SECTION X

SUMMARY AND CONCLUDING REMARKS

SUMMARY AND CONCLUDING REMARKS

The symposium that is the subject of this report was held as a part of an effort to revise MIL-F-8785B, "Military Specification, Flying Qualities of Piloted Airplanes." It was held approximately 12 1/2 years after the last similar conference*, a step in the revision of MIL-F-8785. In this intervening period, MIL-F-8785B was issued in August 1969 and amended in September 1974. Reports have been written validating certain requirements of MIL-F-8785B and not others, suggesting revisions to MIL-F-8785B and even showing how to outsmart MIL-F-8785B. Of particular importance to the authors of the specification is the fact that advancing technology is continually making it more in need of further revision. It is interesting to note then, that some of the discussions at the 1966 conference were repeated in 1978 and some of the same questions remain unresolved.

A. Summary of the Symposium

The symposium papers covered a range of flying qualities topics directly or inderectly related to the specification or the proposed revisions. A total of seven papers directly addressed the subject and these, plus workshop comments and general discussion topics, are discussed in the succeeding two sections. The remaining papers do not necessarily fit in firm categories; however, seven papers suggested new or modified flying qualities criteria. The subjects included high angle of attack, lateral-directional requirements, low speed force gradients, flight path control and the use of equivalent system parameters. Only the last topic was really included in the proposed revisions. Sheer weights of numbers proposing new criteria reinforces the admission that many deficiencies remain and much work is still required.

Five papers are considered to present new results, adding to the total data base. The subjects included higher order system effects (both longitudinal and lateral-directional), sidestick controller characteristics and digital flight control effects. Four papers presented general flying qualities results: an A-10 flying qualities problem that was uncovered by an operational-type mission not by compliance with MIL-F-8785B, flying qualities evaluations of a canard fighter configuration and the Space Shuttle, and a review of ancient but well-used PIO documentation. Finally four papers discussed the Prime-Standard format. A total of eight working groups were convened to discuss the subject topic from a variety of viewpoints. The foregoing is obviously only a very brief summary of the body of this report.

---

* "Flying Qualities Conference, Wright-Patterson Air Force Base, Ohio, 5 and 6 April 1966," AFFDL-TR-66-148, December 1966.

B. Discussion of MIL-F-8785B

The papers on MIL-F-8785B presented to the symposium contained comparisons of the requirements with the C-5A/C-141/L-1011; the B-1; and the Advanced Medium STOL Transport (AMST); plus a summary of validation reports for the F-4, F-5, P-3 and C-5A. The trends shown in these papers are that MIL-F-8785B loses validity for large aircraft and for highly augmented aircraft. In the summary paper, only two items were common to all four validation reports. The requirement for phugoid damping was deemed to be too stringent (not addressed in the current revision). There was also a plea for quantitative requirements for flight in turbulence; there was felt to be insufficient data to accomplish this in the current revision effort. The subject is discussed in Volume II of the revision Working Paper. It is of interest to note that for the AMST, MIL-F-8785B was used more than MIL-F-83300. It is planned to incorporate STOL requirements into the future Prime-Standard and Handbook version of MIL-F-8785B.

There was discussion at the symposium about requirements with and without selectable functions engaged (see Carlson's first paper in this report). Section 3.1.5 of MIL-F-8785B dictates that all configurations required for mission accomplishment shall be examined. It does not require Level 1 characteristics with and without all selectable functions. The example used in the reference paper concerned a speed-hold system used to produce Level 1 characteristics. The system is engaged by pilot selection, and it was stated to be obvious to the pilot if the system were not engaged when attempting a STOL landing. The application of 3.1.5 to this example seems perfectly straightforward. If engagement of the speed-hold system is required for Level 1 characteristics then it has to be made a part of the standard landing procedure, as much as putting the wheels down. 3.1.5 does not then require Level 1 characteristics with the speed-hold system disengaged, although possible failures of the system require consideration for other requirements. On the other hand, if use of the speed-hold system is truly a pilot "option," then MIL-F-8785B and prudence would dictate Level 1 characteristics with and without it.

A related discussion concerned switching off augmentation functions for training purposes. The proposed revision to 3.1.1 includes aircrew training as an operational mission, the intent being to recognize that any airplane is used for operational mission training. There may also be training for Failure States and degraded conditions which obviously requires the appropriate worse Level of flying qualities. Paragraph 3.1.5 does not require Level 1 characteristics for these latter selectable configurations.

