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BACKGROUND INFORMATION AND USER
GUIDE FOR MIL-S-83691

Patrick S. Sharp, et al

Air Force Flight Test Center
Edwards Air Force Base, California

March 1974

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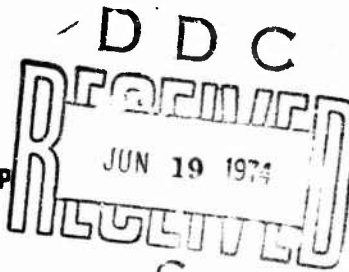
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AND USER GUIDE FOR
MIL-S-83691**

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TECHNOLOGY DOCUMENT No. 73-2

MARCH 1974

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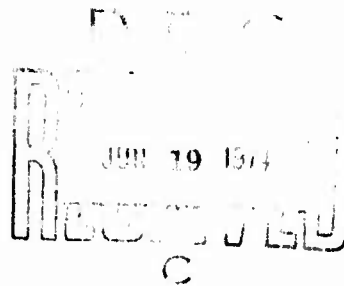
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**BACKGROUND INFORMATION
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FOREWORD

This report is the Background Information and User Guide (BIUG) for Military Specification MIL-S-83691A (USAF), "Stall/Post-Stall/Spin Flight Test Demonstration Requirements for Airplanes." The BIUG is published as an aid in the interpretation and application of MIL-S-83691A (USAF) and to additionally suggest information which would lead to the most effective use in a flight test program.

MIL-S-83691A (USAF), 15 April 1972, is the first revision of MIL-S-83691 (USAF), 31 March 1971; the latter specification was an AFSC-authorized replacement for MIL-S-25015, "Spinning Requirements for Airplanes". This major specification change was a recommendation of the August 1970 F-111 Ad Hoc Committee and was based on the general test approach utilized on the F-4E Stall/Near Stall Investigation completed in 1970.

Upon publication of MIL-S-83691 (USAF), government agencies and industrial firms were formally asked to critique the specification. The technical responses were not only instrumental in generating the 15 April 1972 "A" revision of the specification, they also provided insight as to what areas required special attention in the BIUG.

The participation of AFFTC personnel in BIUG publication reflects the AFFTC's continuing responsibility, as Preparing Activity, for technical maintenance and proper utilization of MIL-S-83691A (USAF). The BIUG is not a contractual document.

The authors of this report wish to acknowledge the assistance of Charles E. Adolph and Jack Strier in the preparation of the specification and the valuable suggestions of Charles E. Adolph and Richard R. Hildebrand in the compilation of this document. Revisions to the BIUG will be issued as MIL-S-83691A (USAF) is amended in the future. Comments, suggestions, and requests for copies of the BIUG should be addressed to the Flight Test Engineering Division, Performance and Flying Qualities Branch, Air Force Flight Test Center, Edwards AFB, California 93523.

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INTRODUCTION

The Background Information and User Guide (BIUG) for MIL-S-83691A (USAF) offers explanation for the objectives and contents of the subject specification and provides guidance by which a stall/spin flight test program can be systematically accomplished. Both the specification and the BIUG acknowledge the multitude of objectives and test parameters and the potential of more than one way to achieve results. With the express intent of being truly a guide, the BIUG serves to firmly direct a flight test program in areas where hard experience warrants and to advise flexibility in those areas where airplane/pilot behavior are understandably more difficult to estimate.

The order in which the material is presented parallels that of MIL-S-83691A (USAF). Each paragraph of MIL-S-83691A (USAF) will be repeated herein, being preceded by the heading "SPECIFICATION". Following this will be the heading "DISCUSSION" and the appropriate substantiating material. Tables II and III will be discussed along with the individual paragraphs. Since Table I and the accompanying notes form an essential part of the specification in terms of test conduct, they will be treated separately.

HISTORICAL DEVELOPMENT

In the five-year period, 1965 to 1970, stall/spin accidents resulted in a dollar loss to the United States Air Force of \$40,000,000 per year. This operational experience indicates that previous approaches to design refinement and flight test have not sufficiently emphasized the requirements of departure resistance and spin avoidance. The F-4E Stall/Near Stall Investigation, completed in June 1970, demonstrated that a new approach to stall/spin testing led to significantly different results than those determined from two classical flight test programs and from a number of analytical studies. Then-existent spin recovery techniques were replaced by a simple and effective spin recovery procedure that was also compatible with the out-of-control recovery procedure. A spin reversal problem, inherent to the previous spin recovery procedure, was eliminated. The effects of store loadings on warning and loss of control were evaluated for the first time and found to be significant. It became apparent that the flight test technique of evaluating stall/spin as the user would encounter these conditions provided the most effective information to the operational pilot.

In August 1970, an Ad Hoc Committee was formed to recommend direction for the F-111 stall/spin investigation effort. As a part of this study, a review was conducted of the stall/spin records of all U.S. maneuvering type aircraft and the specifications which were applicable. It was recognized that the Air Force requirements in the post-stall region were unsatisfactory. The then existing spin test demonstration specification, MIL-S-25015 (USAF), "Spinning Requirements for Airplanes," was originally developed in 1945 and revised in 1954, 1956 and 1957. Each revision embraced no change in the basic concept which was deemed inadequate for two basic reasons. First, it did not contain a requirement to systematically define recovery procedures in the area of primary importance to the operational pilot; i.e., the flight regime between maximum usable lift and the point at which an aircraft enters a fully developed spin. Second, it required that a fully developed spin be sustained well beyond the point at which a pilot would recognize that he was in a developed spin before he applied recovery controls, i.e., the requirement to sustain a spinning condition for five turns.

The Ad Hoc Committee recommended that the Air Force design and test requirements in the post-stall region be revised. The AFFTC was directed on 8 October 1970 to prepare a replacement test specification. At the same time, the Air Force Flight Dynamics Laboratory (AFFDL) was charged with updating the basic design specification, MIL-F-8785B (ASG), "Flying Qualities of Piloted Airplanes," to include new requirements for stall/post-stall characteristics. Close coordination between these two formulating groups was maintained to insure compatibility between the two specifications.

A draft version of the proposed specification, dated 22 February 1971, was prepared and sent out for government and industry comments. The first specification, MIL-S-83691 (USAF), was published 31 March 1971. This date allowed some industry comments to be included. All government and industry comments were examined by a resolution panel in September 1971 and the first revision of the specification, MIL-S-83691A (USAF) was published 15 April 1972. The final version of the revisions to MIL-F-8785B (ASG) was published on 15 April 1973 as Amendment 1.

STATEMENT AND DISCUSSION OF REQUIREMENTS

Throughout this document, specifications are referred to by number. In each case, the current version of that particular specification is the one being referenced. As of this writing, MIL-F-8785 would be used to designate MIL-F-8785b (ASG) and MIL-S-83691 would refer to MIL-S-83691A (USAF).

1. SCOPE

1.1 SCOPE

SPECIFICATION

"This specification contains the demonstration requirements of the stall and post-stall flight characteristics of piloted airplanes. Typical demonstration objectives subject to this specification are the verification of service and permissible angle of attack (AOA) limits, evaluation of natural and artificial stall and loss-of-control warning, and determination of out-of-control characteristics and recovery techniques. A purposeful, milestone approach to high AOA flight test is mandatory to determine compliance with the design requirements and obtain suitable information for the Flight Manual. Flight test demonstration requirements will be a function of airplane Class and specific direction from the procuring activity. Resistance to departure from controlled flight and prevention of departures shall be given the same attention as that directed toward recovery from post-stall gyrations (PSG) and spins."

DISCUSSION

This specification has been developed in conjunction with a revision to MIL-F-8785B (ASG), "Flying Qualities of Piloted Airplanes." In each case (MIL-S-83691 and MIL-F-8785), an attempt has been made to redirect the emphasis. The primary design goal is now resistance to loss of control. MIL-S-83691 provides a test guideline whereby the degree of resistance is qualified and all stall/post-stall characteristics can be thoroughly examined. In general, the objectives of this type program are:

- (a) To evaluate stall warning,
- (b) To evaluate loss of control warning,
- (c) To establish a maximum performance maneuvering AOA and a permissible limit consistent with flight safety,
- (d) To determine all possible out-of-control events and simple, effective recovery techniques,
- (e) To evaluate flight control system and engine operating characteristics in the high AOA environment.

The final sentence of this paragraph, "Resistance to departure from controlled flight and prevention of departures shall be given the same attention as that directed toward recovery from post-stall gyrations and spins," emphasizes the increase in scope over the previous specification, MIL-S-25015. It has been realized in the last few years that resistance to departure and departure avoidance are the items of primary importance in many cases - especially ground attack aircraft. Avoidance of loss of control rather than spin recovery is of major concern if recovery is nose down at 3,000 feet AGL.

This specification represents an attempt to define a systematic approach to an investigation of aircraft flying qualities (or "non-flying" qualities) outside the design operational envelope. There exist many factors which require definition outside the design operational AOA envelope; spin recovery is only one. A properly conducted test program is required to determine all of these factors. The extent of the program can rightfully be estimated before testing begins, but the total extent should never be frozen before all objectives are achieved. Only when the using pilot is provided with all the knowledge he needs will the program be completed.

The specification is based on the premise that it is of equal or of more importance to establish recovery procedures for the initial out-of-control event than to determine fully developed spin recovery procedures. In past programs conducted under MIL-S-25015, developed spin characteristics were fully defined, but stall/post-stall gyration/incipient spin recovery techniques were ignored. It is of more immediate importance to explore recovery from post-stall gyrations and incipient spins. Spin avoidance procedures are of more importance than spin recovery techniques. The basic objective is to develop procedures which will arrest any out-of-control motion before it progresses to the developed spin stage.

In addition, forcing the airplane into a spin may introduce entirely different and somewhat "artificial" entry dynamics. Spins occur as an inadvertent sequel to the mission task; the pilot is maneuvering and suddenly he finds himself out of control. Recovery controls are subsequently applied from a neutral or slightly aft position and the aircraft flight path is transitioning to the vertical; recovery controls are not applied from the cross-controlled position and the flight path is not vertical.

All of the concepts of MIL-S-25015, "Spinning Requirements for Airplanes," have not been totally discarded. The fully developed spin is still required to be investigated. Test results have indicated only the undesirability of sustaining a spinning condition (per MIL-S-25015).

The program authorized under this specification may include the peculiar or hazardous high AOA testing that can be accomplished only on a specially equipped aircraft. For example, a phase of high AOA testing was thought advisable on the F-111 before commencing testing in accordance with MIL-S-83691. The aim was to fly near and slightly above current handbook angle of attack limits. With the emergency recovery systems, more confidence existed in adequately investigating rolling/turning maneuvers outside the operational envelope, but within a departure boundary. In other words, the stall/spin program filled a void in flying qualities knowledge that might have gone untested if the modified vehicle had not been available. Although this type of information should normally fall out of a program which applies MIL-S-83691, it may be desirable to examine maneuvers that are not departure-oriented and, consequently, add special requirements.

1.2 CLASSIFICATION

SPECIFICATION

"An airplane shall be placed in a Class as specified in MIL-F-8785 (6.2.1 [b]). When operational missions and design capabilities so indicate, an airplane of one Class may be required by the procuring activity to meet selected demonstration requirements ordinarily specified for airplanes of another Class. Generally, the most stringent demonstration requirements shall apply whenever an airplane fails to come clearly within one of two possible Classes."

DISCUSSION

An airplane will have already been assigned a class as per MIL-F-8785. This classification will normally carry over to MIL-S-83691 where test requirements vary with Class. Problems arise when testing two aircraft such as a B-57 and a C-130, both Class II aircraft according to MIL-F-8785. Certainly the maneuvering requirements for these two aircraft differ significantly and the B-57 may be required to meet requirements beyond normal Class II testing. Also, a Class IV airplane may have such outstanding stall/post-stall characteristics that it may be subjected to the complete set of tests normally desired for a Class I trainer.

Notes such as (6.2.1[b]) are for the individual writing the detail specification, i.e., the actual procurement document. These are items to be specified which are peculiar to each aircraft. A detailed explanation is given in 6.2.1.

2. APPLICABLE DOCUMENTS

2.1

SPECIFICATION

"The following documents, of the issue in effect on date of invitation for bids or request for proposal, form a part of the specification to the extent specified herein.

SPECIFICATIONS

Military

MIL-F-8785 Flying Qualities of Piloted Airplanes

MIL-F-9490 Flight Control Systems - Design, Installation and Test of, Piloted Aircraft, General Specification For

(Copies of specifications, standards, drawings, and publications required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)"

DISCUSSION

At places it was deemed necessary to refer to other documents in the specific requirements of MIL-S-83691. All such referenced documents are listed in 2.1.

Close coordination was maintained with AFFDL, the Preparing Activity for MIL-F-8785, in order that no contradictions exist between the design (-8785) and the demonstration (-83691) specifications. MIL-S-83691 specifies the test procedures to be utilized to verify that the design goals of MIL-F-8785 have or have not been met.

3. REQUIREMENTS

In the application of this specification, contractors are bound to compliance with this section unless specific waivers are granted. Other sections of the specification do not carry the contractual implications of the "Requirements" section, Section 3. Adherence to this section will be required by government agencies utilizing this specification.

3.1 APPLICATION

SPECIFICATION

"Unless otherwise specified, the stall/post-stall flight characteristics shall be demonstrated in accordance with the provisions contained herein. Manned airplanes requiring lifting surfaces to cruise within the sensible atmosphere shall be tested in accordance with this specification. Aerospace vehicles whose mission includes boost-return, boost-orbit-reentry, low maneuverability/nonpowered approaches and landings, etc., normally will not be tested in accordance with this specification. V/STOL airplanes normally will be tested in accordance with this specification only when configured for flight in which the lift is derived primarily from free stream dynamic pressure rather than the propulsive system (6.2.1[c])."

DISCUSSION

The intent of the specification is to test "normal" aircraft and not shuttle orbiters or Harrier-type aircraft when in hovering or vertical flight. However when the shuttle transitions from its re-entry mode to its conventional flight mode, MIL-S-83691 may provide some guidance as to test conduct.

Harrier-type aircraft must comply with this specification when they are configured for flight in a conventional manner. No guidelines are presented in this specification as to how to test the transition region between conventional and vertical flight. Those who will tackle that problem will update this specification based on their experience.

3.2 FLIGHT TEST VEHICLE

SPECIFICATION

Except as specified in 3.2.1 through 3.2.4, the flight test vehicle shall be representative of the production airplane in all significant respects."

DISCUSSION

What constitutes "significant"? Any characteristic (protuberance for spin chute, for example) which alters the aircraft aerodynamics is significant. Obviously compromises are often necessary, but in the planning stages, the addition of a cannister on the back of the airplane for a recovery chute should be accepted only after all other avenues have been exhausted. Here, as in other areas, many problems can be alleviated or solved if attacked early, i.e., in the design stage, but not after the test program has started.

While it is realized that certain special instrumentation and configuration requirements will be necessary, the intent is to evaluate the aircraft as it will be received by the operational users. The person who is the ultimate user of the test results is the operational pilot, and all information given him must be related to his reference frame. In order to accomplish this, the test vehicle cockpit should be as representative as possible.

In these days of "fly-before-you-buy" prototype competition, a frequent suggestion is to use the prototype for high AOA testing. This is an efficient use of resources if the prototype is truly a preproduction prototype. If the production version has a different wing area or the engines have been moved or the incidence of the horizontal tail has been changed, then a careful examination has to be made as to whether the test vehicle is "representative". Some insight into the problem can be attained by comparing the results of the spin tunnel tests of the prototype and the production models.

3.2.1. EMERGENCY RECOVERY DEVICE

SPECIFICATION

"An emergency recovery system, approved by the procuring activity, shall be provided for each Class I and IV stall/spin test vehicle and shall, when necessary, be specified by the procuring activity for Class II and III test vehicles (6.2.1[d]). Such emergency devices shall be capable of effecting recovery within a reasonable altitude loss established by the contractor and approved by the procuring activity. The emergency recovery system shall be capable of successful operation under the most adverse flight conditions and control positions possible."

DISCUSSION

The term "approved by the procuring activity" means a great deal of procuring activity planning and monitoring will be necessary. The procuring activity will direct the timing of design, qualification, installation quality control and testing. The procuring activity must coordinate with NASA and others involved in recovery system design. Acceptance criteria deal with altitude loss, line fouling, cockpit actuation and displays, choice of chute, canards, or combinations of both as well as the tests used to qualify the device and its reliability. The procuring activity must of necessity give the maximum guidance with respect to details such as routine inspection procedures, USAF familiarization with the systems and the documentation requirements.

In the case of a parachute for spin recovery, it must be sized in the spin tunnel, and both low and high dynamic pressure deployments must be accomplished involving flights and/or taxi tests. Extensive structural tests will be required to be sure that the chute load can be accommodated and that the attachment mechanism functions properly.

The F-4 test aircraft used in the Stall/Near Stall Investigation was lost due a failure in the attachment mechanism. An extensive loads test was performed on the test aircraft prior to test initiation, but only the static case was examined. The failure occurred when the over-center locking device was released after the yoke connecting the chute risers to the rear of the aircraft struck the locking mechanism housing after deployment in a spinning condition.

The F-106 chute size was such that the aircraft required seven turns to recover after deployment in a flat spin. This shortage of a little extra cloth can be very disconcerting to the test pilot!

The requirement that the system function under the most adverse flight conditions possible is an attempt to avoid a repetition of the incident in which an F-4 spin recovery parachute was not deployed to a sufficient distance beyond the aircraft to avoid the adverse flowfield attendant to a flat spin. The chute simply collapsed on top of the aircraft and was useless.

This adverse condition may also be at the other end of the spectrum at high dynamic pressures. A roll coupling problem was encountered during contractor tests on the F-111 Stall/Post-Stall/Spin Program. After control was lost, recovery attempts resulted in the aircraft sustaining roll rates up to 180 degrees per second at Flight Manual limit AOA's. Airspeed continually increased and at the mandatory chute deployment altitude, airspeed was 300 KIAS, which was considerably beyond the design dynamic pressure limit of the chute. The chute was deployed; it tore, but enough of a restoring moment was produced to lower AOA into a region of stability and the rolls stopped. So, all possible out-of-control modes must be considered when designing recovery systems.

It is required that the system be effective under the most adverse control positions, i.e., the system should effect recovery even if full prospin controls are held. Why? The objection has been raised that operation of the flight control system (FCS) should be available to the designer. There is a judgement factor. If the above criteria will adversely affect external modification, cost, etc., then the procuring activity and the contractor can exercise this judgement. Both parties must completely understand the impact of tradeoffs. If the chute is sized only for neutral controls and the pilot applied incorrect controls, can the aircraft be recovered, will the chute function?

