia is obscure. Reference should be made to requirements for loading data (3.1.2), moments of inertia (3.1.3), external stores data (3.1.4) and the criteria of 4.2, the airplane states (Ref 1). Also, it should not be necessary to tabulate all the multitude of possible store loadings (Ref. 2). There is a difficulty in defining all states (i.e. loadings, c.g., etc.)(Ref. 3); consequently it is felt the required information should be defined and tabulated with the guidance and approval of the procuring activity (Ref. 2 & 3).

3.1.6.2 - Airplane Failure States: Revision is needed to reduce the task of compliance. The contractor should define and tabulate those those failure states which have a significant effect on flying qualities (Ref. 1). There is also the need to define realistic requirements for probability of encountering degraded flying qualities and tailoring these by considering the machine and its mission (Ref. 3).

3.1.7 - Operational Flight Envelope: The minimal wording of the specification doesn't ensure the understanding that V-n diagrams are required (Ref. 2). There is potential conflict in the application of the specification Table I for flight phase CR, RT and D: this occurs when a power-off low-speed stall-related boundary intersects an altitude boundary established by the rate of climb capabilities at a specific thrust. The power or thrust requirement differs and presents a quandry. Guidance whould be given when a conflict occurs (Ref. 3).

3.1.8.4 - Service load factors: Identify the specific configurations for which service load factors as a function of speed must be constructed (Ref. 2). Also address the airplanes capabilities and not the minimum angle requirement. Onset of stall warning is the cue by which the pilot determines the proximity to stall and should be the boundary of the service flight envelope (Ref. 3).

3.1.9.2.1 - Minimum permissible speed other than stall speed**: Airspeeds below stall speed should be allowed for special conditions, especially for class IV aircraft with air-to-air combat requirement to permit exploitation of its agility against an adversary. The following stipulation is placed on this recommendation, that pilot safety is not jeopardized and dangerous flight conditions will not arise (Ref. 2).

3.1.10.2.1 - Requirements for specific failures: The definitions of the specific failures are not sufficiently clear to make the requirement comprehensible. There is a need to perform failure state analyses in the design phase and to determine which support systems, subsystems and components affect the flying qualities. Specific failures that are known to affect the flying qualities should be defined by the contractor with the approval of the procuring activity. Also, the inclusion of reliability requirements in the present content of specification encumbers its application and tends to produce an oversimplified approach to reliability analysis (Ref. 3).

3.1.10.3.2 - When Levels are not specified: When Levels are not specified, retention of this requirement in the content of the current specification necessitates further development of some paragraphs in 3.1.10.3.2 for Level 1, Level 2 and Level 3 requirements. The broad nature of 3.1.10.3.2 imposes unduly severe requirements in some cases such as 3.6.1.4 Trim system irreversibility (Ref. 3).

3.2 - Longitudinal Flying Qualities

3.2.1.1 - Longitudinal static stability**: The addition of a statement, "the combined effects of centering, breakout force, stick force, stability and force gradient shall not produce objectionable flight characteristics" is desirable. Also allow neutral gradients for Level 1 category A and B. Define a maximum positive force gradient limit (Ref. 1). There is an incompatibility in the requirement for a fixed trimmer/throttle position for 1g and constant altitude (Ref 2,3, 4). There is no way to conduct tests at constant altitude unless power is varied.

3.2.1.1.2 - Elevator control force variations during rapid speed changes: Reword to exclude manual trim systems at Level 1 Cat. A for Class III aircraft which are required to accelerate and decelerate rapidly over large speed ranges for tactical maneuvers (Ref. 3).

3.2.1.2 - Phugoid stability*: The requirements are felt to be too stringent. Lower Level 2 boundary for ζ_{PH} from 0.1 to $\zeta_{PH} = 0$ (Ref. 1). It was noted that Level 3 values were receiving Level 1 and Level 2 pilot ratings. Three of four aircraft experienced the same recurring problem. They were getting different acceptable values for ζ_{PH} from those considered acceptable in the requirement (Ref. 1,3,34). Subject to the approval of the procuring activity, relaxation of the Level 1 requirement should be permitted when period is greater than 30 seconds (Ref. 4).

3.2.2.1 - Short-period response: Clarify the meaning of coincident Level 2 - Level 3 boundaries in paragraph 6.7.2 of specification. Make sure reference to 3.2.2.1.1 in background document is placed in 3.2.2.1 which discusses the problem (Ref. 3).