C. Comments on the proposed revisions*

The symposium contained one formal paper on the proposed revisions (in addition to the one by the perpetrators) plus much discussion, both

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

in and out of the workshop sessions. There were many comments and suggestions made, and no attempt will be made to editorialize on the majority of these. There was, however, one item that caused strenuous objections and will continue to receive attention, i.e. atmospheric disturbances.

1. Atmospheric disturbances

Environmental conditions, especially atmospheric disturbances, have always been an integral part of flying qualities. The successful design philosophy of the Wright brothers was predicated on minimizing the response to disturbances. To do this they sacrificed stability, with a resulting increase in pilot workload. Report no. 1 of the National Advisory Committee for Aeronautics, "Report on the Behavior of Aeroplanes in Gusts," was concerned with airplane stability and control in gusts. In more recent history, during the effort to produce MIL-F-8785B it was felt necessary to account for the effects of disturbances. Turbulence and gust models were added and some of the requirements were intended to apply in turbulence. The Background Information and User Guide, however, stated: "It was decided, therefore, that turbulence models would be presented in MIL-F-8785B, to be used in any analysis and simulation of flying qualities and ride qualities that the contractor performs." Succeeding discussion concentrated on application to simulation and analyses in general, no specific requirements were imposed. There was no explicit consideration of the effects of disturbances on the Levels of flying qualities.

2. Levels of flying qualities

In the flying qualities community, flying qualities levels commonly are associated with pilot ratings. Pilot (Cooper-Harper) ratings are based on performance and difficulties of the pilot-controlled vehicle in a given task and environment. However, Levels are used to specify values of vehicle parameters acceptable in various flight envelopes, normal and failure states. What determines pertinent tasks and environments is the projected operational usage; the vehicle must be designed to fit these given requisites.

By common observation, pilot rating naturally tends to degrade as the intensity of atmospheric disturbances increases. For conditions encountered not infrequently in a given task or Flight Phase, pilot ratings must be maintained within the appropriate "satisfactory," "acceptable" and "flyable" ranges of Cooper-Harper ratings. Just as clearly, beyond a certain intensity of turbulence it is unreasonable to demand the improvements in vehicle characteristics which would be needed to maintain pilot ratings in the same range (if indeed that were possible). Likewise, there is no desire to lower the numerical requirements as turbulence intensity increases, thus compounding the degradation in pilot rating.

From this discussion it is seen that Levels are associated with the vehicle being procured and its intended missions, whereas pilot ratings are functions of other factors as well. The flying qualities specification, of course, is not intended to be used for selection of pilots or modification of the environment - these must be accepted as given. Thus the required Levels of aircraft flying qualities are related to stated rational combinations of pilot capability (in terms of workload and pilot-vehicle performance) and atmospheric disturbances.

At the symposium a consensus was evident that these considerations need to be taken into account. It seemed, though, that the number of ways proposed to do this approached or exceeded the number of commenters. We definitely need to do a better job of presenting the concepts individually, one at a time, and then relating them to each other in a manner that is rational, acceptable - and understandable.

One source of difficulty is that we proposed to modify the now-historic singular relationship of 8785B Levels with ranges of Cooper-Harper ratings: POR 3.5 the Level 1 boundary, POR 6.5 separating Levels 2 and 3, and roughly POR 9+ the Level 3 floor. This concept or one like it, is necessary to derive numerical bounds on flying qualities parameters; where insufficient basis exists for such numerical bounds it still provides a frame of reference for qualitative evaluation of aircraft suitability. In concept, few would argue the propriety of that. We do not propose to introduce pilot ratings directly into the specification. For much of the data base, atmospheric disturbances were represented in some manner and degree. Now, however, we see a need to state the obvious - that we neither can nor should force the design of airplanes to have a "satisfactory" rating in severe turbulence. With little data for guidance, the changes proposed are frankly based on intuitive judgment of prospect and need.

Considering the data sources, it seems that the numerical requirements on individual parameters should apply in moderate, if not more intense disturbances. But as was brought out at the symposium, there are practical difficulties with severe disturbances. For one thing, flight situations short of disastrous become harder to evaluate in a number of respects: danger potential, time, limit of tolerance, probability of encounter, estimation of parameters and of the crew's reserve capacity. Also, at some point increasing disturbance intensity will saturate the stability augmentation. That may be no problem with full-authority SAS; but with authority limited in order to bound the effect of hard-over failure in a single-channel system, one would expect noticeable degradation of effective damping ratio, etc. in severe turbulence. We do not want to force unnecessary redundancy or complexity on a designer so it is appropriate to have a qualitative alternative to the numerical requirements for high-intensity disturbance inputs.