The problem of whether the chute is necessary or not should be addressed. The intent of this paragraph is to demand the chute for planning purposes and waive it if subsequent testing shows that the chute is unnecessary. The contractor may apply for and be granted an exemption based upon valid evidence, but the system had better be anticipated initially so that the program will not be delayed. Obviously if a Cessna 150 is being purchased, a spin chute would not be required and the waiver would be granted.

Class II and III aircraft are treated in an "iffy" manner with respect to the need for a recovery device. Again judgement must be exercised by the procuring activity. A new aircraft design with a high T-tail would require a recovery system until worries about deep stall were alleviated.

3.2.2 FLIGHT TEST INSTRUMENTATION

SPECIFICATION

"The contractor shall provide onboard instrumentation as approved by the procuring activity (6.2.1[e]). When very high angular rates are anticipated, variable range or additional rate gyros may be required to provide adequate resolution for the pre-stall and post-stall conditions. The frequency response of the instrumentation shall be adequate to measure high-frequency phenomena such as prestall buffet. Except when actuated during emergency situations, flight test auxiliary hydraulic and electrical systems shall not restrict the mission time of the test airplane. Actuation of the auxiliary electrical power system shall not interrupt data acquisition. Consideration shall be given to additional instrumentation for structural purposes when predictive studies or initial flight test results indicate that the airframe or store suspension equipment may experience stall/post-stall loads near or above design values."

DISCUSSION

Spin flight testing requires adequate quantitative information. Qualitative programs have in the past left little of lasting value and misleading rumors have persisted. It is expected that the only accurate qualification of the relative value of different recovery techniques will come from an engineering analysis of the data obtained from such flights.

Again, approval is required by the procuring activity; they should be aware of what and how many parameters need to be displayed. For purposes of a stability investigation, the need for parameter identification techniques may develop. Associated with these techniques are minimum sample rates and certain minimum acceptable "noise"; each of which requires planning. A close association with the flight test agency in discussions of this nature at the planning stage is essential.

It is desired that the program flights be conducted as regularly as possible and that data per flight be maximized. Such flight should only be limited by the endurance of the aircraft, not the design of data systems.

The most recent F-111 stall/spin test aircraft provides a good example of inadequacies in emergency electrical and hydraulic provision design. The F-111 data acquisition system had an automatic calibration cycle of some 5 seconds after the data system switched from airplane to battery power upon actuation of the emergency system. As a result, to prevent loss of data during this critical period, the emergency batteries had to be activated prior to a stall entry rather than when they were actually required for emergency electrical power. This restricted mission time because the batteries were used for each run and were depleted long before

the fuel load was depleted. If this calibration feature were not designed into the system (for example, calibrate prior to data shutdown), the battery could be used only when necessary and thus mission time be limited only by the aircraft. This latter approach was used on the most recent F-4 stall/spin aircraft. Any data interruption during critical regimes of flight is completely unacceptable.

Stability parameters are not always the limiting factor in stalls. Often structural considerations are paramount and the appropriate instrumentation needs to be considered. The limiting factor in C-141 stalls was the structural load on the empennage. Europeans have mentioned problems of engine casing/spool component contact during violent departures. While these examples are rare, special instrumentation may be required to cover potential problem areas.

The maximum roll and yaw rates attained in an out-of-control maneuver may be above the published limits of the Flight Manual, although the resultant structural loading may be within limits because of low dynamic pressure. This should be addressed in the planning stage and appropriate steps should be taken (structural beefing, instrumentation).

3.2.3 COCKPIT INSTRUMENTATION AND LAYOUT

SPECIFICATION

"Cockpit displays in the test vehicle, particularly instruments indicating airspeed, altitude, AOA, turn/slip, normal acceleration, stall warning, attitude reference, and engine parameters, shall be those types to be installed on the production airplane. When special AOA, sideslip, and yaw rate indicators are also provided, they shall be easily readable and compatible in operation with production indicators (e.g., dials turning in the same direction). Unless otherwise specified, controls such as switches for the onboard data recording system, voice tape recorder, gyro cage, and cameras shall be capable of operation from the pilot's position and from another crew station or remotely from the ground to alleviate pilot workload (6.2.1[f]). The production pilot restraint system shall be used after predictive studies and sufficient flight test results are available to indicate that crew station angular rates and accelerations will not incapacitate or greatly hinder the pilot during application of recovery controls."

DISCUSSION

The necessity of providing adequate information to the pilot in the test program is recognized; hence, the special indicators. However, the test pilot must be provided with a representative environment in which he can relate test parameters and impressions to the operational situation. Cockpit cameras, depicting spin motions, should show instrument panel indicators as representative as possible of production aircraft. Consideration might be given to the incorporation of a production airspeed pickup (if possible) in addition to the test noseboom. For example, what about airspeed indications and altimeter lag in F-4 spins where the production probe is on the vertical tail?

Simple things like dials turning in the same direction are easy to handle in the planning stage, difficult to correct after the test vehicle is completed. The F-4 production and special AOA indicators turned in opposite directions. This should be avoided. Such special instruments should be arranged so that they are easily readable (large scales) and placed in the cockpit so that production gauges remain in their normal location. For example, such special instruments could replace the HUD controls or the radar, etc.

The requirement that the special systems be operable from another station brings up the point of the requirement for another crewmember. In past programs on two-place aircraft conducted by the AFFTC, a second crewmember was considered necessary for the efficient conduct of the program. The issue is safety versus information gained per flight. The test pilot will be kept extremely busy flying into the spin area from supersonic and transonic decelerating turns and at the same time attempting evaluations of warning, departure, and out-of-control characteristics as well as recovery control effectiveness and the ensuing dynamics. So it is beneficial to the program to relieve the pilot of all tasks non-essential to the evaluation (such as special systems actuation, test instrumentation switches, etc.). This will allow him time to establish the desired entry conditions, execute the maneuver as planned, and perform the dive pullout without extraneous and distracting tasks. In addition the engineering team obtained more information and gained a better insight and correlation with test information.

Spin tests on many fighter-type aircraft have been conducted with a special restraint system. The concern of the specification is that auxiliary systems are not applicable to the operational pilot. For safety, a special harness may be required at first; however, the production system should also be evaluated. If the rates are too high and the production harness is inadequate, redesign is necessary and should be so identified as one of the test program recommendations.

Obviously, all special instrumentation and activation switches for emergency systems must be so located that they can be reached with the restraints locked. Again, this must be carefully planned. Enough emphasis cannot be given to the importance of adequate pre-flight test planning. The task can be made much much easier with little cost impact if proper attention is given to the task at the outset of the planning effort.

3.2.4 ONBOARD CAMERAS

SPECIFICATION

"Forward-looking cameras, both cockpit and external, shall be employed to document airplane motions; these cameras shall operate at 24 frames per second to allow true-time film review, and an adequate film supply shall be provided to insure representative documentation during each test mission. Onboard cameras that serve as an integral part of the quantitative data acquisition system may operate at any appropriate frame rate. Unless otherwise suitably instrumented, the emergency recovery system shall be covered by an onboard camera operating at an appropriate frame rate."

DISCUSSION

The intent of this paragraph is to assure that the project personnel have sufficient documentary evidence to prepare briefing and training films at the conclusion of the program. It has been found that face-to-face briefings with operational pilots are the most effective means of communicating test results. Certainly, with something as confusing and disorienting and difficult to describe as spins, a picture is truly worth a thousand words and, as such, documentary film becomes a key data requirement. In fact, if camera coverage is not available, it often becomes justifiable to cancel a flight until photographic problems are solved. The cost of such documentary evidence is insignificant compared with the value gained.

The problem of an adequate film supply is easiest solved in the design stage. If space allocation restricts the camera size, then it should be of the type in which cartridges of film can be easily replaced by a crewmember. This problem has been too prevalent in past programs because of inadequate planning and understanding of program goals.

A film speed of 24 frames per second (fps) is desired for use in the training movie. Quality is lost when double framing or step printing is necessary because the film was exposed faster or slower than 24 fps.

Provisions should always be made for photography of spin chute deployments at an appropriate frame rate. However, the best method of instrumentation for a strake or a rocket recovery system would not be photographic.

Sufficient consideration should also be given to the placement/location of external cameras. Just as with spin chute modifications, no alteration of aerodynamic properties is desired.

3.3 ACCOMPLISHMENT OF FLIGHT TEST

SPECIFICATION

"The contractor shall be responsible for demonstrating the flight characteristics of the airplane in accordance with this specification. The contractor and flight test agency of the procuring activity, however, may share a predetermined percentage of the required maneuvers. The flight test agency may be assigned advisory test/engineering functions, witnessing duties, or actual test conduct activities that do not relieve the contractor of the prime demonstration requirements. When the airplane has a single set of controls, the procuring activity shall fly a number of missions agreed to between the contractor and procuring activity, with representative participation in each test phase (6.2.1[g]). When a second seat is available with cockpit controls, the procuring activity may provide a crewmember for all flights; in addition, a qualified service flight test pilot, as airplane commander, shall fly the number of flight test data missions agreed to between the contractor and procuring activity."

DISCUSSION

The new flight test demonstration specification requires that the stall/post-stall/spin test program be accomplished on a joint basis. In contrast, the Air Force did not actively participate in many past stall/spin programs. In fact there was essentially no participation by either Air Force pilots or test engineers during any of the spin programs on Century series aircraft such as the various models of the F-100, F-101, F-102, F-104, F-105 and F-106. These programs were accomplished solely by the contractor. In contrast, on future programs, Air Force pilots and engineers will participate from the outset of the program. A joint program encompasses far more than having an Air Force pilot fly contractor test cards. Air Force test personnel will be deeply involved in the initial test planning and in formulating data reduction and analysis procedures in conjunction with contractor personnel. They will also participate in the determination of test parameters and data acquisition system hardware. Air Force pilots will fly a number of the test missions, with representative participation in each of the test phases. When a second seat is available with cockpit controls, the Air Force may provide a crewmember for all flights. In addition, the specification provides for Air Force pilot participation as aircraft commander on a number of flight test missions in multiplace aircraft.

There has been a mixed reaction to the joint test concept. The joint test approach is not unique to stall/spin testing, but is a fact of life in the Air Force today. The concept of separate Category I and Category II testing by the contractor and the Air Force, respectively, has been eliminated in the latest revision of AFR 80-14 "Air Force Testing and Evaluation of Systems, Subsystems and Equipment". It is Air Force policy that test programs be conducted on a joint basis, and MIL-S-83691 has been written to reflect this policy.

Joint testing, at least in the areas of performance and flying qualities, is nothing new. It has been done with varying degrees of success on major programs such as the T-38, F-5A, C-133B, C-141 and C-5A. Going back even farther, the B-52A, B-52G and B-52H performance and flying qualities test programs were joint efforts in many important respects. Numerous smaller programs have been conducted almost entirely on a joint basis. Joint tests are being planned for the YF-16, YF-17, and the B-1A.

Some contractors have made comments as follows relative to the joint program: "The joint program fails to recognize the different functions of military and contractor test pilots. The military pilot's task is evaluation and judgement as to acceptability. The task of the contractor pilot is to establish an envelope of safe operation, to define characteristics, to develop techniques or equipment required within the envelope. Thus the test program is a development/demonstration followed by a phase of evaluation... Customer experimental flight testing in a regime not opened by the contractor is a major objection."

In any test program there is a certain amount of envelope expansion, development testing and engineering test and evaluation followed by certification testing or demonstration of the production configuration. During the development tests, problem areas are identified, investigated and corrected. The contractor is normally responsible for establishing an envelope of safe operation. However, the definition of the characteristics within the envelope and development of techniques and procedures which optimize the use of a vehicle with a given set of characteristics is to be a joint effort under the current guidelines. Further, it must be a joint effort if duplication is to be minimized, for it is in the areas of characteristics and procedures definition that duplication has existed in the past. In many cases there are no clear-cut lines of demarcation between development and certification. If the hardware "fix" or recovery procedure is adequate, what started out to be a development test may suffice for a demonstration of the adequacy of the fix or procedure. This is one reason why the test effort must be integrated if duplication is to be avoided.

Why then have a joint stall/spin test program? It is the only way to minimize duplication of effort and provide the Air Force with proper visibility, as well as giving better assurance that operational-mission-oriented entries are thoroughly explored early in the test program. As far as pilot participation in a spin program is concerned, continuity demands that pilots not be alternated on a flight-by-flight basis. However, this does not mean that one pilot must accomplish all of phase A, for instance. Further, under the joint test concept, Air Force pilots will fly "engineering test and evaluation" test missions. In past programs, this has been referred to as "flying contractor cards"; however, in the future these will be test missions which have been jointly planned. In addition, participation with the contractor on an aircraft equipped with spin recovery devices may provide the Air Force with the only opportunity to evaluate post-stall characteristics. The Flight Characteristics section of the Flight Manual and the procedures for recovery from out-of-control events should be written jointly by the Air Force and the contractor, or in some cases solely by the Air Force, rather than as a unilateral contractor effort.

An added benefit of joint testing in a specialized area such as stall/spin testing is that the Air Force can lend continuity by developing and maintaining a cadre of personnel with expertise in this area. A given contractor may be involved in a spin program only once in a decade. Active participation by Air Force test agency personnel in the planning, test and analysis efforts provides a vehicle for transferring the lessons learned from one program to the next.

3.4 FLIGHT TEST DEMONSTRATION

SPECIFICATION

"Each airplane type shall demonstrate, by flight test according to table I, the degree of compliance with the stall warning, loss-of-control

warning when required, resistance to loss of control, loss-of-control prevention, out-of-control recovery, and spin recovery criteria as specified in MIL-F-8785. Reasonably delayed recovery attempts after a stall or departure, and exaggerated misapplication of controls following a stall or departure, to simulate possible incorrect pilot responses, shall be investigated under the least conservative circumstances to ascertain the degree of spin susceptibility/resistance for operational users. When spins do result as a natural consequence of testing through departures (6.3.9) from controlled flight or as a result of deliberate spin attempts, a satisfactory spin recovery technique shall be demonstrated in accordance with MIL-F-8785. Unless otherwise specified, the use of prolonged pro-spin controls to sustain a developed spinning condition for more than three turns shall not be required except for trainer type airplanes to be cleared for intentional spins (6.2.1[k])."

DISCUSSION

The demonstration requirements are established according to the philosophy expressed earlier in that the aircraft is maneuvered as the operational pilot is expected to operate the aircraft. MIL-S-83691 is the test specification to be used to evaluate the degree of compliance with the design requirements of MIL-F-8785 and MIL-C-9490 specifically related to the high AOA flight regime near and beyond permissible limits. The prime purpose is not only to ascertain the degree of compliance with MIL-F-8785, but to obtain necessary information for the operational user. This was of immediate concern when rewriting the specification; the previous specification had to be re-oriented to include the latter objective.

An attempt should be made to classify airplanes as to degree of susceptibility/resistance in order that comparisons between airplanes can be generated and a common understanding between technical designers and testers can be established. In this manner the lessons learned from one program can be applied to subsequent programs. For example, when an aircraft is classified as extremely resistant to departures and spins, one should know that the susceptibility criterion of the aircraft in question is similar to that of a T-38. When an aircraft is described as extremely susceptible to departure but resistant to spins, then one should know that the susceptibility criterion of the aircraft in question is similar to that of an A-7.

TABLE I
FLIGHT TEST DEMONSTRATION MANEUVERS

| Test Phase | Maneuver Requirements | | | | | |
|---|---|--------------------------------|--------------------------------|--------------------------------|--------------------------|-----------------------|
| | Control Application | Entry Conditions ¹ | | | | Tactical ² |
| | | Smooth AOA Rate ³ | | Abrupt AOA Rate ⁴ | | |
| | | On a g | Accelerated ² | On a g | Accelerated ² | |
| A Stalls | Pitch control applied to achieve the specified AOA rate, roll and yaw controls neutral or small roll and yaw control inputs as normally required for the maneuver task. Recovery initiated after the pilot has a clear indication ⁵ of: (a) a definite g-break, or (b) a rapid, uncommanded angular motion, or (c) the aft stick stop has been reached and AOA is not increasing, or (d) sustained, intolerable buffet. | Class: I II III IV | Class: I II III IV | Class: I II III IV | Class: I IV | Class: I IV |
| B Stalls with Aggravated Control Inputs | Pitch control applied to achieve the specified AOA rate, roll and yaw controls as required for the maneuver task. When condition (a), (b), (c), or (d) from above has been attained, controls briefly misapplied, intentionally or in response to unscheduled airplane motions, before recovery attempt is initiated. | Class: I II III IV | Class: I II III IV | Class: I II III IV | Class: I IV | Class: I IV |
| C Stalls with Aggravated and Sustained Control Inputs ¹¹ | Pitch control applied to achieve the specified AOA rate, roll and yaw controls as required for the maneuver task. When condition (a), (b), (c), or (d) has been attained, controls are misapplied, ^{7,9} intentionally or in response to unscheduled airplane motions, and held for three seconds ^{8,9} before recovery attempt is initiated. | Class: I II IV | Class: I II IV | Class: I II IV | Class: I IV | Class: I IV |
| D Post-Stall Gyration, Spin, and Deep Stall Attempts ¹¹ (this Phase required only for training airplanes which may be intentionally spun and for Class I and IV airplanes in which sufficient departures and developed spins did not result in Test Phase A, B or C to define characteristics of each possible out-of-control mode) | Pitch control applied to achieve the specified AOA rate, roll and yaw controls as required for the maneuver task. When condition (a), (b), (c), or (d) has been attained, controls applied in the most critical ¹² manner to attain each possible mode of post-stall motion and held for various lengths of time up to 15 seconds or three spin turns, whichever is longer, before the recovery attempt is initiated. ^{9,10} | Class: I IV | Class: I IV | Class: I IV | Class: I IV | Class: I IV |

TABLE I

Organization

The flight test demonstration maneuvers required in MIL-S-83691 are summarized in table I. This table is a structured matrix of four test phases, designed in a logical test progression. In test phase A, recovery is initiated as soon as the pilot has a positive indication of a stall (per the MIL-F-8785 definition of stall speeds and minimum permissible speeds). In test phase B, an attempt is made to aggravate the stall by misapplying control inputs immediately upon recognition of the stall. In test phase C, the effects of delays in applying proper recovery controls as well as improper control inputs are tested. If no out-of-control motions have developed, test phase D is provided to attempt to force the aircraft into a spin.

There are very important reasons for having four distinct test phases, with the deliberate spin attempts at the end. It requires recovery attempts starting with the most docile post-stall maneuver; consequently, the initial attention is forced in the region where operational pilots will first contend with an out-of-control condition. The phases are structured in a build-up fashion so that there is a higher probability of arresting the out-of-control motions in the early stages. Thus, as more and more information is gained, the departure severity is increased so that the extent of the out-of-control condition will probably be increased. This progressive approach is deemed to provide the most information with the least hazard to the crew.

In the event developed spins do occur in the first three test phases, spin recovery will be attempted from positions representative of operational conditions, not from full pro-spin settings. This enhances the chance of demonstrating a "compatible" spin recovery procedure.