3.2.2.1.2 - Short-period damping*: Pilot comments indicate that interactions of various parameters have an effect on pilot opinion, and the extent of the influence of ζ_{sp} alone on the quoted rating is sometimes unclear. Further investigation is warranted. NATC reports suggest differences up to .05 in ζ_{sp} are below pilot threshold, yet .05 is the total bandwidth of the Level 3 band in Category B. With this in mind Level 2 and 3 bandwidths seem impractically narrow (Ref. 1). The specified minimum ζ_{sp} of .25 for Level 2 Catagory A & C flight phases for Class IV is not considered to be the lowest acceptable minimum value (Ref. 2). Additional data needs to be obtained for Class III airplanes to support or revise the Category A Flight Phase requirement. For Category B the lower bounds of Level 1 should be relaxed for Class III airplanes contingent upon procuring activity approval. For Class III reduce the lower bounds of figure 2 for Level 1 by 10% (Ref. 4).

3.2.2.2.1 - Control forces in maneuvering flight**: Relax Level 3 minimum boundary to 2.0 lb/g (Ref. 1). Average gradient needs to be defined (Ref. 2). For wheel control airplanes required to maneuver tactically or designed to be flown one-handed, the upper and lower force limits should be relaxed (Ref. 3).

3.2.2.2.2 - Control motions in maneuvering flight: Pilots commented that a defined upper limit for Class III Level 1 flying qualities to control force per inch might result in lower F_s/N values being found acceptable during tactical maneuvers (Ref. 3).

3.2.2.4 - Longitudinal Pilot Induced Oscillations **: A definitive criterion which would catch an PIO problem in the design stage is certainly desirable. The qualitative form of the requirement as it presently stands is considered insufficient as a specification to ensure no PIO tendency (Ref. 1 & 2).

3.2.2.3.1 - Transient control forces: Relaxation is needed for Class IV airplanes in CO Flight Phase at the discretion of the procuring activity. This relaxation should not be allowed to cause any adverse effects such as a tendency to PIO (Ref. 1). Also 6 lb/g is felt to be too low for wheel control Class III airplanes. Class III should be excluded from coverage under 6 lb/g requirement. A more complete survey of the sudden pullup characteristics of Class III airplanes should be conducted; this should be the impetus for establishing a new minimum F_s/n for Class III airplanes (Ref. 3).

3.2.3.4 - Longitudinal Control in Landing: Requirement should indicate whether the airplane should be in or out of ground effect when compared with the requirement (Ref. 1). Change 3.2.3.4/3.2.3.4.1 to provide similar coverage during landing as 3.2.3.3 provides during take off (Ref. 3).

3.2.3.5 - Longitudinal control in dives**: Requirement appears to excessively overlap 3.6.1.2. For Class III consider wheel control aircraft with manual trim systems as a center-stick-controller aircraft for the longitudinal force characteristics (Ref. 3 & 4).

3.2.3.7 - Longitudinal control in sideslips: This requirement should be rewritten to provide adequate coverage for multi-engined aircraft with asymmetric drag or thrust or the need to crab and de-crab in cross-winds during take off, approach, and landing (Ref. 3).

3.3 - Lateral-directional flying qualities

3.3.1.1 - Dutch roll**: There is a general disagreement with pilot rating and specification requirements for Class III airplanes. Additional data should be obtained to substantiate any revision (Ref. 3 & 4).

3.3.1.2 - Roll mode*: There is a need for a study to specifically review the roll mode time constant and the effect of roll-rate damping augmentation which has been utilized in aircraft design (Ref. 2). Ref. 3 proposed two new roll rate damping requirements based on 1) the quality of response to a pilot input and 2) the adequate suppression of lateral gust disturbances. For airplanes in which personnel are located at a considerable distance from the principal roll axis the requirement of 3.3.1.2 should be reasonably relaxed. Additional information is needed to support this Class III requirement (Ref. 4).

3.3.1.3 - Spiral stability**: The entire question of acceptable spiral mode characteristics for tactical instrument flight should be reviewed (Ref. 3).

3.3.2.4 - Sideslip excursion*: A clear definition of $\Delta\beta$ is desirable and guidance as to which time to use when calculating "K" is needed. Directions on application of the paragraph are not stated (Ref. 3 & 4). Uniform applicability of the requirement to all classes of aircraft is questionable. The requirement for a bank-angle change of 90° is excessive for Class III. Aileron command should be held in long enough to establish (ϕ_t) command and β (Ref. 4).

3.3.3 - Lateral-direction Pilot Induced Oscillation*: Little or no work has been conducted in the industry to establish criteria to evaluate lateral PIO quantitatively. It is considered essential that a method be derived and quantitative evaluation be specified. It is recommended that research work be conducted in this field to establish a quantitative specification (Ref. 2).

3.3.4 - Roll control effectiveness**: For Class IV-L and C aircraft the Level 1 minimum time to bank to 30° requirement should be relaxed to 1.3 seconds and the lower Level 3 boundary for the time to bank to 30° should be relaxed to 2.8 seconds (Ref. 1). It appears the requirements of 3.3.4 for Class III airplanes have been arbitratily selected. C-5 results indicate large, heavy transport airplanes can have satisfactory performance (Level 1 from pilot rating and comments) without meeting Level 1 requirements. Class III roll control effectiveness requirements are considered to be too stringent, and further investigation and re-evaluation are required (Ref. 4).