3. Proposed requirements

The necessity for providing more explicit requirements to account for the effects of disturbances was acknowledged at the symposium. In a practical sense this seems quite simple - it is basically a design problem. The designer may minimize response to gusts, add turbulence to a simulation, calculate or simulate response to a wind shear, etc. using rules of thumb. Flight tests are normally scheduled at less turbulent times of the day and certainly not in bad weather. The problem is to formulate this "simple" design requirement in specification format. At the symposium, there was little real disagreement over the announced intent of the revisions proposed by AFFDL/FGC. The comments concerned misinterpretations, both real and anticipated, and counter-proposals for ways to implement the revision. The concensus was to leave the definitions of Levels as in MIL-F-8785B (section 1.5) and add requirements to section 3.1.10, Applications of Levels. In implementing these suggestions, we have found it to be advantageous to define qualitative degrees of suitability to complement the current Levels of flying qualities. There is generally degradation in pilot workload or task performance (i.e. pilot rating) with increasing disturbance intensity, even for an airplane with Level 1 quantitative characteristics. It is now proposed to account for these possible effects by a requirement of the form (as a modification to 3.1.10.1):

Atmospheric Disturbances	Within Operational Flight Envelope	Within Service Flight Envelope
LIGHT TO CALM	Quantitative requirements Level 1; qualitative requirements Satisfactory	Quantitative requirements Level 2; qualitative requirements Acceptable
MODERATE TO LIGHT	Quantitative requirements Level 1; qualitative requirements Acceptable or better	Quantitative requirements Level 2; qualitative requirements Controllable or better
SEVERE TO	Qualitative requirements Controllable or better	Qualitative requirements Recoverable or better

We are still assuming, in application to simulation, that a pilot does not know, or need to know, the actual intensity of the disturbances. His rating is a function of the airplane responses to the disturbances and the workload necessary to achieve the task performance he desires, if possible.

D. Philosophy

In 1966 it was stated*: "The flying qualities specification... is one or more of:

A contractual document
A set of minimum requirements
A design guide
A flight-test standard or guide
A cause of added drag, weight, cost...
A definition of a related subsystem
Assurance, to an extent, of safety, mission capability and good working conditions for the pilot
A research goal

Further evidence of the conflicting requirements is contained in the results of a recent survey** of users of MIL-F-8785B. The document was assessed as a firm specification (48% yes vs 52% no); a design guide (91% yes vs 9% no); and as test and evaluation criteria (87% yes vs 13% no). From the viewpoint of those responsible for MIL-F-8785B it has to be, or form the basis for, all three. It probably follows that it can never be perfectly suited for any one of those uses. MIL-F-8785B will still continue to effect a compromise, and sympathy will be offered to the specialists.

Signal Corps Specification No. 486 is frequently cited as a desirable performance-oriented specification (e.g. F. M. Wilson's paper in this report). The design requirements are explicit in terms of speed, payload, endurance, etc. The flying qualities requirements are implicit in the stated method of demonstrating compliance: "Before acceptance a trial endurance flight will be required of at least one hour during which time the flying machine must remain continuously in the air without landing. It shall return to the starting point and land without any damage that would prevent it immediately starting upon another flight. During this trial flight of one hour it must be steered in all directions without difficulty and at all times under perfect control and equilibrium." It should be noted, however, that this essentially means that the requirement was simply for controlled flight. Although flying was no mean feat in 1907, defining the explicit requirements for many new airplane systems is now a major

* Woodcock, R. J. and Mabli, R. A., "USAF Views on Handling Qualities Criteria," Flying Qualities Conference, WPAFB, Ohio, 5 and 6 April 1966, AFFDL-TR-66-148, December 1966.
** Rediess, H. A. and Shafer, M. F., "Results of Subcommittee D Survey on Future of Research on Flying Qualities and Criteria for Highly Augmented Aircraft," presented to SAE Aerospace Control and Guidance System Committee, October 1977.

task as tactics continually evolve. No longer can we merely demand perfection. G. Brandeau's paper in this report illustrates the flying qualities design problems that resulted from changes in the parameters of a mission task.