A consistent objection has been that in a joint test program, the military pilot may be the first to experience a spin; and if the contractor has not previously demonstrated spin recovery under controlled circumstances, the military pilot may not be prepared for his surprise spin. Someone has to experience the first spin, and the military pilot should be no less competent than the contractor pilot. Furthermore, why stop at spin familiarization? The airplane could go into an inverted spin following erect recovery, or experience recovery rolls, or enter an erect mode different than that expected; so the contractor pilot can just as easily encounter a maneuver that was unplanned. Obviously, both pilots are going to have to be aware of all potential modes of motion and know the set of cues that is characteristic to each. This testing is not steady-state - you can't predetermine your test conditions after departure. An AF pilot could only truly be prepared if the contractor had done the complete job first; but then we would be back to duplication.

There will always be the possibility of losing the test airplane because of unforeseen recovery system design or criteria. The order of testing prescribed in MIL-S-83691 allows the most important data to be gathered first before testing proceeds to the maneuvers where the spin chute is more likely to be needed.

Each test phase includes both one-g and accelerated stalls for a variety of aircraft loadings and configurations. Additionally, stalls are accomplished both by slowly increasing angle of attack and by abruptly increasing it. The degree of the abruptness is increased commensurate with the phase. For fighter-type aircraft and certain types of trainers, stalls are accomplished from tactical entries, e.g., from the types of maneuvers that would be associated with air combat maneuvering in an air superiority fighter.

Test phases B and C require that the controls be misapplied. This "misapplication" implies neither an unintentional or random control input during the test program. It is desired to effectively simulate probable pilot response to an inadvertent out-of-control condition, for example, it is to be expected that an operational pilot will attempt to counteract the roll at stall with lateral control. This may not be the optimum response and possibly the wrong response, but it is a natural response and must be investigated in the test program.

Also the effect of delays must be evaluated. It was reported in the Navy F-4B spin program results that even experienced test pilots, who were forcing an out-of-control condition, delayed in applying proper recovery control techniques - a much slower response is to be expected from an operational pilot who inadvertently loses control and experiences an out-of-control condition for the first time.

The following conditions form the basis for subsequent control delay and aggravation in each test phase.

"Recovery initiated after the pilot has a clear indication of:

- (a) a definite g-break, or
- (b) A rapid, uncommanded angular motion, or
- (c) the aft stick stop has been reached and AOA is not increasing, or
- (d) sustained, intolerable buffet."

Each phase begins with the attainment of one of conditions (a), (b), (c), or (d); either you recover, or delay and recover, or misapply controls. Condition (a) will generally be the normal acceleration change associated with a loss in lift. However, this criteria can apply to lateral acceleration in the event an obvious side motion occurs before (b), (c), or (d).

Condition (b) will most likely apply to fighter-type aircraft, and here, the phase "rapid, uncommanded angular motion" should have a rather broad interpretation. Examples could include:

- (1) An actual rapid, uncommanded angular motion as evidenced by a nose slice or the pitch down during a classical stall.
- (2) An angular excursion from initial conditions which, although slow, reaches such a magnitude that it is quite apparent that the airplane is deviating from a normal condition (e.g., a wing drop of approximately 30 degrees or a limiting "stall" value specified in the design specification).
- (3) An angular oscillation that changes so markedly in magnitude or frequency from the previous stall warning that the pilot is aware that impending loss of control is indicated.

In condition (d), if the buffet is intolerable from a structural design standpoint, don't encourage the possibility of damage by increasing AOA. However, intolerable buffet is not just a degree of buffet which inhibits precise tasks; this is not a reason to terminate the maneuver.

Test phases A through C require only specific control applications, up to a three-second time limit, after the stated criteria are observed. PSG's, deep stalls, or spins are not prerequisite of these phases. The airplane is being given a chance to demonstrate some degree of departure resistance. Again, it should be emphasized that departure is a finite event, to be followed by a spin, deep stall, or a PSG of sufficient extent to constitute a dangerous flight condition. The conditions (a) through (d) cited above may eventually prove to be characteristic of the incipient portion of departure, which could be terminated by the recovery attempt, but conditions (a) through (d) do not inherently, by definition, satisfy a departure condition.

The final phase, phase D, consists of deliberate spin attempts. This phase is required only for training aircraft which are to be spun intentionally and for Class I and IV aircraft in which sufficient spins did not occur in the previous test phases to completely define out-of-control characteristics. Phase D requires that the controls be applied in the most critical position to attain the expected spin modes and held for up to 15 seconds or three turns, whichever is longer, before the recovery attempt is initiated, unless the pilot definitely recognizes a spin mode.

It should be noted that, at the outset of the test program on a Class IV aircraft, the need for and the extent of the testing required in phase D may not be known in the sense that out-of-control characteristics may be completely defined in the preceding phases unless the airplane is extremely resistant to spins. Future aircraft will be designed to meet the revised design requirements of MIL-F-8785 and will be extremely departure- and spin-resistant. For this type of aircraft, phases A, B and C will be accomplished in short order, and phase D will be a large portion of the test program. Conversely, there may be a requirement for little or no testing in phase D on a spin-susceptible aircraft since the modes of motion and associated recovery techniques will have already have been defined in earlier test phases.

There is considerable controversy over the need to sustain a developed spin for test purposes. MIL-S-83691 is based on the premise that there is no need to maintain pro-spin controls beyond the point at which a recognizable fully developed spin occurs. This premise is based on the fact that there is no known tactical requirement to purposely maintain a fully developed spin. The previous spin specification, MIL-S-25015 (USAF), required that the spin be maintained with the directional and longitudinal controls in the full pro-spin position and the lateral control neutral for five turns before initiating recovery. On the opposite end of the spectrum there are those who believe that any aggravated and/or sustained pro-departure control inputs beyond the stall are unwarranted.

The concept employed in the preparation of MIL-S-83691 was to explore the susceptibility of the aircraft to departures and, for Class I and IV aircraft, spin susceptibility as a natural consequence of operation of the aircraft at high angles of attack. It is mandatory that the behavior of the aircraft between the stall and the fully developed spin be thoroughly evaluated to provide the pilot with recovery procedures before a spin is allowed to become fully developed. The emphasis in the test program should be placed on recovery from the initial out-of-control event. This event precedes every fully developed spin and is obviously the most desirable place to arrest the out-of-control maneuver, should it occur.

However, it is also important, to define developed spin characteristics. The key area of controversy is how long it is necessary to maintain what might be considered as pro-spin controls. A developed spin condition presupposes that a repeatable mode of motion has occurred. Recognition of the fact that a mode of motion is indeed repeatable, requires, by definition, at least two turns. (We are here simulating what the service pilot might be expected to recognize without prior exposure to the maneuver.) The preparers of the specification recognized the requirement to explore fully developed spins. To do this it is necessary to maintain the spin for from two to three turns to insure that the mode of motion is in fact repeatable, i.e., that it is indeed a developed spin. It could be argued that, for some airplanes, the spin is easily recognizable in the incipient phase and that there is no need to carry it beyond that point. However, for a given airplane one does not know this a priori. Additionally, leaving the requirement to a purely qualitative interpretation of what is recognizable in terms of an out-of-control event invites trouble. The procuring activity can end up with an incomplete test program if the specification is written in only qualitative terms. Therefore, to avoid this controversy, it is better to specify a requirement for delays of X seconds or Y turns at the outset. Otherwise recovery controls may be applied at the first indication of departure as observed by a trained engineer interpreting telemetered data.

For test purposes, it is necessary to structure the specification so as to insure that all modes of motion that the aircraft will encounter are adequately defined.

The specification requires, for phase D, that the controls be "applied fully pro-spin for the selected direction and held in the most critical positions for up to 15 seconds or three spin turns, whichever is longer". "Critical" control positions are meant to include, but not be necessarily limited to, the control positions required to attain the spin mode. The reason for this is that the spinning motion may be sustained with the controls in other than in the initial pro-spin position. Examples of control positions which might be explored for test purposes are neutral, the out-of-control recovery settings, or stick forward. The test program should be structured so as to determine whether a recovery attempt from a spinning condition with controls displaced from the initial pro-spin conditions results in a recovery capability, duration or reversal tendency different from that which would occur if recovery were attempted from the initial pro-spin control position. The non-operational use of prolonged pro-spin controls may mask the warning and recovery information that would best serve the fighter pilot during an inadvertent out-of-control maneuver. For example, sustained pro-spin controls with an asymmetric loading may repeatedly promote unrecoverable spins, while with controls neutralized after a departure, a multi-turn, recoverable spin mode might consistently result and provide useful information for the using pilot. Consideration should be given to the possible exaggerated effect of immediately swapping from full pro-spin controls to full anti-spin controls as compared to the operational pilot's spin recovery attempt with a potentially neutral or forward stick condition. Although the terminal control positions may be identical for attempted recovery in each case, the difference in total control moment and impulse changes may result in different recovery duration or reversal tendency. Recovery procedures

for the A-37 when spinning with the stick in the neutral position differ from those with the stick in the full aft position in that, with neutral stick, it is necessary to go to the full aft position and then rapidly full forward in order to effect recovery. There is no guarantee that full pro-spin controls are the only "critical" controls to be examined or, in some circumstances, are reasonable to use whatsoever. Consequently, the analysis of pro-departure and pro-spin controls requires as much thought as the recovery procedure.

Some concern has arisen that MIL-S-83691, as structured, will penalize the spin-resistant aircraft by requiring an additional phase of testing. Proponents of this contention fail to realize that spins will be evaluated as they occur for the spin-susceptible aircraft. Thus, in order to illustrate the implementation of the specification, a sample test program has been prepared.

Following is an approximation of the number of flights which would be necessary in each phase for an extremely spin-resistant and an extremely spin-susceptible aircraft. For the aircraft which is extremely susceptible to spinning, spins will first occur in phase A. This phase will require much more flight time to complete than would be the case for the spin-resistant aircraft. For the latter type of aircraft, phase A consists merely of stalls and recoveries which result from various types of maneuvers required in the phase.

SAMPLE TEST PROGRAM

| Aircraft | Number of Flights | | | |
|----------------------------|-------------------|---------|---------|---------|
| | Phase A | Phase B | Phase C | Phase D |
| Extremely Spin Susceptible | 20 | 10 | 20 | -- |
| Extremely Spin Resistant | 10 | 5 | 5 | 20 |

It should be noted that, while phase D is not required for the extremely spin-susceptible aircraft, the total number of flights required to complete the program is greater than the total for the extremely spin-resistant aircraft. The reason for this is primarily that, since spins will be occurring more frequently, more flight time will be required to verify/develop any out-of-control spin recovery procedures than for the spin-resistant aircraft.

Notes

Note 1

SPECIFICATION

- "1. Configurations, loadings, cg's, entry speed/attitude, etc., shall be in accordance with 3.4.1.1. With the airplane configured for the Flight Phase Category C tasks identified in MIL-F-8785, only Test Phases A and B of this specification are required to be accomplished unless the procuring activity specifically requires the next or both remaining Test Phases to be accomplished (6.2.1[h]). An abrupt AOA rate, as a maneuver entry condition, is not required when the airplane is configured for Flight Phase Category C, except as specified at the end of note 4."

Engine requirements shall include:

- (a) Takeoff (TO) configuration: All engines at TO thrust; critical engine inoperative, others at TO thrust (stall approach. Test Phase A only).
- (b) Power approach (PA) configuration: All engines at normal approach thrust; critical engine inoperative, others at required approach thrust.
- (c) Climb (CL) configuration: All engines at normal climb thrust; critical engine inoperative, others at normal climb thrust.
- (d) Cruise (CR) configuration: All engines at thrust for level flight (TLF); all engines at idle thrust.
- (e) Combat (CO) configuration: All engines at military rated thrust (MRT), maximum augmented thrust (MAT).

Throttle requirements for those cases where flameouts or compressor stalls occur shall include:

- (f) Throttle retarded to idle from the maneuver entry setting position for a malfunctioning engine (for MAT, MRT, TLF).
- (g) Throttle left at the entry setting position until stall, PSG, or spin recovery has been accomplished (for MAT, MRT, TLF) unless compliance would result in exceeding engine operating limitations.

Stability and control augmentation requirements shall include:

- (h) All augmentation on.
- (i) Any number of channels disengaged if authorized or considered for service use.

The airplane shall be trimmed (controls and throttle[s]) at settings consistent with the maneuver task. The effects of each designated flight test variable, from 3.4.1.1 and (a) through (i) above, shall be determined individually in each required Test Phase or until such effects are definitely established and predictable for succeeding Test Phases. Variables need to be tested in combination only when that combination could possibly yield less conservative results from those obtained by individual testing."

DISCUSSION

The final report should address every selected flight test variable as to its influence on stall and post-stall characteristics. In order to limit the program to a reasonable size, it will be necessary to make judicious interpretation of the quantitative and qualitative data to decide when one variable has been evaluated and to go to another. The combining effects of variables should be even more difficult to define, but they will have to be determined in short order.

For most airplanes, test phases C and D are not required when configured for takeoff and landing type tasks. If departure occurs near the ground, the recovery capability will be meaningless. However, for trainer airplanes, the Air Training Command (ATC) may want to demonstrate stall characteristics (warning and recovery) at altitude, and an out-of-control and spin recovery procedure may come in handy (especially a spin recovery procedure for a Class I trainer that won't fall as fast). And for a Class IV airplane, it may be desirable to investigate the recovery contributions of leading edge droop or slats which may entail some buildup of Category C Flight Phase departures. For condition 1(a), the takeoff configuration maneuver with critical engine inoperative can be terminated in the stall approach. The objective is to determine the warning characteristics (they may be degraded significantly from those experienced during zero sideslip stalls).

Note 2

SPECIFICATION

- "2. Accelerated entries, encompassing a representative range of Mach number, dynamic pressure, and allowable load factor, shall include windup turns, constant-altitude turns, and wings-level pullouts from dives appropriate to the airplane Class and mission."

DISCUSSION

Recent flight testing has shown that the entry conditions, particularly Mach and dynamic pressure, can have a very profound influence on the type of ensuing out-of-control event, even at times, somewhat independent of the control inputs at departure. For this reason, it is necessary to evaluate the aircraft at representative conditions throughout the flight envelope.

Note 3

SPECIFICATION

- "3. Smooth, 1-g entries shall be approached utilizing a slow control rate which would produce a speed deceleration of approximately one knot per second for normal stalls ($\approx 1-g$). Smooth, accelerated entries shall be approached utilizing a control rate to achieve an AOA rate of approximately one-half degree per second."

DISCUSSION

Because speed bleed-off rate during accelerated flight in the stall/post-stall area may be unsteady, "smooth" accelerated entries should be accomplished by aiming for an AOA rate. For aircraft with production and test AOA indicators, this can be easily accomplished, and for those with only airspeed indicators, it will properly require thinking in terms of AOA. Stall and its related characteristics are AOA effects - not speed effects. The fact of supersonic departures is sometimes surprising to the uninitiated. The one knot per second level deceleration is retained to maintain compatibility with historical precedent, and it is a realistic requirement.

Note 4

SPECIFICATION

- "4. In the required abrupt entries, the entry AOA rate for Category A and B Flight Phases shall be at least:

| | |
|-----------|-----------|
| Class I | 4 deg/sec |
| Class II | 2 deg/sec |
| Class III | 1 deg/sec |
| Class IV | 8 deg/sec |

except as limited by maximum available control deflection and rate. The magnitude of the abrupt entry rates for Class I, II and IV airplanes may be graduated in Test Phases A through C, commensurate with the increasing severity of the control requirements, but the stated minimum AOA rates shall be achieved in Test Phase C. For those airplanes designated for Category C Flight Phase investigated beyond Test Phases A and B, abrupt AOA rates suitable to the configuration and Test Phase shall be employed."

DISCUSSION

The intent of the specification as a whole and this section is to have a gradual buildup in successive test phases. The following sample could be typical of Class IV testing in term of abrupt AOA rate:

| <u>Test Phase</u> | <u>AOA Rate (build up to -)</u> |
|-------------------|----------------------------------|
| A | 2 |
| B | 4 |
| C | 8 |
| D | Max attainable |

Class III aircraft will achieve 1 degree per second by phase B.

Note 5

SPECIFICATION

"5. These entries shall be initiated from offensive/defensive, ground-attack, or other tactical maneuvers associated with the capability and Class of the airplane. The maneuvers, conducted with a suitable AOA rate, may include:

- (a) Inverted stalls and aborted vertical reversements, loops, or Immelmans to investigate inverted out-of-control events.
- (b) High AOA turn reversals with roll control only, with coordination attempted, and with yaw control only.
- (c) High pitch attitudes (>45 degrees).
- (d) Head-out-of-cockpit air combat maneuvering or ground-attack maneuvering.
- (e) High-g, supersonic turns/transonic decelerations.
- (f) Sudden idle power/speed brake decelerations.
- (g) Sudden asymmetric thrust transients prior to stall."

DISCUSSION

This note is an affirmation of the test philosophy of analyzing the airplane in the type of situation operational users will see. From Test Phase A through D, the tactical exploration will range from "controlled" to "abused".

For ground attack aircraft, the definition of departure and post-stall gyration characteristics is of paramount importance. In order to perform these tests there should be an adequate Operational Flight Envelope for test purposes. In MIL-F-8785B, the nonterminal flight phases (other than takeoff, landings, and associated maneuvers), are broken into two categories, the Category A tasks that require rapid maneuvering, precision tracking or precise flightpath control, and the less demanding Category B tasks that are normally accomplished using gradual maneuvers and without precision tracking. There are operational flight envelopes associated with each Category and the appropriate flight phase task(s) for the airplane. As an illustration, for an airplane with a ground attack mission, the stringent MIL-F-8785B requirements for flight phase Category A apply up to limit load factor and up to medium altitude. However, above a medium altitude, the requirements apply over a much smaller envelope in terms of normal load factor (0.5 to 2.0 g's). For an aircraft with only a ground attack mission, this can, depending upon interpretation, result in very few requirements above an altitude of roughly 20,000 feet and at load factors greater than 2.0. The procuring activity should insure that the envelope is adequate for high angle of attack testing at altitude particularly for aircraft with only a ground attack role.

Note 6

SPECIFICATION

- "6. For those Class II or III airplanes where clear indications of stall are not evident and considerations as identified in MIL-F-3785 define the minimum permissible speed other than stall speed, recovery may be initiated somewhat beyond the arbitrary angle of attack, speed, or load factor limit. Both the arbitrary limit(s) and the respective margins to be tested beyond the limit(s) are subject to the approval of the procuring activity (6.2.1[i])."

DISCUSSION

In some cases, minimum permissible speeds will be established because conventional stall warning cues do not exist to properly indicate maximum usable lift or because the airplane can achieve a dangerous flight condition so abruptly (e.g., F-101 and F-104 pitch-up). But legislating an arbitrary limit doesn't preclude someone from getting there inadvertently. With the exception of structural damage, the flight test will be carried beyond arbitrary limits to determine the airplane characteristics.