3.3.4.1.1 - Air to air combat**: Level 3 requirement could be relaxed provided that the resulting roll performance is adequate to break off an engagement and escape from an opponent (Ref. 1). Also allow pilots to use rudder pedals in extreme α and β situations where he is confident in his ability to maintain control. A feasibility study of relaxing restriction on rudder-pedal-augmented rolls should be made (Ref. 2).

3.3.4.2 - Aileron control forces*: For Class IV specify a Level 2 band separating Level 1 and Level 3 requirement. According to figure 1 there is a markedly different standard of mission between Level 1 and Level 3 requirements. This should be recognized by the inclusion of a Level 2 band (Ref. 1). The upper limit force characteristics of Table X should be re-evaluated for Class III airplanes that required the pilot to fly "one hand on the wheel" in order to perform tactical maneuvers (Ref. 3).

3.3.4.3 - Linearity of roll response*: Research is needed to investigate, identify and establish the objections (through pilot rating and comments) to various degrees nonlinearity in response. It is suggested that a quantitative requirement can be specified in terms of maximum variation in a local slop, from a mean gradient (Ref. 2).

3.3.7 - Lateral-directional control in crosswinds: For Class III, rewrite the Level 3 requirements since they appear to be inconsistent with Level 1 and Level 2 flying qualities. Add requirement for Class III to demonstrate Level 2 flying qualities in crosswinds up to 40 knots instead of 30 knots (Ref. 3). [Note, however, that an extensive study of crosswind requirements was made for MIL-F-8785B.]

3.3.7.3 - Taxiing wind speed limits*: Requirement could impose an engine design penalty for airplanes with fan engines, which is probably not intended. A review of the impact of the requirement should be undertaken on other currently operating airplanes which employ high-powered fan engines. The C-5 fan engines operating in crosswind and tailwind conditions up to 30 k ots experience no performance degradation. But above 30 knots reduced power settings must be observed. At 45 knots there is insufficient power generated in order to taxi. The recommendation is to establish taxi wind requirement as amargin above the required crosswind components on the basis of operating experience (Ref. 4).

3.4 - Miscellaneous flying qualities

3.4.2.4 - Stall recovery and prevention: For Class IV airplanes, since three aerodynamic controls are allowed to be used in stall recovery there is no apparent reason why throttle manipulation should not be allowed (Ref. 2). For Class III airplanes further studies should be accomplished to establish acceptable limits for excursions in pitch, roll and yaw (Ref.3).

3.4.3 - Spin recovery: Consideration should be given to revising spin-demonstration requirements to include spin susceptibility (Ref. 1). (This was done in the amendments to MIL-F-8785B).

3.4.4 - Roll-pitch-yaw coupling: Class IV airplane requirements place emphasis more on structural limits then on resulting dangerous flight conditions due to rolling at high angles of attack (especially in the $C_{L_{MAX}}$ region). When rolled at $C_{L_{MAX}}$, some aircraft will spin or uncontrollable motion will occur. Also replace ".8n_L" by "$C_{L_{MAX}}$" or .8n_L, whichever comes first (Ref. 2). For Class III aircraft it is considered not a definitive requirement. Inlcusion of the 100% structural demonstration compliance with requirement is somewhat incompatible. This should be performed at 80% of the structural capability of the airplane. Also, heavy transports may not be allowed to roll 120° (90° is felt to be more applicable). Abrupt, uncoordinated rolls at load factors from 0g to .8N_L may not be possible for large CIII transports.

3.5 - Characteristics of the primary flight control system

3.5.2.1 - Control centering and breakout forces*: Relax breakout force limits for Class IV as follows; elevator for Level 1 should be 4 lb; set aileron upper limit for Level 1 to 2 lb and 5 lb for Level 2; and increase rudder to 14 lb (Ref. 1 & 2). For airplanes with cable systems lower breakout forces and force gradients should be considered (Ref. 4). A revision to descirbe a specific technique to be used for measuring breakout point is desired (Ref. 3 & 4). It has been suggested that the breakout forces should be the force measured at the first significant movement of the control surface (Ref. 3). Also it is desirable to measure forces inflight (Ref. 4).

3.5.2.2 - Cockpit control free play: There is a need for a quantitative requirement based upon real-world operational experiences. Also it is desirable to establish maximum allowable normal and failure-state free-play limits for wheel and stick control systems for all Classes of airplane (Ref. 3).

3,5,2,3 - Rate of control displacement: Reword to specifically include emergency flight operations where the combinations of a large control displacement accompanied by high controller force limits the ability of the pilot to maneuver (Ref. 3).