An additional problem with truly mission-performance requirements is deciding who flies the airplane. In this context it is interesting to speculate how many modern-day lawyers could gain employment from a dispute of the Signal Corps' requirement that: "It should be sufficiently simple in its construction and operation to permit an intelligent man to become proficient in its use within a reasonable length of time." It is suggested that flying qualities requirements and methods of compliance should properly be negotiated for each new procurement. The future MIL-PRIME-STD and MIL-HDBK is intended to both require and facilitate such tailoring.

1. Flight test

Anxiety was expressed over requirements for which flight testing to demonstrate compliance would be extremely difficult or time-consuming. Requirements related to atmospheric disturbances were of particular concern. However, neither past practice, present procedures nor foreseeable future demands show such difficulty. Flight testing has always been a most pragmatic occupation. That certainly holds with flying qualities. The following discussion attempts to show what reasonably can be expected.

Our first military flying qualities specification, Army Air Forces Specification C-1815, was published in 1943. In all the years since, we believe no flight test program has ever thoroughly checked sensor availability and capability, data recording and reduction equipment, engineering manpower limitations, flight safety considerations, funds availability, aircraft availability, configuration or subsystem changes, urgent problems with other parts of the aircraft, emphasis on operational aspects - the list seems endless. The complexity of a contemporary flight control system itself may preclude flight evaluation of all failure modes.

Currently flight test costs are up, flying hours are down, and emphasis has shifted from engineering evaluation to investigation of conditions approximating operational use. In this climate we must seek optimized flight test techniques to extract the greatest quantity of most-needed flying qualities data in the available flight test time. There is no hope of a flight handling evaluation of the type and scope of AFFTC's Phase IV evaluations of former years. The change is not all bad.

While parameter identification data reduction techniques will never replace flight test time history records of aircraft response for many analysis purposes, they are seeing more widespread application. As AFFTC has shown here, using appropriate control inputs, data for small perturbations can be accumulated quickly over a large flight envelope for reduction by computer to transfer functions or stability derivatives. Twisdale describes a means of extracting such data from air combat tracking related to the manner in which fighter aircraft are intended to be used. From accurate, well-documented results the aircraft designer's stability and control predictions can be corrected to obtain a validated analytical model.

Those flight tests themselves generate the values of many motion parameters needed to determine MIL-F-8785B compliance. Where they don't an engineer can use the validated model to investigate any aspect of specification compliance at will. With this procedure there are now, of course, many more chances for error along the way. For meaningful results a good deal of coordination is necessary among all those involved in design, testing, evaluation and procurement.

Response to turbulence, gusts, etc. is one example of a type of specification requirement which, though necessary, is practically impossible to flight test. Structural flight loads specifications were the first to put design requirements in such terms. MIL-A-8861 (1960, still used by the Navy) and MIL-A-008861A (USAF) continue use of the time-honored 1-cosine gust which cannot be found at all in flight (especially when looking for one). Compliance with gust-response requirements has always been shown by analysis and ground testing. That holds equally for the statistical turbulence introduced in 1971, by MIL-A-008861A for mission and design envelope analyses. In 1969 MIL-F-8785B introduced flying qualities requirements pertaining to similar gusts and turbulence. In 1975 MIL-F-9490D, the current AF flight control system specification, introduced requirements applicable in atmospheric disturbances that also include wind shears.

As stated in the proposed revision to the British flying qualities specification, Av. P. 970 (RAE Tech. Memo Structures 863, April 1975 Leaflet 600/1), "Compliance with some requirements cannot readily be determined by flight testing... In these cases, compliance can be shown by theoretical calculation or simulation, by agreement with the Aeroplane Project Director, provided that the data used is derived as far as possible from flight testing and provided that some back-up qualitative flying is done; for example, some flying must be done in real turbulence." That approach seems about the best that can be done in flight testing for the effects of atmospheric disturbances. It also greatly expands the ability to show compliance with other flying qualities requirements for which direct demonstration would be very demanding of flight time - such as MIL-F-8785B's roll-sideslip coupling requirements.

E. Concluding remarks

With perspicacity of hindsight it would be possible to improve the symposium - more time allocated to the working sessions and a smaller number of papers. It was judged to be a success from our viewpoint in providing a forum for comment on the proposed revisions and airing many possible misinterpretations of both the existing and proposed requirements. With the forthcoming change in format to the Prime-Standard and Handbook these discussions will assume greater importance. In the near future, it is our intent to hold such symposia more frequently than once every twelve years.