The comment is frequently made for Class II and III aircraft that a "flight limit AOA" should be arbitrarily established. The rationale for this is that these class aircraft are not as maneuverable and susceptible to out-of-control problems as Class IV aircraft. When any aircraft goes into service, limits are established which allow for an adequate margin of safety. It is the purpose of initial high AOA flight tests to determine any problems that exist. Extreme caution must be taken to insure that arbitrary limits are not established which only serve to hide problem areas.

Note 7

SPECIFICATION

- "7. Misapplied controls shall consist of moving controls in the most critical directions an amount significantly greater than that expected during operational use. This shall generally require full deflection for Class I and IV airplanes and somewhat less for other Classes depending upon the mission and expected pilot reaction. The magnitude of the control misapplication shall be approved by the procuring activity (6.2.1[j])."

DISCUSSION

Similar to the phrase "rapid, uncommanded angular motion", "misapplied controls" is a set of words that can represent several control combinations appropriate to the test objectives. "Misapplied" does not connote random or arbitrary control applications. The testing should be viewed as gathering precise data from the response to certain control inputs in the stall region. The test team should build up to the control position and time requirements. For a Class IV example, initially the stick could be held aft, briefly and up to three seconds, following attainment of one of the four criteria. Then the stick could be held aft and full aileron applied to pick up a dropping wing. Then the stick could be held aft and full cross controls applied to simulate slow speed air combat maneuvering (ACM) in which a pilot would try to achieve maximum drag for overshoot purposes while pulling up to keep the target in sight.

An area of controversy in MIL-S-83691 is the requirement to do the Phase C maneuvers (stalls with aggravated and sustained control inputs) on Class II airplanes. (Class II airplanes are medium weight, low-to-medium maneuverability airplanes such as medium transports, cargo, assault transports, tactical bombers, reconnaissance and heavy attack aircraft.) Phase C maneuvers in this instance may or may not be appropriate depending upon the mission of the aircraft. They are probably not appropriate for a T-43A (737 navigator trainer) but are most certainly required for a B-57 type aircraft.

What is the magnitude of the misapplication for Class II and III aircraft? The consensus of contractor opinions is that, for Class II and III airplanes, full throws of the control wheel are not realistic or to be expected in service use. If the assumption is valid for a given aircraft, there is no need to evaluate the full throw condition as a part of the test. The governing criteria should be to evaluate only that which can reasonably be expected to occur operationally.

Note 8

SPECIFICATION

- "8. This time requirement may be increased for airplanes that do not exhibit a clear indication to the pilot of impending loss of control."

DISCUSSION

This requirement is needed for certain aircraft where there is no clear indication of loss of control. If incipient departure motions are so slow and subtly enmeshed with the previous warning indications, it is necessary to wait a little longer to adequately simulate what could reasonably be expected from the operational pilot. Or, the nose may be so high, and visibility so poor, that mild departure motions cannot be perceived from pilot station accelerations.

Note 9

SPECIFICATION

- "9. The test pilot shall insure that routine familiarity with stalls, post-stall gyrations, and spins does not negate the intent of the delay/misapplication simulation and does not result in premature application of spin recovery controls before a developed spin has been attained (as subsequently confirmed by flight records when necessary)."

DISCUSSION

In any test such as this, there are two eventualities: (a) the pilot is so attuned to the fact that an out-of-control event is going to occur that he puts in recovery controls before the out-of-control event develops and, (b) the pilot becomes so familiar with the out-of-control characteristics of the airplane that he lets it go too long. This is not desired and flight data can be used as necessary to be the arbitrator. The response must be operationally representative.

Note 10

SPECIFICATION

- "10. For trainer airplanes, recovery shall also be demonstrated from a fully developed spin if such a spin is attainable within a limited number of turns after spin entry."

DISCUSSION

Since fully developed spins can be a planned experience in the ATC, training personnel should be provided with a full set of test data pertaining to the precise maneuver they will see. The data would include the altitude loss, recovery characteristics, and recovery duration associated with the fully developed spin. Thus, a fully instrumented aircraft should be used.

Note 11

SPECIFICATION

- "11. In addition to the demonstration of a satisfactory spin recovery procedure, the effect of delayed application of the out-of-control recovery procedure shall be investigated briefly during the final phase of testing. The effects of premature application of the spin recovery procedure(s) under consideration, if different from the out-of-control recovery procedure, shall also be determined."

DISCUSSION

It should be emphasized that this note and the following note require some of the most important testing in the application of the specification. The out-of-control recovery procedure should be a natural fall-out of the initial testing. But the consequences of delaying its application longer than the three-second requirement in phase C must also be assessed. For the F-111, dynamic model tests showed that forward stick applied in the incipient phase of a spin could create a flat spin condition. The potential problems in delays in applying the out-of-control recovery procedure must be evaluated. The purpose of the test is to determine whether or not the procedure previously evaluated is equally satisfactory when there is a delay in applying recovery controls. In addition, the spin recovery procedure should be applied before three turns have been achieved and even during incipient spins or PSG's. If misinterpretation of spin and PSG's is highly possible, will a premature application of the spin recovery procedure actually create a worse situation?

Note 12

SPECIFICATION

"12. With respect to spin attempts, "critical" control positions shall include, but not be necessarily restricted to full pro-spin settings. For some combinations of airplane state and entry test variables, the spinning motion may be sustained with controls in positions (neutral, out-of-control recovery settings, or stick forward, for example), other than full pro-spin positions, and a recovery attempt with controls displaced from the former positions may result in recovery capability, duration, or reversal tendency materially different from that which would occur if recovery were initiated from the full pro-spin condition. If it appears possible to encounter these circumstances in service use, then "critical" controls shall be any set necessary to define all out-of-control modes and determine recovery characteristics specifically applicable to operational users."

DISCUSSION

Not only are the final anti-spin control positions of importance, the location from which the pilot initiates his recovery may also be critical. Service pilots will ordinarily not be attempting recovery from the full pro-spin settings; will this make a significant difference? The test team should look at the 15-second/3-turn/"critical controls" requirements as a maximum allowance to: a) determine each type of out-of-control mode in a user-oriented fashion, and b) the best recovery procedures to place in the Flight Manual.

3.4.1 GENERAL REQUIREMENTS FOR ALL CLASS AIRPLANES

3.4.1.1 Stall/Spin Flight Test Variables

SPECIFICATION

"The contractor shall establish, with the approval of the procuring activity (6.2.1[1]), what ranges and increments of the following variables are to be tested for influence on stall and post-stall flight characteristics:

- (a) Configuration.
- (b) Gross weight.
- (c) Center of gravity
- (d) Stability and control augmentation system status.
- (e) Loadings, both internal and with external stores; critical combinations of aerodynamic and inertial loadings to include:
 - (1) Symmetric, fuselage heavy.
 - (2) Symmetric, wing heavy.
 - (3) Asymmetric (maximum allowable asymmetry).
 - (4) Any other loadings found critical in preliminary tests and analyses.
- (f) Stall and departure speed, altitude, and attitude.
- (g) Thrust and engine gyroscopic effects."

DISCUSSION

In the comments received on the specification, some concern was raised regarding the magnitude of the test program which would be necessary to meet all the requirements of MIL-S-83691. Obviously, it is neither feasible nor desirable to test every possible airplane/damper configuration, set of entry flight conditions, entry control inputs, etc. Some judgement must be applied. But the emphasis should be given to the types of entry conditions that are most likely to occur operationally.

For each airplane the procuring activity along with the contractor and the military test activity must arrive at a representative list of flight test demonstration maneuvers. From a test point of view, it would be desirable to have a somewhat open-ended approach to the stall/spin effort; i.e., to delay writing the detailed test plan for each phase until the previous phase had been completed. This would provide for more flexibility from a test point of view, but might present contractual problems.

Situations will always arise where test demonstration requirements are neither safe nor reasonable with respect to the peculiarities of a given airplane for a given set of circumstances. Examples might be the necessity of the airplane to remain at low altitude to satisfactorily simulate Category C Flight Phase tasks because of engine power/bleed features or water injection limitations. Another example might be exposure of a low maneuverability aircraft to an overstress situation because the requirement to demonstrate accelerated stall entries. Obviously, for test situations predicted to create an unnecessarily hazardous environment or results which are not applicable, the contractor, the procuring activity, and the military test activity must mutually agree to a substitute course of action that best satisfies the original intent of the requirement in question. It is equally obvious that a specification written to anticipate every one of these contingencies would be very weak indeed and would have little utility.

In the application of paragraph 3.4.1.1, for example, gross weights, center of gravity positions, stability augmentation system (SAS), and control augmentation system (CAS) status should be representative of normal operation in initial testing. Operationally representative loadings should be tested to encompass the categories listed in the specification. Additionally, the contractor should not be limited to only those listed; it is desirable to test several symmetric loadings and to build up to the maximum allowable asymmetry.

For subsonic airplanes in the nonterminal flight phases, stall and departure characteristics should be generalized into low speed and high speed categories. For supersonic airplanes, stall and departure characteristics should be generalized into low speed, high speed, transonic and supersonic categories as applicable and appropriate. This insures that stalls/departures of various energies are investigated. The F-4 flat spin encountered in the F-4E Stall/Near Stall Investigation was the result of a high energy departure and, in general, spin susceptibility increased with increasing Mach number (energy). Also the F-4 low spin susceptibility from nose-high, zero airspeed entries resulted from the low energy "departures"; even though the AOA was above stall, there was insufficient dynamic pressure to force the yaw divergence.

Throttle chops and throttle transients at departure should be accomplished to determine their effects on departure/spin susceptibility. SAS operation also can assume importance in the departure/spin susceptibility or recovery capability of a given aircraft and must be investigated. The A-7 has an automatic roll damper cut-out in order to decrease spin susceptibility. The F-111 requires that the roll damper be turned off as a step in the Out-of-Control Recovery Procedure.

Store loadings, while not investigated in most spin flight test programs, can be expected to have a pronounced effect on stall/spin characteristics. On the F-4, symmetric high drag loadings rarely produced spins while high AOA, highly oscillatory spins consistently resulted from departures with asymmetric loadings.

An investigation of gyroscopic effects would include an analysis of left versus right spins, not just spins in one direction. The average angle of attack for the F-4 high AOA, highly oscillatory spins was 10 degrees higher to the left than to the right due to engine gyroscopic effects. F-104 early contractor spin testing was accomplished at high power settings and most departures were to the right. As a result, an incomplete presentation of the airplane's spin characteristics was developed.

3.4.1.2 Natural Stall Warning

SPECIFICATION

"It shall be determined if natural stall warning (6.3.2) meets the requirements of MIL-F-8785."

DISCUSSION

No special test missions are to be flown in an attempt to categorize warning but it should be noted on each flight. As before, information for the operational pilot is of equal importance to specification compliance. The requirements of MIL-F-8785 are repeated below for information.

3.4.2.1.1 Stall approach. The stall approach shall be accompanied by an easily perceptible warning. Acceptable stall warning for all types of stalls consists of shaking of the cockpit controls, buffeting or shaking of the airplane, or a combination of both. The onset of this warning shall occur within the ranges specified in 3.4.2.1.1.1 and 3.4.2.1.1.2 but not within the Operational Flight Envelope. The increase in buffeting intensity with further increase in angle of attack shall be sufficiently marked to be noted by the pilot. The warning shall continue until the angle of attack is reduced to a value less than that for warning onset. At all angles of attack up to the stall, the cockpit controls shall remain effective in their normal sense, and small control inputs shall not result in departure from controlled flight. Prior to the stall, uncommanded oscillations shall not be objectionable to the pilot. These requirements apply whether V_S is as defined in 6.2.2 or as allowed in 3.1.9.2.1.

3.4.2.1.1.1 Warning speed for stalls at lg normal to the flight path. Warning onset for stalls at lg normal to the flight path shall occur between the following limits when the stall is approached gradually:

| <u>Flight Phase</u> | <u>Minimum Speed for Onset</u> | <u>Maximum Speed for Onset</u> |
|---------------------|---|--|
| Approach | Higher of $1.05V_S$ or $V_S + 5$ knots | Higher of $1.10V_S$ or $V_S + 10$ knots |
| All Other | Higher of $1.05V_S$ or $V_S + 5$ knots | Higher of $1.15V_S$ or $V_S + 15$ knots |

3.4.2.1.1.2 Warning range for accelerated stalls. Onset of stall warning shall occur outside the Operational Flight Envelope associated with the Airplane Normal State and within the following range of percentage of lift at stall at that airspeed, in that Airplane State, when the stall is approached gradually:

| <u>Flight Phase</u> | <u>Minimum Lift at Onset</u> | <u>Maximum Lift at Onset</u> |
|---------------------|------------------------------|------------------------------|
| Approach | 82% C_{Lstall} | 90% C_{Lstall} |
| All Other | 75% C_{Lstall} | 90% C_{Lstall} " |

3.4.1.3 Artificial Stall Warning

SPECIFICATION

"When installed, artificial stall warning shall be evaluated to determine whether it meets the requirements of MIL-F-8785.

The flight test demonstration shall determine if:

- (a) the output from tactile stall warning devices, such as stick shakers, is not masked by airframe buffet or flight control system dynamics and is readily discernible with the body in any normally anticipated position.
- (b) visual stall warning devices are readily discernible near peripheral vision limits, for any normally anticipated head position, during day or night operation.
- (c) aural stall warning signals are easily distinguishable from gear, flap, malfunction tones or other aural signals and do not block voice communication channels."

DISCUSSION

The second paragraph of this section does not actually list requirements because requirements for warning can be included only in MIL-F-8785. These are listed here for the flight test team to verify and to give guidance as to what to anticipate. Basically, is the artificial system doing the job for all flight regimes? Historically, rudder pedal shakers have been inadequate because their warning is masked by airframe buffet.

The impact of artificial systems that interact with the aircraft flight control system or the aircraft structure must be carefully analyzed. The original stall warning system in the C-133 consisted of an AOA probe on the left side of the fuselage, a flap position calibration that was a function of the flap selection lever, and a motor with an eccentric cam which was connected to the stick and served as a stick shaker. (First of all, the calibration could change without the flaps moving simply by moving the lever --- but that's a separate problem.) The reliability of the system was questioned by the user and it was decided to duplicate the entire system for the right or copilot's side of the airplane. As the stall was approached, the new system would develop a beat frequency where the combined vibration of the motors interacted with the aircraft structure and the vibration shook the cockpit area and crew and raised questions of structural loads. The problem was solved by changing the cams. This illustrates some of the considerations that should be included in initial design.

An additional consideration brought out by this same series of C-133 tests was the problem of low reliability and maintainability of the system as well as the lack of adequate, detailed, pre-, and post-flight checkout procedures and test equipment. As a result, test team checks of operational airplanes found the stall warning circuit breaker pulled. As a goal, such systems should be considered go/no-go items especially for aircraft with poor stall characteristics. If the system causes too much trouble, the tendency will be to ignore it.

3.4.1.4 Natural Loss-of-Control Warning

SPECIFICATION

"The effectiveness of loss-of-control warning or indication (6.3.8) shall be determined for representative flight conditions when different from natural stall warning."

DISCUSSION

Aircraft design has made "stall" a more difficult term to define in terms of specific flight characteristics. Consequently, a stall angle of attack has been defined as maximum usable angle of attack. Stall warning means those aircraft characteristics that signal the approach or attainment of maximum usable lift. Suppose there is an aircraft with sufficient elevator power to pull to an angle of attack well beyond the value for α_s before experiencing a departure. In this α region, the airplane may exhibit an uncommanded sink rate, wing rock, or markedly higher buffet intensity that did not appear in the pre stall AOA region. These latter warnings do not indicate the approach of stall. Because they occur after stall, they are considered loss-of-control warning.

3.4.1.5 Artificial Loss-of-Control Warning

SPECIFICATION

"When artificial loss-of-control warning or indication is provided, it shall be demonstrated whether the devices are effective in allowing the pilot to prevent departure by application of pitch control during the most abrupt maneuvering permitted in service use. The flight test demonstrations shall determine if warning signals satisfy those characteristics noted in 3.4.1.3 and are clearly distinguishable from stall warning."

DISCUSSION

Artificial loss of control warning is necessary only when there is a wide band between stall and loss of control. If it is a design intent to provide distinctive artificial warning in the large AOA region between stall and departure, then this warning would be evaluated as loss-of-control warning.

For example, the F-4 aural tone generator presents a 1600-Hz/20 pulse per second warning beyond 22.3 units AOA. This tone not only is quite different from the signals at lower AOA, it occurs over an AOA region well beyond that for the recommended optimum usable AOA. This signal is indicative of an approach to departure from controlled flight and may be considered as loss-of-control warning.

The objection often is raised that there are already too many tones in the cockpit, another - for loss of control warning - is not needed. While an appreciation of this problem exists, the consequences of stall on many of our fighter type aircraft make a warning mandatory. Certainly some ingenuity here could solve some problems. A voice warning would alleviate the need for recognition and interpretation of the appropriate tone.

3.4.1.6 Artificial Loss-of-Control Prevention Device

SPECIFICATION

"When a loss-of-control prevention device has been installed, it shall be demonstrated whether the device effectively prevents departures under critical combinations of test parameters and maneuvering circumstances and whether restrictions are imposed on the various flight envelopes."

DISCUSSION

The question to be answered is "does the device actually prevent or inhibit a departure?" How is the test to be accomplished? Should testing for basic data be accomplished with the device off or should it be left on at all times? Some combination of systems test (compatibility with other electro-mechanical systems) and flying qualities tests will be required. It is expected that such systems would be tested in a manner similar to the evaluation of a basic SAS, i.e., most of the testing is conducted SAS on, since that is how the airplane will be flown. However, here are certain conditions for which it would be judicious to test the basic airframe before examining out-of-control characteristics with extraneous control movements due to such a device. Eventually, some type of abuse testing will be necessary. Is it possible to fool the system? Out of control will mean rather abrupt changes in AOA, sideslip, pitch rate, etc; can the device handle these situations and not put in incorrect surface movements if the airplane is forced out of control?

There is sometimes an objection to any type of stall prevention systems as they "take control away from the pilot." Or there are statements like "stall warning is sufficient - we'll train around the problem". There is always the fear of removal of part of the maneuver envelope. The question as to whether the stall warning is enough becomes one of the difference between an active and a passive device. The passive device, such as artificial stall warning, requires recognition, interpretation, and response. Past history has indicated that two conditions were common to most out-of-control accidents: either stall warnings were so masked during flight that they could not be recognized in time to prevent departure, or the pilot continued maneuvering in spite of stall warning. The latter would be especially likely if the pilot experienced no natural cues to the approach of a stability limit. The active device, however, requires a conscious effort to override the system, and thus there is no lag in recognition and response time. The active device actually provides a greater maneuver envelope when compared to a passive device. A stall warning device, for safety purposes, must be triggered at some AOA well below stall to provide a margin for pilot recognition and reaction. Since stall warning should be heeded immediately, a portion of the maneuver

envelope is lost. An active device can be set at a higher angle of attack, thus preserving this maneuver envelope. In addition, an active device is able to reinforce the confidence (or restore the absence of it) of operational pilots in that they are able to maneuver the aircraft to its limits without apprehension.