3.6 - Characteristics of secondary flight control system**:

3.6.1 - Trim systems**: Relax the requirement for asymmetric loadings provided the operational effectiveness of the aircraft is not unduly compromised (Ref. 1). Allowable aileron force for Level 3 after failure should be increased above allowable breakout force (Ref. 3). [Note: recommendation differs from revision in Ref. 7.]

3.6.3.- Transient and trim change**: The trim shange is not dealt with. Requirement should cover objectionable transient nature of trim changes. Also add a statement ot prohibit excessive control forces or other objectionable demands on the pilot (Ref. 1). (Note recommendation differes from revision in Ref. 7.)

3.7 - Atmospheric disturbances

3.7.5 - Application of the turbulence models in analysis*:

Requirement does not specify criterion for flying in turbulence (Ref. 1,2,3,4). (This is discussed in Volume II of Reference 7.)

Conclusions

In general, the authors of Refs 1-4 consider MIL-F-8785B to represent a substantial improvement over past specifications with regard to requirements definition, format, and overall clarity. Reference 1 considers the following areas of the specification as candidates for further investigation:

1) Longitudinal Short Period damping ratio (3.2.2.1.2)
2) Longitudinal Pilot induced oscillations (3.2.2.3)
3) Roll mode time constant (3..31.2)
4) Spin recovery (3.4.3)
5) Control system mechanical characteristics (3.5.2)
6) Engine control and response characteristics (3.6.2)
7) Quantitative requirements on atmospheric disturbances (3.7)

in addition to the above, the following general topics are considered to be in need of further study:

8) Practicability of the General Requirements section
9) Specification of parameters relavant to aircraft with stability augmentation systems
10) Effect of interaction of 'good' and 'bad' parameters on overall mission capability.

Finally the authors of Reference 1 reached the following general conclusions:

1) The flying qualitiessspecification is a considerable improvement over its predecessors
2) The intent of the General Requirements section is understood;

however, it presents an obscure and idealistic definition of a mammoth task.

3) In a number of cases overly conservative quantitative requirements have been specified when substantiating data are absent, scant or inconclusive.
4) A number of requirements have limited applicability to aircraft with artificial stability augmentation systems.
5) The importance of using a pilot opinion rating method such as the Cooper-Harper scale in testing for compliance with qualitative requirements, cannot be too strongly emphasized; the authors in many cases found assigning even a level of flying qualities to a qualitative remark was difficult or impossible.
6) The assessment of 'poor' flying qualities is difficult; in this connection Level 3 is often ill-defined.

Reference 2 yielded the following general conclusions:

1) the specification represents an outstanding improvement over past specifications
2) the two most pertinent new requirements needed to be expanded for more comprehension are:
   a) the "Airplane Failure States" (by including guidelines and sample approaches to provide evaluation methods for contractor guidance when comparing or designing airplanes to this specification).
   b) the "Atmospheric Disturbances" (requirements should be defined and should include quantitative values for compliance levels).

Reference 3 gave no formal overall conclusion, only the conclusions present in the comparison of each paragraph. It is this author's personal opinion after reviewing the report that Reference 3 agrees with the general conclusion that the specification is an improvement over the past specifications. Reference 4 presented the following conclusions:

1) generally, the data compared favorably with the specification except in certain sections where the requirements appear to

have been based primarily on medium and light weight airplane data.

2) based on the dats, the following sections are far too stringent for Class III airplanes.

   a) Roll mode (τ_R) (3.3.12)
   b) Sideslip excursions (3.3.2.4)
   c) Roll control effectiveness (3.3.4)

3) additional data from Class III heavy aircraft be gathered to substantiate or revise the requirements in the following sections:

   a) Phugoid stability (3.2.1.2)
   b) Short period response (3.2.2.1)
   c) Control forces in maneuvering flight (3.2.2.2.1)
   d) Lateral-directional oscillations (dutch roll) (3.3.1.1)
   e) Roll mode (τ_R) (3.3.1.2)
   f) Sideslip excursions (3.3.2.4)
   g) Roll control effectiveness (3.3.4)
   h) Resistance to loss of control (3.4.2.2.1)

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7. Proposals for Revising MIL-F-8785B, Flying Qualities of Piloted Airplanes, AFFDL-FGC Working Paper, February 1978

Col. Shall, 4950th Test Eing: What is meant by your comment to define "$\Delta\beta$ and the time to K" in 3.3.2.4?

Answer: $\Delta\beta_{MAX}$ is defined in MIL-F-8785B, but not $\Delta\beta$. Also, there is a need to define an appropriate time for calculating "K".

Don West, Boeing: Does the Air Force really have a need to land in 40 knots cross wind?

Answer (from Moorhouse, AFFDL): What is presented in the paper is the recommendation in one of the validation reports. A large study of crosswinds was done for MIL-F-8785B; we do not plan to revise those requirements.