3.4.1.7 Permissible Flight Limit AOA

SPECIFICATION

"The results of sections 3.4.1.2, 3.4.1.3, 3.4.1.4, 3.4.1.5, and 3.4.1.6 shall be used to establish a permissible flight limit AOA."

DISCUSSION

The basic objective of the tests is to determine the limits from a flying qualities point of view. It may be that there is some lower limit based on structural or other considerations. If this is the case, the most restrictive limiting factor must be observed.

Permissible AOA may be beyond stall AOA, especially if the pilot can make use of excess drag without fear of departure.

3.4.1.8 Demonstration of Departure/Spin Resistance'

SPECIFICATION

"The degree of departure/spin resistance (6.3.13 - 6.3.16) for all Class airplanes specified in 1.2 shall be determined by the test phase in which departures/spins first occur while performing those maneuvers listed in table I. Refer to table II for susceptibility/resistance classification."

TABLE II

SUSCEPTIBILITY/RESISTANCE CLASSIFICATION

| TEST PHASE | CLASSIFICATION | |
|---|-----------------------|-----------------------|
| | Departures | Spins |
| A - Stalls | extremely susceptible | extremely susceptible |
| B - Stalls with aggravated control inputs | susceptible | susceptible |
| C - Stalls with aggravated and sustained control inputs | resistant | resistant |
| D - Post-stall gyration, spin, and deep stall attempts | extremely resistant | extremely resistant |

DISCUSSION

There is a qualitative correlation between the specification test phases and departure and spin resistance. The degree of resistance to departures and spins is associated with the specification test phases as shown in table II. This table represents a qualitative definition of departure and spin resistance. The susceptibility/resistance classification is determined by the test phases in which departures or spins first occur. As an example, if the airplane will not spin unless control inputs are aggravated and sustained at the stall, the airplane would be categorized as spin-resistant. If departure for this same aircraft occurs consistently in phase A, then the same aircraft is extremely departure susceptible. Thus, there are two categories into which an aircraft may be placed. It does not necessarily follow that an aircraft which is susceptible to departure is equally susceptible to spin, e.g., the A-7.

Test phases A through C do not require a departure or spin. The purpose of the classification is to determine if an airplane falls into a given category. This classification guide has a direct correlation with MIL-F-8785 requirements. Airplanes that can be classified in any phase other than D do not meet the intent or the requirements of MIL-F-8785.

This section does not imply that departure characteristics or spins, if they occur before Phase D, will not be investigated. If the aircraft is extremely spin-susceptible, spins will occur in Phase A and that is where they will be evaluated.

3.4.2 OUT-OF-CONTROL RECOVERY PROCEDURE

SPECIFICATION

"When an airplane is subject to departure from controlled flight while performing the maneuvers outlined in table I, a simple out-of-control recovery procedure, acceptable to the procuring activity, shall be demonstrated. The out-of-control recovery procedure shall be the first reaction required of a pilot in response to a departure from controlled flight. Such a recovery procedure shall not require the pilot to determine the nature or the direction of the post-stall motion in order to properly execute the recovery steps. No other recovery procedures shall be recommended unless they are for a deep stall condition, erect spin, or inverted out-of-control events (6.2.1[m]). With the accepted recovery procedure, the brief recovery dynamics that can be associated with a rapid unloading to zero or negative normal acceleration are allowable. A production device, such as a drag chute, may be qualified as a recovery aid. The altitude loss values associated with the out-of-control events shall be determined. It shall be determined if the airplane is subject to any appreciable recovery-inhibiting effects due to asymmetric thrust or drag for possible failed-engine characteristics. It shall also be determined whether flight control systems as specified in MIL-F-9490 adversely affect the control surface displacements that are intended during high AOA flight before and following a stall or departure."

DISCUSSION

The out-of-control recovery procedure does not require that the direction of the maneuver be determined. The word "simple" implies one movement. If aileron or rudder were required, there would be a built-in delay, i.e., the time required to determine direction. In addition, if recovery is made with the lateral-directional controls neutralized, the pilot can distinguish between residual motions such as recovery rolls and motions that are commanded by control inputs. Important parts of the out-of-control recovery procedure (as well as the spin procedure) are the pilot cues and action to be taken to complete recovery. As an illustration, an out-of-control procedure which specifies only stick forward is an incomplete procedure. This is only the first step in the procedure. The pilot maintains forward stick only until such time as he has a positive indication that the AOA has been reduced below stall. The cues which provide him this information and steps to be taken subsequently must be specified. It makes little difference whether the crew ejects because the aircraft was indeed out of control 10,000 feet above the terrain or because the pilot believed the aircraft was out of control when in fact it was not.

Because of the surprise factor, the motions at and just following a departure are likely to be the most confusing; to allow aileron or rudder as a part of the out-of-control recovery procedure would be jeopardizing its success. Historically, unsuspecting operational pilots (a) can't distinguish between a PSG and spin and (b) are probably unaware of what is exactly happening for at least one turn (roll). The post-departure region is precisely where a rapid, simple recovery technique is needed - not one that requires a determination of what is going on, other than the fact that the airplane is out of control. Besides, the pilot might delay proper steps if he waited until he figured out which way the world was moving. Pilots are consistently told not to counter uncommanded motions prior to departure with aileron or rudder for fear of worsening the situation. It is somewhat inconsistent to require the pilot to move controls in response to any of the myriad, immediate departure motions possible.

F-111 experience has amply proved that the pilot can roll the airplane to such an extent after departure that recovery is hard to recognize and aileron can be incorrectly maintained. In an attempt to reduce spin susceptibility, lateral stick with the departure direction was applied immediately upon departure. However, roll effectiveness was still maintained and this roll with the departure direction only served to aggravate the situation. The AOA initially decreased but the rolling, through inertial coupling, caused AOA to increase again. Thus, the AOA transients were not out-of-control motions due only to lateral-directional instability, but were forced by the lateral stick input.

Flight control and augmentation systems are designed primarily for use in the operational envelope and have at times proven to be a problem outside the operational envelope. The A-7 and F-111 both require that the roll damper be turned off as a step in the out-of-control recovery procedure. The prototype CAS (TWaD system) installed in the F-4C required excessive forward stick displacement and force for stall recovery because of its particular characteristics.

3.4.3 SPIN RECOVERY - CLASS I AND IV AIRPLANES

SPECIFICATION

"When a departure from controlled flight or a deliberate spin attempt results in a spin while performing the maneuvers outlined in table I, a satisfactory spin recovery technique shall be demonstrated. Turns for recovery or altitude loss in spin recovery shall not exceed those values specified in MIL-F-8785. Under normal application circumstances, the recovery procedure shall not subject the airplane to (a) spin reversals, or (b) a change of spin mode that prolongs recovery. The spin recovery procedure shall be compatible with the out-of-control recovery procedure and possess a minimum of changes or additions. The accomplishment of the recovery procedure shall not be compromised by accelerations at the crew station. Control forces shall not exceed those values specified in MIL-F-8785."

DISCUSSION

Any spin recovery technique will not do. A procedure that requires too much precision to prevent reversal or maintains or worsens a spin if applied too early is unsatisfactory.

It is the responsibility of the test team to obtain the best operational spin recovery procedure and operational considerations should govern the selection process. Do not get "tunnel vision" when trying to define the optimum spin recovery procedures. There has been a tendency to generalize when predictive studies have been accomplished, i.e., if an aircraft was fuselage-loaded, then the "optimum" spin recovery procedure involved aft stick. This was the result of a simplification of linearized equations of motion and may not always reflect the behavior of a given aircraft undergoing large amplitude motions influenced by unsteady aerodynamics. For example, during flight test of the F-4, when stores were added asymmetrically, spin recovery was obtained with forward stick every time for over 40 spins. The one time the aft stick method (recommended from predictive studies) was attempted, the aircraft did not recover from the spin. Subsequently, it was learned that for the same configuration a satisfactory recovery using aft stick was never obtained during predictive studies. Forward stick was not attempted because "theory" said aft stick was "optimum."

The "change of spin mode" in item (b) includes inverted spin entry from erect spin; an airplane may be able to spin with controls in positions other than full pro-spin. It may recover with any of several sets of recovery controls. The objective is to select the procedure most probably successful in the operational environment of surprise and duress. The fact that a given technique shows minimum altitude loss during controlled test conditions doesn't necessarily mean its acceptable for operational use.

3.4.4 ENGINE OPERATING CHARACTERISTICS

SPECIFICATION

"Engine operating characteristics shall be documented while performing the maneuvers outlined in table I. When engine malfunction occurs during the post-stall interval of flight, it shall be demonstrated that recovery from the existing or ensuing out-of-control mode(s) can be accomplished at least 10 seconds prior to the projected time at which loss of ability to position the flight controls would occur because of the engine malfunction. This requirement shall be met with the throttles remaining in the least conservative position."

DISCUSSION

Problems with engine/inlet behavior at high AOA's and sideslip is just as dangerous as poor out-of-control characteristics and has to be investigated just as thoroughly. On the early F-111's the engines wound down to zero rpm within 20 seconds of airframe stall. On a production aircraft this would have meant the loss of hydraulics and thus the flight controls. F-111 engine performance was improved by leaving the throttles at whatever setting they were prior to stall. If engine performance was qualified in only this manner, testing is inadequate. All original F-104 stall/spin testing was accomplished at high engine rpm settings. As a result the flat spin mode for this aircraft was not discovered because engine gyroscopic effects promoted oscillatory spins to the right. A constant throttle setting might be a procedure but all methods have to be tested since using command pilots will not always leave the throttles in a fixed position.

3.4.5 RECOVERY CHARACTERISTICS

SPECIFICATION

"Recovery dynamics and maximum effort dive pullout characteristics shall be thoroughly determined. Altitude loss in post-stall events and total recovery altitude values shall be reported over a wide range of post-stall maneuvers and store loadings. The contractor shall also examine steep rolling maneuvers and erect and inverted spirals to determine if these motions may appear similar to out-of-control or recovery events. When potential misinterpretation of the maneuvers can lead to improper control application, the contractor shall identify all cues to the pilot that will allow proper recognition."

DISCUSSION

Low AOA recovery rolls and spirals are sometimes confused with out-of-control events. There is an obligation to investigate maneuvers associated with out of control flight even if they occur at low AOA's in the aftermath of a post-stall gyration or spin. As a result of this analysis there should be the recommendation of a speed to begin, an AOA to maintain and a configuration for dive pullout. Some of this data may be qualitative, i.e., the pilot may recommend an AOA for pullout based upon his ability (which is subjective) to maintain a given AOA without overrotating to a higher value. An important part of this part of the program is to convey to the operational pilots the cues available for recovery recognition: visual, unloading, AOA, or speed. Altitude loss should be documented in terms of AOA, entry speed, recovery speed, stores and configuration.

In planning the test program when recovery considerations are addressed, a minimum bailout altitude must be established for flight test. Additionally, the jettisoning of external stores in a post-stall maneuver is one of the most difficult problems associated with stall/spin testing because of the collision potential. Thought should be given as to what to do in flight test if, after an emergency recovery system failure, the aircraft, which was recoverable without stores, proves to be unrecoverable with a given store loading. If ejection is necessary, if time permits, should a streaming or flailing spin chute be jettisoned or should it be kept attached to the aircraft?

3.4.6 TRAINING MANEUVERS

SPECIFICATION

"The contractor shall establish flight training maneuvers, appropriate to the airplane Class and mission, to illustrate the high AOA flight characteristics near the limits of the permissible AOA envelope; inverted flight shall be included as required. It shall be possible for service pilots to safely practice these maneuvers established by the contractor. Specific guidelines concerning the type of training maneuvers to be defined by the contractor will be provided by the procuring activity (6.2.1[n])."

DISCUSSION

An important consideration in the reduction of accidents is to avoid loss of control. Thus it becomes mandatory to acquaint the operational pilot with aircraft behavior at high AOA's. Examples would be: thrust required limits, excess drag/sink rate regions, speed stability, adverse yaw, drag chute deployments, transonic pitch-up characteristics ("dig-in"), the effects of lateral-directional control inputs at high AOA's, engine behavior, and zoom recoveries. It is important to distinguish between the applicabilities of conventional techniques versus the need for specific near stall/post-stall techniques or recovery procedures.

3.4.7 BASELINE STABILITY TESTS

SPECIFICATION

"When the procuring activity anticipates that special modifications may significantly alter the basic properties of the test airplane, high AOA longitudinal and lateral-directional stability flight tests shall be conducted early in the demonstration program to compare test results with similar data from a production configured airplane (6.2.1[o])."

DISCUSSION

This effort needs to be completed early in the program to assure that the results attained from the test vehicle are representative of operational configuration. It potentially affects Flight Manual information and design-oriented test data; e.g., where do you trigger the loss of control prevention device?

High AOA as referred to in this paragraph depends on the type of aircraft. But the baseline stability tests should be accomplished to at least the limits of the service flight envelope, or to near the limits of the permissible envelope if a significant difference exists between the limits of the service and permissible envelopes.

The phrase "alter the basic properties of the test airplane" includes but is not limited to aerodynamic and inertial characteristics, as well as possible flight control system modifications.

3.5 INTERPRETATION OF QUALITATIVE REQUIREMENTS

SPECIFICATION

"In several instances throughout the specification, qualitative terms such as "intolerable buffet", "normally anticipated", "clear indication", "significantly greater", "premature application", "compatible spin recovery procedure", and "reasonably delayed" have been employed to permit latitude where absolute quantitative criteria might be unduly inflexible for all airplanes to be tested. Final determination of compliance with requirements so worded shall be made by the procuring activity."

4. QUALITY ASSURANCE PROVISIONS

4.1 COMPLIANCE DEMONSTRATION

SPECIFICATION

"Compliance with the associated high AOA requirements specified in MIL-F-8785 and MIL-F-9490 shall be demonstrated through flight test demonstration maneuvers in accordance with this specification."

DISCUSSION

This program and test vehicle may be required, in unusual or suspected hazardous circumstances, to confirm other MIL-F-8785 requirements not necessarily directly related to stall/spin. Examples: service envelope stability and roll performance at high AOA.

4.2 PRESENTATION OF PREDICTIVE STUDIES

SPECIFICATION

"Those predictive analytical/laboratory studies contracted for by the procuring activity shall be accomplished and reported sufficiently prior to scheduled initiation of the flight test program to allow for direction and limitation of scope in test planning. Predictive studies can include high AOA wind tunnel tests, dynamic model tests, and computer simulations."

DISCUSSION

Timely action on the part of the procuring activity to initiate requirements is as important as contractor performance and response in getting the task accomplished in time to be of maximum value to the test program.

6. NOTES

DISCUSSION

While Section 6 is not a contractual requirement, the information presented should provide valuable guidance in the application of the specification.

6.1 INTENDED USE

SPECIFICATION

"This specification contains the flight test demonstration requirements for determination of piloted airplane compliance with the stall and post-stall design requirements. A concurrent objective of this specification is the reporting of detailed information for inclusion in the Emergency and Flight Characteristics sections of the airplane Flight Manual."

DISCUSSION

The test team must think continuously along two lines - 1) technical and 2) informational. Using Command inputs should be obtained and integrated for the latter (magazine articles, training syllabus, training film, script review, briefing review).

6.2 ORDERING DATA

SPECIFICATION

"Purchasers should exercise any desired options offered herein, and procurement documents should specify the following:

6.2.1 PROCUREMENT REQUIREMENTS

SPECIFICATION

- (a) Title, number, and date of this specification.
- (b) Classification of airplane (1.2).
- (c) V/STOL airplane configuration (3.1).
- (d) Emergency recovery device (3.2.1).
- (e) Onboard instrumentation (3.2.2).
- (f) Onboard data switches (3.2.3).
- (g) Service participation (3.3).
- (h) Test phases to be accomplished for Flight Phase Category C tasks (table I)
- (i) Margin beyond arbitrary limit(s) (table I).
- (j) Magnitude of control misapplication (table I).
- (k) Prolonged pro-spin controls (3.4).
- (l) Stall and post-stall variables (3.4.1.1).
- (m) Deep stall condition, erect spin, or inverted out-of-control events (3.4.2).
- (n) Guidelines for training maneuvers (3.4.6).
- (o) Baseline stability tests (3.4.7)."

DISCUSSION

This section is included for the preparers of the detail specification. Each of the items in the above list will need to be definite in the detail specification. Each of these items is cross referenced to facilitate use. For example, section 1.2 states: "An airplane shall be placed in a Class as specified in MIL-F-8785." The detail specification must include this classification. Any item which requires procuring activity concurrence or approval is cross-referenced in this manner.

6.2.2 CONTRACT DATA REQUIREMENTS

SPECIFICATION

"Data conforming to Data Item Descriptions DI-T-3718 (Test Reports - General), DI-A-3012/M-108-1 (Complete Motion Picture Film Reports), DI-A-3010/M-106-1 (Motion Picture Film Clips), and DI-A-3013/M-109-1 (Motion Picture Coverage [Footage]) will usually be required for delivery in connection with this specification. When so required, such data will be specified for delivery on a DD Form 1423 included in the contract."

6.2.2.1 Documentation of Test Results

SPECIFICATION

"The contractor shall provide documentation of stall/post-stall studies and demonstrations to the procuring activity. This can entail documenting three areas: (1) predictive studies, (2) flight test demonstration, and (3) flight test confirmation of predictive studies."

DISCUSSION

A primary effort in a program of this type is to provide information to the operational user. Secondary results are the academic pursuits of a determination of the characteristics of the airplane and production of a historical perspective on the applicability of model test techniques to the flight test program and the flight test techniques themselves. Each effort requires adequate documentation with accessibility to same for governmental agencies and contractors.

6.2.2.1.1 Predictive Studies

SPECIFICATION

"The contractor shall provide documentation by way of a written report of those studies for which the contractor is responsible. The impact of related stall/post-stall studies conducted by other agencies shall be acknowledged by the contractor in a suitable manner."

DISCUSSION

If NASA accomplishes model tests, the contractor should evaluate the results and comment as to what they mean to design objective confirmation and test conduct. In the past, predictive studies have sometimes been completed with results obtained that were not confirmed by flight test; but nothing was done about explaining possible discrepancies or acknowledging the differences. Someone must serve as a coordinator for all the various stall/spin studies and tests. Since these tasks are, in many respects, design-oriented, the contractor should be responsible for reviewing, comparing, and providing improvements/recommendations for the predictive studies.

6.2.2.1.2 Flight Test Demonstration

SPECIFICATION

"The flight test stall/post-stall/spin demonstration shall be documented with a written technical report and preparation of appropriate flight characteristics descriptions and emergency procedures for the Flight Manual. In addition, a motion picture presentation shall be required if specified by the procuring activity."

DISCUSSION

The documentation of a program of this type is included in Section 6 of this specification. While this section is not contractually binding, the information on the methods and types of documentation should provide guidance to both the contractor and procuring activity on what is necessary. Since the end result is to provide information and help to the operational user, these documentation efforts are important.

6.2.2.1.2.1 Technical Report

SPECIFICATION

"The written report shall include, but not be limited to, the information that follows:

- (a) Test airplane: a description of the airplane shall be included, detailing instrumentation, special modifications such as recovery devices, and differences from production vehicles.
- (b) Stall/post-stall terminology: terminology shall be included as defined in 6.3.
- (c) Test and evaluation: test variables considered, and test techniques used, in conducting the flight test demonstration, as outlined in accordance with this specification, shall be detailed within the report. The results of the flight test demonstration shall be substantiated by sufficient time histories of maneuvers so as to encompass all entry conditions and airplane states. As a function of airplane Class and extent of the maneuvers expected or encountered, the procuring activity may direct that special data presentations supplement time histories for reporting of test results. The report shall include operational training maneuvers as determined by flight test."

DISCUSSION

The contractor is required to submit a report; the Air Force test agency will normally submit one also. Special modifications to the airplane should be discussed in light of the results as well as differences from the production configuration if a pre-production version of the aircraft is used.

The test report must contain quantitative data and requirements should be adequately specified. Test reports with only qualitative pilot comments on stall characteristics are incomplete in most cases. Also, if data are not presented, they tend to become lost in company archives and are of no value to future programs or designers. In addition, it is highly probable that this data will be used for future aerodynamic modifications not just to improve stall characteristics, but to develop/improve an aileron-rudder interconnect, etc.

6.2.2.1.2.2 Flight Manual Synopses

SPECIFICATION

"Results of the flight test demonstration shall be consolidated into a pilot-oriented presentation for the Flight Characteristics and, when necessary, Emergency Procedures section of the Flight Manual."

DISCUSSION

While it is desirable to have joint programs for testing, it is preferable to have separate reporting efforts. The Air Force should have a vital role in the Flight Manual rewrite effort because of its understanding of operational needs.

6.2.2.1.2.3 Motion Picture

SPECIFICATION

"A technical briefing film summary of the flight test demonstration results shall be prepared with extensive coverage of in-flight demonstrations of stall/post-stall flight characteristics and out-of-control recovery techniques. At the discretion of the procuring activity, and within the scope of contractual agreement, a formal aircrew training film will be produced. This film shall include sufficient information to thoroughly instruct a pilot in high AOA maneuvering, stall and loss-of-control warning, out-of-control and, when applicable, spin recovery procedures."

DISCUSSION

Who will make the formal movie? It is preferable that the Air Force be responsible for this task in the course of normal training film production. It must be decided early in order that the organization of test footage can be accomplished efficiently. Project personnel should plan on major scripting and editing themselves to assure accuracy.

There is only one set of original film and this must be saved for the training film; sufficient masters should be initially produced to handle the periodic and final briefing films. The project personnel are solely responsible for cataloging and storing film; it is best to review and document all film as it returns. Examples of formal training or instructional type films are: USAF TF 6553 (F-4), USAF FR 875 (F-106), USAF TF 6753 (F-111), NAVY MN-10870 (A-7).

6.2.2.1.3 Evaluation of Predictive Studies

SPECIFICATION

"A comprehensive evaluation of the overall development and flight test stall/post-stall/spin demonstrations shall be prepared, in which predictive studies are to be evaluated and compared to flight test results, conclusions, and recommendations."

DISCUSSION

Predictive techniques for high AOA and out-of-control flight are inexact at present and a large national effort is underway to improve or supplement them. Detailed comparison/analysis of predicted and flight test characteristics are essential to this task. The contractor is best equipped to gather and comment on these data.

There is no intent to penalize the contractor for studies or untimely received data generated by other agencies. None of these studies is ever done without contractor knowledge and the results should be used in flight test program planning. Even if studies are completed during the flight test program, the discrepancies or similarities should be discussed in view of flight test results.

6.3 DEFINITIONS

SPECIFICATION

"The following standard terminology shall be applied whenever possible. Terms and definitions stated in 6.3.14 through 6.3.16 may be used to qualify degree of departure susceptibility or resistance for a given flight condition. The same terminology used to qualify degrees of departure susceptibility or resistance of the airplane to spin entry."

DISCUSSION

This section is designed primarily to give background information as to the thought that went into the definitions. Users are encouraged to fit airplane characteristics within the general definitions now provided and define new, specific sub-definitions as necessary. A feedback on how well existing definitions apply and any need for any new or modified definitions is desired. For all modified or new definitions: If the contractor or USAF, in future applications of the specification, wish to submit new definitions, a thorough literature search of similar concepts and personal contact with other stall/spin personnel is encouraged to obtain the most compatible definition possible.

SPECIFICATION

"6.3.1 Stall Angle of Attack. the AOA for maximum usable lift at a given flight condition (α_s defined in MIL-F-8785)."

SPECIFICATION

"6.3.2 Stall Warning. that natural airplane behavior or artificial signal(s) that indicates to the pilot the approach of maximum usable lift. Normally, the onset and development of stall warning shall be described as a function of AOA or airspeed for a given airplane state."

DISCUSSION

The pilot needs to know where the warning commences, how it changes, and what significantly indicates the stall AOA so that he can reverse his AOA rate. There is often an objection to the aircraft because there are, in many fighter aircraft, an abundance of tones of various and varying frequencies. Certainly, for an aircraft with poor stall characteristics this tone assumes more importance. Work needs to be done in this area; perhaps a voice warning system which could differentiate between ECM, stall, gear, etc., without the pilot having to recognize which tone is sounding could be devised.

SPECIFICATION

"6.3.3 Wing Rock. uncommanded lateral-directional motion, viewed by the pilot primarily as roll oscillation."

DISCUSSION

Wing rock can be either stall or loss-of-control warning. Study is required to determine the amplitude and frequency of wing rock (or any stall/loss-of-control warning for that matter) that makes flying at that AOA not useful. The task must be examined as well. For example +5 degrees wing rock may be objectionable for power approach but +20 degrees wing rock may be acceptable for maneuvering during a max g defensive turn where tracking is not the objective.

SPECIFICATION

"6.3.4 Bucking. uncommanded pitching oscillation."

DISCUSSION

The term is used to describe an oscillation of normal force without an associated change in pitching moment; not precisely a pitching oscillation as would generally be described.

SPECIFICATION

"6.3.5 Nose Slice. uncommanded lateral-directional motion viewed by the pilot primarily as a divergence in yaw."

SPECIFICATION

"6.3.6 Pitch-Up. uncommanded, sudden increase in AOA."

DISCUSSION

Pitch-up defines an aerodynamic effect that is associated with an aerodynamic pitching moment or sudden flight control system nose up input; not an AOA increase due to excess drag or the AOA increase after departure that can occur because of inertial coupling.

SPECIFICATION

"6.3.7 Post-Stall. the flight regime involving angles of attack greater than nominal stall angles of attack. The airplane characteristics in the post-stall regime may consist of several more or less distinct types of airplane motion: departure, post-stall gyration, spin, and deep stall."

DISCUSSION

Departure will always precede deep stall, PSG, and spin, but there is no necessity that the latter three must occur in order during post-stall motion. That is, the aircraft may experience a deep stall or spin after departure without an intervening PSG.

SPECIFICATION

"6.3.8 Loss-of-Control Warning. that natural airplane behavior or artificial signal(s) that indicate to the pilot the approach or loss of control. As per stall warning, the onset and development of loss-of-control warning shall be described as a function of AOA or airspeed for a given airplane state.

Note: Natural stall warning and loss-of-control warning encompass successive AOA ranges. For some designs or flight conditions, departure may occur with only a slight increase in AOA beyond that for maximum usable lift. In such cases, stall warning and loss-of-control warning become practically synonymous and descriptions of flight characteristics should emphasize this fact when appropriate. However, in those cases when departure occurs at a significantly higher AOA than that for maximum usable lift, natural stall warning and loss-of-control warning should be independently discussed."

DISCUSSION

The fact that there may be a difference in AOA between stall and loss of control is common to several aircraft. It has been brought about by the aerodynamic characteristics of swept wing supersonic aircraft and as a result of the approach to testing outlined in this specification. Throughout this specification, stall and loss of control are not used synonymously.

SPECIFICATION

"6.3.9 Departure. the event in the post-stall flight regime which precipitates entry into a post-stall gyration, spin, or deep stall condition. The departure may be characterized by divergent, large-amplitude, uncommanded aircraft motions, such as nose slice or pitch-up. Departure is synonymous with complete loss of control."

DISCUSSION

Departure is the brief, but finite, airplane motion that marks the transition from controllable flight to an uncontrolled condition. Because it is finite, departure has a beginning and an end, and during this interval, the angles of attack and sideslip for example, may increase from easily controllable values to those which are consistent with the start of a PSG, deep stall, or spin. Departure is the event which precipitates entry into one of these events.

The resulting post-stall motion after departure does not have to be sustained over a long period of time or be comprised of a given number of uncommanded rolls in the form of a PSG. A PSG may be constituted by as little as a partial roll after a nose slice type of departure if the airplane has undergone a potentially dangerous change in flightpath and airspeed. If an airplane experienced a sudden 90-degree pitch down and large airspeed loss from unaccelerated, wings level flight; the airplane has done more than stall, there has been a departure. As another illustration, if the airplane slices and rolls only 35 degrees but in the process attains a near vertical pitch attitude at a very reduced airspeed; again, a departure has occurred, regardless of the brevity of the post-stall gyration, because the airplane has experienced such significant uncommanded motions to change flight from controllable to dangerous.

Unless extremely unusual aerodynamic and flight control system characteristics prevail, an airplane can be unloaded to a safe AOA prior to the occurrence of a departure, and perhaps within its incipient phase, even though small to moderate uncommanded motions are evident. This unloading indicates nothing about the airplane's out-of-control characteristics and recovery capability. The F-4 at high subsonic speeds, for example, can experience a rather severe wing rock (magnitude and frequency); but the airplane can be readily and rapidly returned to a low AOA by easing off the back pressure. Departure means complete loss of control. After departure, there is no guarantee of, and usually there will not be, a rapid and easy return to a safe angle of attack as would happen prior to departure. The one-g stall of a T-33 is not a departure under this definition.

SPECIFICATION

"6.3.10 Post-Stall Gyration (PSG). uncontrolled motion about one or more airplane axes following departure. While this type of airplane motion involves angles of attack higher than the stall angle, lower angles may be encountered intermittently in the course of the motion. When the airplane motion is other than random about all axes, a further classification of the PSG may be used for descriptive purposes. Such terms as snap roll, rolling departure or tumble may be appropriate; however, they should all imply a PSG. The PSG is differentiated from a spin by the lack of a predominant, sustained yawing motion and by the potential for exhibiting sub-stall angles of attack."

DISCUSSION

Post-stall gyration is a generic term which encompasses all out-of-control motions including spins and deep stall. In general usage, a PSG is any post-stall out-of-control event which is not specifically describable as a spin or deep stall.

The out-of-control recovery procedure is not intended to be the response to a PSG (as spin recovery is the required response to a spin); the out-of-control recovery procedure should provide recovery from a PSG, but it is to be applied after departure.

SPECIFICATION

"6.3.11 Spin. a sustained yaw rotation at AOA's above stall. The rotary motions of the spin may have oscillations in pitch, roll and yaw superimposed upon them. The incipient spin is the initial, transitory phase of the motion during which it is not possible to identify the spin mode. The developed spin is the phase of the spin during which it is possible to identify the spin mode. The fully developed spin is attained when the trajectory has become vertical and no significant change is noted in the spin characteristics from turn to turn.

Note: Spin modes may be identified by average values of AOA and body axis yaw rate and by the magnitude of the three-axis angular oscillations. One modifier from each group listed in table III may be used to characterize the mode:"

Table III

SPIN MODE MODIFIERS

| <u>Sense</u> | <u>Attitude</u> | <u>Rate</u> | <u>Oscillations</u> |
|--------------|-----------------|-----------------|-----------------------|
| Erect | Extremely steep | Slow | Smooth |
| Inverted | Steep | Fast | Mildly oscillatory |
| | Flat | Extremely rapid | Oscillatory |
| | | | Highly oscillatory |
| | | | Violently oscillatory |

DISCUSSION

Recent fighter spin tests have demonstrated that older, traditional definitions of spin, with phrases such as "...descending rapidly toward the earth... at an angle of attack between stall and 90 degrees ... etc.", are too limited with respect to modern aircraft behavior. As an example, under high entry energy conditions and with asymmetric loads, it was not at all uncommon for the F-4E test aircraft to spin nearly horizontally for several turns before "descending rapidly toward the earth". Ninety degrees AOA is not an upper limit for spin. Spin AOA's well above 110 degrees AOA have been routinely observed. Since aircraft can begin spinning directly after departure and follow ballistic paths, it seems appropriate to define spin in the most general terms possible - namely in terms of angle of attack (a post-stall value) and a sustained yaw rotation (the body axis yaw rate that contributes to inertial coupling pitch-up exists regardless of the instantaneous attitude of the airplane or direction of the flightpath; the yaw rate is also there even though the pilot's impression may be roll-dominated by alternating view of the ground and sky in the ballistic, or developing portions of the spin). At night or in weather, there are only two consistent cockpit cues to indicate a spinning condition - the angle of attack indicator (or airspeed) and the turn needle. The attitude indicator and the compass might possibly be interpreted for a spin, but correctly only towards the fully developed portion of the spin and that requires too long a wait for recognition. AOA and turn needle provide the necessary spin cues and are good whether or not the pilot can see the ground and regardless of trajectory.

The following comments are offered with respect to the columns of table III:

Sense - either negative or positive AOA

Attitude - The term attitude is used as one spin mode modifier because this is a readily established visual cue and the aircraft may not have a production AOA indicator.

The following AOA ranges would be offered for the "attitude" modifiers:

extremely steep: stall AOA to 35 degrees
steep: 35 to 70 degrees
flat: 70 degrees

Rate - the following ranges are suggested for describing the turn rate (body axis yaw rate)

slow: up to 60 degrees per second
fast: 60 - 120 degrees per second
extremely rapid: 120 degrees per second

Oscillations - These are qualitative terms. As an example, the F-4 showed the first four types; the difference between "smooth" and "mildly oscillatory" was that the former had a fairly constant roll rate, while the latter showed roll rate sign changes periodically in the spin; these differences were most evident to the pilot.

SPECIFICATION

"6.3.12 Deep Stall. an out-of-control flight condition in which the airplane is sustained at an angle of attack well beyond that for q_s while experiencing negligible rotational velocities. The deep stall may be distinguished from a PSG by the lack of significant motions other than a high rate of descent."

DISCUSSION

There is a need to distinguish deep stall as an out-of-control flight condition as opposed to a post-stall maneuver obtained by simply holding the stick full back and maintaining some post-stall angle of attack and a low or moderate rate of descent. For the latter, recovery to a safe AOA would rapidly and easily be accomplished by a simple release of back pressure. By classifying deep stall as an out-of-control event, it is acknowledged that it may be "locked in" (unrecoverable by any feasible means) or so slow to recover, or possess such a high rate of descent that it must be considered a dangerous flight condition. Restrictions for any deep-stall recovery procedure recommendations are not specified because of a lack of definitive precedents. However, the procedure should be fairly simple to remember and perform and not to produce other undesirable post-stall or recovery events.

If there is a question as to whether a post-stall descent truly is a deep stall, the entry into the maneuver should be examined. If the entry to a high post-stall AOA condition is sudden or deceptive, then the condition is dangerous and would be considered loss of control.

SPECIFICATION

"6.3.13 Extremely Susceptible to Departure. departure from controlled flight will generally occur with the normal application of pitch control alone or with small roll and yaw control inputs."

DISCUSSION

Each of the susceptibility classifications (6.3.13 to 6.3.16) applies to spins as well as to departures. Substitute the word spin for the word departure in each of the definitions. The tendency for an airplane to depart from controlled flight is not inherently related to the tendency to enter a spin. Also, the effects of some variables, such as entry speed or asymmetric stores, may also change the susceptibility/resistance rating of the airplane. That is, the basic airframe may be resistant to spin entry, but when utilized with a full asymmetric store load, it may be extremely susceptible to spin entry. In this case, departure/spin will occur simply by increasing AOA to a region of sufficient instability; no other forcing function is required. For such an airplane, departures/spins will occur in Phase A.

SPECIFICATION

"6.3.14 Susceptible to Departure. departure from controlled flight will generally occur with the application or brief misapplication of pitch and roll and yaw controls that may be anticipated in operational use."

DISCUSSION

The term "application or brief misapplication" implies that there be a delay in recovery controls or departure is induced by roll and yaw controls normally anticipated for the operational task. For this case, departures/spins will first occur in Phase B.

SPECIFICATION

"6.3.15 Resistant to Departure. departure from controlled flight will only occur with a large and reasonably sustained misapplication of pitch and roll and yaw controls."

DISCUSSION

The A-7, although extremely susceptible to departure, is resistant to spin; it takes full deflection rudder and aileron at departure to force the aircraft to spin. Spins on the A-7 would first occur in Phase C.

SPECIFICATION

"6.3.16 Extremely Resistant to Departure. departure from controlled flight can only occur after an abrupt and inordinately sustained application of gross, abnormal, pro-departure controls."

DISCUSSION

The T-38 is extremely resistant to departure. Directional instability for this aircraft occurs around 40 degrees AOA but the maximum static trim AOA is 22 degrees AOA. Thus, a large pitch rate is required to force the overshoot to get it out-of-control. At the same time full rudder and aileron are applied and held. These control inputs are considered gross and abnormal.

SPECIFICATION

"6.3.17 Recovery. the transition from out-of-control conditions to controlled flight. This is normally considered to be that period between pilot initiation of recovery controls and that point when the AOA is at a value below stall and no significant, uncommanded angular motions remain.

Note: The out-of-control recovery procedure requirements specified in 3.4.2 are directed primarily toward departures at a positive AOA rather than at a negative AOA. Erect flight is emphasized because out-of-control occurrences in training and operational activities usually take place more often and with more susceptibility at a positive AOA. Also, recovery capabilities from erect out-of-control conditions (positive AOA) are usually less favorable than from inverted situations (negative AOA) and the recommended recovery procedures correspondingly more extensive. The out-of-control recovery procedure shall always apply to loss of control from erect flight, but it may serve for both erect and inverted flight if the recovery procedures are identical (neutral controls for example). Or, an airplane may experience a departure at negative AOA that can be easily countered by a simple relaxation of pro-departure controls. In this instance, a bold-face, inverted out-of-control recovery procedure

may not be warranted since an adequate flight characteristics description in the Flight Manual would suffice. However, if the airplane exhibits a departure at negative AOA that requires an intricate recovery procedure, consideration should be given to specifying both an erect and inverted out-of-control recovery procedure.

Roll and yaw control displacements are allowable steps in the recovery procedures for erect and inverted spins in the event the out-of-control recovery procedure does not satisfy spin recovery requirements.

A separate recovery procedure may be proposed for the deep stall since this out-of-control mode is of a unique nature and may require recovery techniques (prolonged nose down pitch control, control stick pumping, asymmetric thrust, configuration changes, for example) that are significantly more extensive than normal stall recovery techniques and totally distinct from the out-of-control and spin recovery requirements."

DISCUSSION

For most foreseeable out-of-control maneuvers, this definition should be acceptable. However, it may seem somewhat awkward to discuss a two-roll PSG as part of recovery, since it occurred after pilot application of the out-of-control recovery procedure.

The definition will probably work for spin and deep stall and some PSG's. For more sustained PSG's after application of out-of-control recovery controls, an exception to the "normally considered" may be required and recovery will be defined as the interval between the point where the pilot first sees cues that the airplane is going back to a lower AOA/normal flight condition and the point where the airplane is at an AOA below stall.....

The notes on various recovery procedure requirements are fairly explanatory but one additional comment should be made. Some may be tempted to combine recovery procedure steps for various out-of-control modes (erect and inverted spin, deep stall, or for departure from erect or inverted flight) and specify the exception(s) within the boldface recover procedure as it applies to a specific maneuver. This may be satisfactory if the exceptions are very minimal, and if it can be shown that hesitation in separating the two events won't create a worse situation. But in questionable cases, the supposed savings gained by combining procedures may jeopardize both because of confusion or slowness in application. There are advantages to addressing each required recovery procedure separately in the Flight Manual. It forces the pilot to associate a given event with a given recovery procedure. If he has to read it this way, he will have a better chance of applying the procedure precisely where it's needed.

SPECIFICATION

"6.3.18 Dive Pullout. the transition from the termination of recovery to level flight."

DISCUSSION

Where does the dive pullout begin? It begins when the aircraft has recovered from out-of-control, normally when the AOA is below stall and significant, uncommanded angular motions have ceased. It does not begin when the spin "breaks".

SPECIFICATION

"6.3.19 Total Recovery Altitude. the sum of the altitude losses during the recovery and dive pullout."

DISCUSSION

There is a need to differentiate between the altitude loss during the out-of-control motion and the recovery and dive pullout; this is the purpose of this term.

SPECIFICATION

"6.3.20 Recovery Rolls. uncommanded rolling motions near or below stall AOA that may occur during the recovery phase of the spin or PSG."

DISCUSSION

The key words in this definition are "rolls" and "below stall AOA". This term was coined at the conclusion of the F-4E Stall/Near Stall Investigation program although this was not the first time the phenomenon had been observed. The connotation of the recovery rolls implies a transitory motion which is proceeding toward recovery.

For the F-4, the initial phase of recovery from out-of-control motions demonstrated a large residual sideslip angle and yaw rate as the AOA rapidly reduced through the stall region. The aircraft began a rapid, uncommanded rolling motion because of the favorable dihedral effect in the lower AOA region, and the subsequent high roll and yaw rates provided a nose-up pitching moment due to inertial coupling. This coupling momentarily prevented full forward stick from reducing AOA. Since these rolling motions occurred in a region of positive directional stability, the sideslip angle forcing the rolls was transient, and recovery rolls always damped within two or three rolls.

This definition was not applied to the roll coupling maneuver encountered on the F-111. The same basic functional mechanisms were present to cause the rolling motion, however, the rolls occurred in an AOA range where directional stability was marginal, and there was no forcing function to reduce the sideslip, and thus the rolls continued. Since the rolls were not transitory, the definition did not apply.

APPENDIX I

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MILITARY SPECIFICATION

STALL/POST-STALL/SPIN FLIGHT TEST DEMONSTRATION REQUIREMENTS FOR AIRPLANES

1. SCOPE

1.1 Scope. This specification contains the demonstration requirements of the stall and post-stall flight characteristics of piloted airplanes. Typical demonstration objectives subject to this specification are the verification of service and permissible angle of attack (AOA) limits, evaluation of natural and artificial stall and loss-of-control warning, and determination of out-of-control characteristics and recovery techniques. A purposeful, milestone approach to high AOA flight test is mandatory to determine compliance with the design requirements and obtain suitable information for the Flight Manual. Flight test demonstration requirements will be a function of airplane Class and specific direction from the procuring activity. Resistance to departure from controlled flight and prevention of departures shall be given the same attention as that directed toward recovery from post-stall gyrations (PSG) and spins.

1.2 Classification. An airplane shall be placed in a Class as specified in MIL-F-8785 (6.2.1[b]). When operational missions and design capabilities so indicate, an airplane of one Class may be required by the procuring activity to meet selected demonstration requirements ordinarily specified for airplanes of another Class. Generally, the most stringent demonstration requirements shall apply whenever an airplane fails to come clearly within one of two possible Classes.

2. APPLICABLE DOCUMENTS

2.1 The following documents, of the issue in effect on date of invitation for bids or request for proposal, form a part of the specification to the extent specified herein.

MIL-S-83691A(USAF)
15 April 1972
SUPERSEDING MIL-S-83691(USAF)
31 March 1971

FSC 1500

MIL-S-83691A(USAF)

SPECIFICATIONS

Military

- MIL-F-8785 Flying Qualities of Piloted Airplanes
- MIL-F-9490 Flight Control Systems - Design, Installation and Test of, Piloted Aircraft, General Specification For

(Copies of specifications, standards, drawings, and publications required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

3. REQUIREMENTS

3.1 Application. Unless otherwise specified, the stall/post-stall flight characteristics shall be demonstrated in accordance with the provisions contained herein. Manned airplanes requiring lifting surfaces to cruise within the sensible atmosphere shall be tested in accordance with this specification. Aerospace vehicles whose mission includes boost-return, boost-orbit-reentry, low maneuverability/nonpowered approaches and landings, etc., normally will not be tested in accordance with this specification. V/STOL airplanes normally will be tested in accordance with this specification only when configured for flight in which the lift is derived primarily from free stream dynamic pressure rather than the propulsive system (6.2.1(c)).

3.2 Flight test vehicle. Except as specified in 3.2.1 through 3.2.4, the flight test vehicle shall be representative of the production airplane in all significant respects.

3.2.1 Emergency recovery device. An emergency recovery system, approved by the procuring activity, shall be provided for each Class I and IV stall/spin test vehicle and shall, when necessary, be specified by the procuring activity for

Class II and III test vehicles (6.2.1[d]). Such emergency devices shall be capable of effecting recovery within a reasonable altitude loss established by the contractor and approved by the procuring activity. The emergency recovery system shall be capable of successful operation under the most adverse flight conditions and control positions possible.

3.2.2 Flight test instrumentation. The contractor shall provide onboard instrumentation as approved by the procuring activity (6.2.1[e]). When very high angular rates are anticipated, variable range or additional rate gyros may be required to provide adequate resolution for the pre-stall and post-stall conditions. The frequency response of the instrumentation shall be adequate to measure high-frequency phenomena such as pre-stall buffet. Except when actuated during emergency situations, flight test auxiliary hydraulic and electrical systems shall not restrict the mission time of the test airplane. Actuation of the auxiliary electrical power system shall not interrupt data acquisition. Consideration shall be given to additional instrumentation for structural purposes when predictive studies or initial flight test results indicate that the airframe or store suspension equipment may experience stall/post-stall loads near or above design values.

3.2.3 Cockpit instrumentation and layout. Cockpit displays in the test vehicle, particularly instruments indicating airspeed, altitude, AOA, turn/slip, normal acceleration, stall warning, attitude reference, and engine parameters, shall be those types to be installed on the production airplane. When special AOA, sideslip, and yaw rate indicators are also provided, they shall be easily readable and compatible in operation with production indicators (e.g., dials turning in the same direction). Unless otherwise specified, controls such as switches for the onboard data recording system, voice tape recorder, gyro cage, and cameras shall be capable of operation from the pilot's position and from another crew station or remotely from the ground to alleviate pilot workload (6.2.1[f]). The production pilot restraint system shall be used after predictive studies and sufficient flight test results are available to indicate that crew station angular rates and accelerations will not incapacitate or greatly hinder the pilot during application of recovery controls.

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3.2.4 Onboard cameras. Forward-looking cameras, both cockpit and external, shall be employed to document airplane motions; these cameras shall operate at 24 frames per second to allow true-time film review, and an adequate film supply shall be provided to insure representative documentation during each test mission. Onboard cameras that serve as an integral part of the quantitative data acquisition system may operate at any appropriate frame rate. Unless otherwise suitably instrumented, the emergency recovery system shall be covered by an onboard camera operating at an appropriate frame rate.

3.3 Accomplishment of flight test. The contractor shall be responsible for demonstrating the flight characteristics of the airplane in accordance with this specification. The contractor and flight test agency of the procuring activity, however, may share a predetermined percentage of the required maneuvers. The flight test agency may be assigned advisory test/engineering functions, witnessing duties, or actual test conduct activities that do not relieve the contractor of the prime demonstration requirements. When the airplane has a single set of controls, the procuring activity shall fly a number of missions agreed to between the contractor and procuring activity, with representative participation in each test phase (6.2.1[q]). When a second seat is available with cockpit controls, the procuring activity may provide a crewmember for all flights; in addition, a qualified service flight test pilot, as airplane commander, shall fly the number of flight test data missions agreed to between the contractor and procuring activity.

3.4 Flight test demonstration. Each airplane type shall demonstrate, by flight test according to table I, the degree of compliance with the stall warning, loss-of-control warning when required, resistance to loss of control, loss-of-control prevention, out-of-control recovery, and spin recovery criteria as specified in MIL-F-8785. Reasonably delayed recovery attempts after a stall or departure, and exaggerated misapplication of controls following a stall or departure, to simulate possible incorrect pilot responses, shall be investigated under the least conservative circumstances to ascertain the degree of spin susceptibility/resistance for operational users.

TABLE I
FLIGHT TEST DEMONSTRATION MANEUVERS

| Test Phase | Control Application | Maneuver Requirements | | | | Entry Conditions ¹ | | | | Tactical ³ |
|---|--|---|---|---|---|---|---|---|---|-----------------------|
| | | Smooth AOA Rate ¹ | | Abrupt AOA Rate ² | | One g | | Accelerated ² | | |
| | | One g | Accelerated ² | One g | Accelerated ² | One g | Accelerated ² | One g | Accelerated ² | |
| A Stalls | <p>Pitch control applied to achieve the specified AOA rate, roll and yaw controls neutral or small roll and yaw control inputs as normally required for the maneuver task.</p> <p>Recovery initiated after the pilot has a clear indication³ of:</p> <ul style="list-style-type: none"> (a) a definite g-break, or (b) a rapid, uncommanded angular motion, or (c) the aft stick stop has been reached and AOA is not increasing, or (d) sustained, intolerable buffet. | <p>Class: I II III IV</p> | <p>Class: I II III IV</p> | <p>Class: I II III IV</p> | <p>Class: I II III IV</p> | <p>Class: I II III IV</p> | <p>Class: I II III IV</p> | <p>Class: I II III IV</p> | <p>Class: I II III IV</p> | |
| B Stalls with Aggravated Control Inputs | <p>Pitch control applied to achieve the specified AOA rate, roll and yaw controls as required for the maneuver task. When condition (a), (b), (c), or (d) from above has been attained, controls briefly misapplied, intentionally or in response to unscheduled airplane motions, before recovery attempt is initiated.</p> | <p>Class: I II III IV</p> | <p>Class: I II III IV</p> | <p>Class: I II III IV</p> | <p>Class: I II III IV</p> | <p>Class: I II III IV</p> | <p>Class: I II III IV</p> | <p>Class: I II III IV</p> | <p>Class: I II III IV</p> | |
| C Stalls with Aggravated and Sustained Control Inputs ¹ | <p>Pitch control applied to achieve the specified AOA rate, roll and yaw controls as required for the maneuver task. When condition (a), (b), (c), or (d) has been attained, controls are misapplied, intentionally or in response to unscheduled airplane motions, and held for three seconds⁹ before recovery attempt is initiated.</p> | <p>Class: I II IV</p> | <p>Class: I II IV</p> | <p>Class: I II IV</p> | <p>Class: I II IV</p> | <p>Class: I II IV</p> | <p>Class: I II IV</p> | <p>Class: I II IV</p> | <p>Class: I II IV</p> | |
| D Post-Stall Gyration, Spin, and Deep Stall Attempts ¹ (this Phase required only for training airplanes which may be intentionally spun and for Class I and IV airplanes in which sufficient departures and developed spins did not result in Test Phase A, B or C to define characteristics of each possible out-of-control mode) | <p>Pitch control applied to achieve the specified AOA rate, roll and yaw controls as required for the maneuver task. When condition (a), (b), (c), or (d) has been attained, controls applied in the most critical¹⁰ manner to attain each possible mode of post-stall motion and held for various lengths of time up to 15 seconds or three spin turns, whichever is longer, before the recovery attempt is initiated.^{9,10}</p> | <p>Class: I IV</p> | <p>Class: I IV</p> | <p>Class: I IV</p> | <p>Class: I IV</p> | <p>Class: I IV</p> | <p>Class: I IV</p> | <p>Class: I IV</p> | <p>Class: I IV</p> | |

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TABLE I NOTES:

1. Configurations, loadings, cp's, entry speed/altitude, etc., shall be in accordance with 3.4.1.1. With the airplane configured for the Flight Phase Category C tasks identified in MIL-8785, only Test Phases R and B of this specification are required to be accomplished unless the procuring activity specifically requires the next or both remaining Test Phases to be accomplished (6.2.1(h)). An abrupt AOA rate, at a maneuver entry condition, is not required when the airplane is configured for Flight Phase Category C, except as specified at the end of note 4.

Engine requirements shall include:

- (a) Takeoff (TO) configuration: All engines at TO thrust; critical engine inoperative, others at TO thrust (stall approach, Test Phase A only).
- (b) Normal approach (PA) configuration: All engines at normal approach thrust; critical engine inoperative, others at re-quire approach thrust.
- (c) Climb (CL) configuration: All engines at normal climb thrust; critical engine inoperative, others at normal climb thrust.
- (d) Cruise (CR) configuration: All engines at thrust for level flight (TLF); all engines at idle thrust.
- (e) Combat (CO) configuration: All engines at military rated thrust (MRT), maximum augmented thrust (MAT).

Throttle requirements for those cases where flameouts or compressor stalls occur shall include:

- (f) Throttle retarded to idle from the maneuver entry setting position for a malfunctioning engine (for MAT, MRT, TLF).
- (g) Throttle left at the entry setting position until stall, PEG, or spin recovery has been accomplished (for MAT, MRT, TLF) unless compliance would result in exceeding engine operating limitations.

Stability and control augmentation requirements shall include:

- (h) All augmentation on.
- (i) Any number of channels disengaged if authorized or considered for service use.

The airplane shall be trimmed (controls and throttles) at settings consistent with the maneuver task. The effects of each designated flight test variable, from 3.4.1.1 and (a) through (i) above, shall be determined individually in each required Test Phase or until such effects are definitively established and predictable for succeeding Test Phases. Variables need to be tested in combination only when that combination could possibly yield less conservative results from those obtained by individual testing.

2. Accelerated entries, encompassing a representative range of Mach number, dynamic pressure, and allowable load factor, shall include windup turns, constant-altitude turns, and wings-level pullouts from dives appropriate to the airplane Class and mission.

3. Smooth, 1-g entries shall be approached utilizing a slow control rate which would produce a speed deceleration of approximately one knot per second for normal stalls ($\approx 1-g$). Smooth, accelerated entries shall be approached utilizing a control rate to achieve an AOA rate of approximately one-half degree per second.

4. In the required abrupt entries, the entry AOA rate for Category A and B Flight Phases shall be at least:

- Class I 4 deg/sec
- Class II 2 deg/sec
- Class III 1 deg/sec
- Class IV 8 deg/sec

except as limited by minimum available control deflection and rate. The magnitudes of the abrupt entry rates for Class I, II and IV airplanes may be graduated in Test Phases A through C commensurate with the increasing severity of the control requirements, but the stated minimum AOA rates shall be achieved in Test Phase C. For those airplanes designated for Category C Flight Phase investigation beyond Test Phases A and B, abrupt AOA rates suitable to the configuration and Test Phase shall be employed.

TABLE I NOTES (Concluded)

5. These entries shall be initiated from offensive/defensive, ground-attack, or other tactical maneuvers associated with the capability and Class of the airplane. The maneuvers, conducted with a suitable AOA rate, may include:
 - (a) Inverted stalls and aborted vertical reverses, loops, or Immelmans to investigate inverted out-of-control events.
 - (b) High AOA turn reversals with roll control only, with coordination attempted, and with yaw control only.
 - (c) High pitch attitudes (>45 degrees).
 - (d) Head-out-of-cockpit air combat maneuvering or ground-attack maneuvering.
 - (e) High-g, supersonic turns/transonic decelerations.
 - (f) Sudden idle power/speed brake decelerations.
 - (g) Sudden asymmetric thrust transients prior to stall.
6. For those Class II or III airplanes where clear indications of stall are not evident and considerations as identified in MIL-F-8785 define the minimum permissible speed other than stall speed, recovery may be initiated somewhat beyond the arbitrary angle of attack, speed, or load factor limit. Both the arbitrary limit(s) and the respective margins to be tested beyond the limit(s) are subject to the approval of the procuring activity (6.2.1[i]).
7. Misapplied controls shall consist of moving controls in the most critical directions an amount significantly greater than that expected during operational use. This shall generally require full deflection for Class I and IV airplanes and somewhat less for other Classes depending upon the mission and expected pilot reaction. The magnitude of the control misapplication shall be approved by the procuring activity (6.2.1[j]).
8. This time requirement may be increased for airplanes that do not exhibit a clear indication to the pilot of impending loss of control.
9. The test pilot shall insure that routine familiarity with stalls, post-stall gyrations, and spins does not negate the intent of the delay/misapplication simulation and does not result in premature application of spin recovery controls before a developed spin has been attained (as subsequently confirmed by flight records when necessary).
10. For trainer airplanes, recovery shall also be demonstrated from a fully developed spin if such a spin is attainable within a limited number of turns after spin entry.
11. In addition to the demonstration of a satisfactory spin recovery procedure, the effect of delayed application of the out-of-control recovery procedure shall be investigated briefly during the final phase of testing. The effects of premature application of the spin recovery procedure(s) under consideration, if different from the out-of-control recovery procedure, shall also be determined.
12. With respect to spin attempts, "critical" control positions shall include, but not be necessarily restricted to full spin settings. For some combinations of airplane state and entry test variables, the spinning motion may be sustained with controls in positions (neutral, out-of-control recovery settings, or stick forward for example) other than full spin positions, and a recovery attempt with controls displaced from the former positions may result in recovery capability, duration, or reversal tendency materially different from that which would occur if recovery were initiated from the full pro-spin condition. If it appears possible to encounter these circumstances in service use, then "critical" controls shall be any set necessary to define all out-of-control modes and determine recovery characteristics specifically applicable to operational users.

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When spins do result as a natural consequence of testing through departures (6.3.9) from controlled flight or as a result of deliberate spin attempts, a satisfactory spin recovery technique shall be demonstrated in accordance with MIL-F-8785. Unless otherwise specified, the use of prolonged pro-spin controls to sustain a developed spinning condition for more than three turns shall not be required except for trainer type airplanes to be cleared for intentional spins (6.2.1[k]).

3.4.1 General requirements for all Class airplanes.

3.4.1.1 Stall/spin flight test variables. The contractor shall establish, with the approval of the procuring activity (6.2.1[l]), what ranges and increments of the following variables are to be tested for influence on stall and post-stall flight characteristics:

- (a) Configuration.
- (b) Gross weight.
- (c) Center of gravity.
- (d) Stability and control augmentation system status.
- (e) Loadings, both internal and with external stores; critical combinations of aerodynamic and inertial loadings to include:
 - (1) Symmetric, fuselage heavy.
 - (2) Symmetric, wing heavy.
 - (3) Asymmetric (maximum allowable asymmetry).
 - (4) Any other loadings found critical in preliminary tests and analyses.
- (f) Stall and departure speed, altitude, and attitude.
- (g) Thrust and engine gyroscopic effects.

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3.4.1.2 Natural stall warning. It shall be determined if natural stall warning (6.3.2) meets the requirements of MIL-F-8785.

3.4.1.3 Artificial stall warning. When installed, artificial stall warning shall be evaluated to determine whether it meets the requirements of MIL-F-8785.

The flight test demonstration shall determine if:

- (a) the output from tactile stall warning devices, such as stick shakers, is not masked by airframe buffet or flight control system dynamics and is readily discernible with the body in any normally anticipated position.
- (b) visual stall warning devices are readily discernible near peripheral vision limits, for any normally anticipated head position, during day or night operation.
- (c) aural stall warning signals are easily distinguishable from gear, flap, malfunction tones or other aural signals and do not block voice communication channels.

3.4.1.4 Natural loss-of-control warning. The effectiveness of loss-of-control warning or indication (6.3.8) shall be determined for representative flight conditions when different from natural stall warning.

3.4.1.5 Artificial loss-of-control warning. When artificial loss-of-control warning or indication is provided, it shall be demonstrated whether the devices are effective in allowing the pilot to prevent departure by application of pitch control during the most abrupt maneuvering permitted in service use. The flight test demonstrations shall determine if warning signals satisfy those characteristics noted in 3.4.1.3 and are clearly distinguishable from stall warning.

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3.4.1.6 Artificial loss-of-control prevention device. When a loss-of-control prevention device has been installed, it shall be demonstrated whether the device effectively prevents departures under critical combinations of test parameters and maneuvering circumstances and whether restrictions are imposed on the various flight envelopes.

3.4.1.7 Permissible flight limit AOA. The results of sections 3.4.1.2, 3.4.1.3, 3.4.1.4, 3.4.1.5, and 3.4.1.6 shall be used to establish a permissible flight limit AOA.

3.4.1.8 Demonstration of departure/spin resistance. The degree of departure/spin resistance (6.3.13 - 6.3.16) for all Class airplanes specified in 1.2 shall be determined by the test phase in which departures/spins first occur while performing those maneuvers listed in table I. Refer to table II for susceptibility/resistance classification.

TABLE II

SUSCEPTIBILITY/RESISTANCE CLASSIFICATION

| TEST PHASE | CLASSIFICATION | |
|---|-----------------------|-----------------------|
| | Departures | Spins |
| A - Stalls | extremely susceptible | extremely susceptible |
| B - Stalls with aggravated control inputs | susceptible | susceptible |
| C - Stalls with aggravated and sustained control inputs | resistant | resistant |
| D - Post-stall gyration, spin, and deep stall attempts | extremely resistant | extremely resistant |

3.4.2 Out-of-Control recovery procedure. When an airplane is subject to departure from controlled flight while performing the maneuvers outlined in table I, a simple out-of-control recovery procedure, acceptable to the procuring activity, shall be demonstrated. The out-of-control recovery procedure shall be the first reaction required of a pilot in response to a departure from controlled flight. Such a recovery procedure shall not require the pilot to determine the nature or the direction of the post-stall motion in order to properly execute the recovery steps. No other recovery procedures shall be recommended unless they are for a deep stall condition, erect spin, or inverted out-of-control events (6.2.1[m]). With the accepted recovery procedure, the brief recovery dynamics that can be associated with a rapid unloading to zero or negative normal acceleration are allowable. A production device, such as a drag chute, may be qualified as a recovery aid. The altitude loss values associated with the out-of-control events shall be determined. It shall be determined if the airplane is subject to any appreciable recovery-inhibiting effects due to asymmetric thrust or drag for possible failed-engine characteristics. It shall also be determined whether flight control systems as specified in MIL-F-9490 adversely affect the control surface displacements that are intended during high AOA flight before and following a stall or departure.

3.4.3 Spin recovery-Class I and IV airplanes. When a departure from controlled flight or a deliberate spin attempt results in a spin while performing the maneuvers outlined in table I, a satisfactory spin recovery technique shall be demonstrated. Turns for recovery or altitude loss in spin recovery shall not exceed those values specified in MIL-F-8785. Under normal application circumstances, the recovery procedure shall not subject the airplane to (a) spin reversals, or (b) a change of spin mode that prolongs recovery. The spin recovery procedure shall be compatible with the out-of-control recovery procedure and possess a minimum of changes or additions. The accomplishment of the recovery procedure shall not be compromised by accelerations at the crew station. Control forces shall not exceed those values specified in MIL-F-8785.

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3.4.4 Engine operating characteristics. Engine operating characteristics shall be documented while performing the maneuvers outlined in table I. When engine malfunction occurs during the post-stall interval of flight, it shall be demonstrated that recovery from the existing or ensuing out-of-control mode(s) can be accomplished at least 10 seconds prior to the projected time at which loss of ability to position the flight controls would occur because of the engine malfunction. This requirement shall be met with the throttles remaining in the least conservative position.

3.4.5 Recovery characteristics. Recovery dynamics and maximum effort dive pullout characteristics shall be thoroughly determined. Altitude loss in post-stall events and total recovery altitude values shall be reported over a wide range of post-stall maneuvers and store loadings. The contractor shall also examine steep rolling maneuvers and erect and inverted spirals to determine if these motions may appear similar to out-of-control or recovery events. When potential misinterpretation of the maneuvers can lead to improper control application, the contractor shall identify all cues to the pilot that will allow proper recognition.

3.4.6 Training maneuvers. The contractor shall establish flight training maneuvers, appropriate to the airplane Class and mission, to illustrate the high AOA flight characteristics near the limits of the permissible AOA envelope; inverted flight shall be included as required. It shall be possible for service pilots to safely practice these maneuvers established by the contractor. Specific guidelines concerning the type of training maneuvers to be defined by the contractor will be provided by the procuring activity (6.2.1[n]).

3.4.7 Baseline stability tests. When the procuring activity anticipates that special modifications may significantly alter the basic properties of the test airplane, high AOA longitudinal and lateral-directional stability flight tests shall be conducted early in the demonstration program to compare test results with similar data from a production configured airplane (6.2.1[o]).

3.5 Interpretation of qualitative requirements. In several instances throughout the specification, qualitative terms such as "intolerable buffet," "normally anticipated," "clear indication," "significantly greater," "premature application," "compatible spin recovery procedure," and "reasonably delayed" have been employed to permit latitude where absolute quantitative criteria might be unduly inflexible for all airplanes to be tested. Final determination of compliance with requirements so worded shall be made by the procuring activity.

4. QUALITY ASSURANCE PROVISIONS

4.1 Compliance demonstration. Compliance with the associated high AOA requirements specified in MIL-F-8785 and MIL-F-9490 shall be demonstrated through flight test demonstration maneuvers in accordance with this specification.

4.2 Presentation of predictive studies. Those predictive analytical/laboratory studies contracted for by the procuring activity shall be accomplished and reported sufficiently prior to scheduled initiation of the flight test program to allow for direction and limitation of scope in test planning. Predictive studies can include high AOA wind tunnel tests, dynamic model tests, and computer simulations.

5. PREPARATION FOR DELIVERY

5.1 Section 5 is not applicable to this specification.

6. NOTES

6.1 Intended use. This specification contains the flight test demonstration requirements for determination of piloted airplane compliance with the stall and post-stall design requirements. A concurrent objective of this specification is the reporting of detailed information for inclusion in the Emergency and Flight Characteristics sections of the airplane Flight Manual.

6.2 Ordering data. Purchasers should exercise any desired options offered herein, and procurement documents should specify the following:

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6.2.1 Procurement requirements.

- (a) Title, number, and date of this specification.
- (b) Classification of airplane (1.2).
- (c) V/STOL airplane configuration (3.1).
- (d) Emergency recovery device (3.2.1).
- (e) Onboard instrumentation (3.2.2).
- (f) Onboard data switches (3.2.3).
- (g) Service participation (3.3).
- (h) Test phases to be accomplished for Flight Phase Category C tasks (table I).
- (i) Margin beyond arbitrary limit(s) (table I).
- (j) Magnitude of control misapplication (table I).
- (k) Prolonged pro-spin controls (3.4).
- (l) Stall and post-stall variables (3.4.1.1).
- (m) Deep stall condition, erect spin, or inverted out-of-control events (3.4.2).
- (n) Guidelines for training maneuvers (3.4.6).
- (o) Baseline stability tests (3.4.7).

6.2.2 Contract data requirements. Data conforming to Data Item Descriptions DI-T-3718 (Test Reports - General), DI-A-3012/M-108-1 (Complete Motion Picture Film Reports), DI-A-3010/M-106-1 (Motion Picture Film Clips), and DI-A-3013/M-109-1 (Motion Picture Coverage [Footage]) will usually be required for delivery in connection with this specification. When so required, such data will be specified for delivery on a DD Form 1423 included in the contract.

6.2.2.1 Documentation of test results. The contractor shall provide documentation of stall/post-stall studies and demonstrations to the procuring activity. This can entail documenting three areas: (1) predictive studies, (2) flight test demonstration, and (3) flight test confirmation of predictive studies.

6.2.2.1.1 Predictive studies. The contractor shall provide documentation by way of a written report of those studies for which the contractor is responsible. The impact of related stall/post-stall studies conducted by other agencies shall be acknowledged by the contractor in a suitable manner.

6.2.2.1.2 Flight test demonstration. The flight test stall/post-stall/spin demonstration shall be documented with a written technical report and preparation of appropriate flight characteristics descriptions and emergency procedures for the Flight Manual. In addition, a motion picture presentation shall be required if specified by the procuring activity.

6.2.2.1.2.1 Technical report. The written report shall include, but not be limited to, the information that follows:

- (a) Test airplane: a description of the airplane shall be included, detailing instrumentation, special modifications such as recovery devices, and differences from production vehicles.
- (b) Stall/post-stall terminology: terminology shall be included as defined in 6.3.
- (c) Test and evaluation: test variables considered, and test techniques used, in conducting the flight test demonstration, as outlined in accordance with this specification, shall be detailed within the report. The results of the flight test demonstration shall be substantiated by sufficient time histories of maneuvers so as to encompass all entry conditions

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and airplane states. As a function of airplane Class and extent of the maneuvers expected or encountered, the procuring activity may direct that special data presentations supplement time histories for reporting of test results. The report shall include operational training maneuvers as determined by flight test.

6.2.2.1.2.2 Flight Manual synopses. Results of the flight test demonstration shall be consolidated into a pilot-oriented presentation for the Flight Characteristics and, when necessary, Emergency Procedures sections of the Flight Manual.

6.2.2.1.2.3 Motion picture. A technical briefing film summary of the flight test demonstration results shall be prepared with extensive coverage of in-flight demonstrations of stall/post-stall flight characteristics and out-of-control recovery techniques. At the discretion of the procuring activity, and within the scope of contractual agreement, a formal aircrew training film will be produced. This film shall include sufficient information to thoroughly instruct a pilot in high AOA maneuvering, stall and loss-of-control warning, out-of-control and, when applicable, spin recovery procedures.

6.2.2.1.3 Evaluation of predictive studies. A comprehensive evaluation of the overall development and flight test stall/post-stall/spin demonstrations shall be prepared, in which predictive studies are to be evaluated and compared to flight test results, conclusions, and recommendations.

6.3 Definitions. The following standard terminology shall be applied whenever possible. Terms and definitions stated in 6.3.13 through 6.3.16 may be used to qualify degree of departure susceptibility or resistance for a given flight condition. The same terminology used to qualify degrees of departure susceptibility or resistance will be used to define the susceptibility or resistance of the airplane to spin entry.

6.3.1 Stall angle of attack: the AOA for maximum usable lift at a given flight condition (α_g defined in MIL-F-8785).

6.3.2 Stall warning: that natural airplane behavior or artificial signal(s) that indicates to the pilot the approach of maximum usable lift. Normally, the onset and development of stall warning shall be described as a function of AOA or airspeed for a given airplane state.

6.3.3 Wing rock: uncommanded lateral-directional motion, viewed by the pilot primarily as roll oscillation.

6.3.4 Bucking: uncommanded pitching oscillation.

6.3.5 Nose Slice: uncommanded lateral-directional motion viewed by the pilot primarily as a divergence in yaw.

6.3.6 Pitch-up: uncommanded, sudden increase in AOA.

6.3.7 Post-Stall: the flight regime involving angles of attack greater than nominal stall angles of attack. The airplane characteristics in the post-stall regime may consist of several more or less distinct types of airplane motion: departure, post-stall gyration, spin, and deep stall.

6.3.8 Loss-of-Control Warning: that natural airplane behavior or artificial signal(s) that indicate to the pilot the approach of loss of control. As per stall warning, the onset and development of loss-of-control warning shall be described as a function of AOA or airspeed for a given airplane state.

Note: Natural stall warning and loss-of-control warning encompass successive AOA ranges. For some designs or flight conditions, departure may occur with only a slight increase in AOA beyond that for maximum usable lift. In such cases, stall warning and loss-of-control warning become practically synonymous and descriptions of flight characteristics should emphasize this fact when appropriate. However, in those cases when departure occurs at a significantly higher AOA than that for maximum usable lift, natural stall warning and loss-of-control warning should be independently discussed.

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6.3.9 Departure: the event in the post-stall flight regime which precipitates entry into a post-stall gyration, spin, or deep stall condition. The departure may be characterized by divergent, large-amplitude, uncommanded aircraft motions, such as nose slice or pitch-up. Departure is synonymous with complete loss of control.

6.3.10 Post-Stall Gyration (PSG): uncontrolled motion about one or more airplane axes following departure. While this type of airplane motion involves angles of attack higher than the stall angle, lower angles may be encountered intermittently in the course of the motion. When the airplane motion is other than random about all axes, a further classification of the PSG may be used for descriptive purposes. Such terms as snap roll, rolling departure or tumble may be appropriate; however, they should all imply a PSG. The PSG is differentiated from a spin by the lack of a predominant, sustained yawing motion and by the potential for exhibiting sub-stall angles of attack.

6.3.11 Spin: a sustained yaw rotation at AOA's above stall. The rotary motions of the spin may have oscillations in pitch, roll and yaw superimposed upon them. The incipient spin is the initial, transitory phase of the motion during which it is not possible to identify the spin mode. The developed spin is the phase of the spin during which it is possible to identify the spin mode. The fully developed spin is attained when the trajectory has become vertical and no significant change is noted in the spin characteristics from turn to turn.

Note: Spin modes may be identified by average values of AOA and body axis yaw rate and by the magnitude of the three-axis angular oscillations. One modifier from each group listed in table III may be used to characterize the mode:

TABLE III
SPIN MODE MODIFIERS

| Sense | Attitude | Rate | Oscillations |
|----------|-----------------|-----------------|-----------------------|
| Erect | Extremely steep | Slow | Smooth |
| Inverted | Steep | Fast | Mildly oscillatory |
| | Flat | Extremely rapid | Oscillatory |
| | | | Highly oscillatory |
| | | | Violently oscillatory |

6.3.12 Deep stall: an out-of-control flight condition in which the airplane is sustained at an angle of attack well beyond that for α_{st} while experiencing negligible rotational velocities. The deep stall may be distinguished from a PSG by the lack of significant motions other than a high rate of descent.

6.3.13 Extremely susceptible to departure: departure from controlled flight will generally occur with the normal application of pitch control alone or with small roll and yaw control inputs.

6.3.14 Susceptible to departure: departure from controlled flight will generally occur with the application or brief misapplication of pitch and roll and yaw controls that may be anticipated in operational use.

6.3.15 Resistant to departure: departure from controlled flight will only occur with a large and reasonably sustained misapplication of pitch and roll and yaw controls.

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6.3.16 Extremely resistant to departure: departure from controlled flight can only occur after an abrupt and inordinately sustained application of gross, abnormal, pro-departure controls.

6.3.17 Recovery: the transition from out-of-control conditions to controlled flight. This is normally considered to be that period between pilot initiation of recovery controls and that point when the AOA is at a value below stall and no significant, uncommanded angular motions remain.

Note: The out-of-control recovery procedure requirements specified in 3.4.2 are directed primarily toward departures at a positive AOA rather than at a negative AOA. Erect flight is emphasized because out-of-control occurrences in training and operational activities usually take place more often and with more susceptibility at a positive AOA. Also, recovery capabilities from erect out-of-control conditions (positive AOA) are usually less favorable than from inverted situations (negative AOA) and the recommended recovery procedures correspondingly more extensive. The out-of-control recovery procedure shall always apply to loss of control from erect flight, but it may serve for both erect and inverted flight if the recovery procedures are identical (neutral controls for example). Or, an airplane may experience a departure at negative AOA that can be easily countered by a simple relaxation of pro-departure controls. In this instance, a bold-face, inverted out-of-control recovery procedure may not be warranted since an adequate flight characteristics description in the Flight Manual would suffice. However, if the airplane exhibits a departure at negative AOA that requires an intricate recovery procedure, consideration should be given to specifying both an erect and inverted out-of-control recovery procedure.

Roll and yaw control displacements are allowable steps in the recovery procedures for erect and inverted spins in the event the out-of-control recovery procedure does not satisfy spin recovery requirements.

A separate recovery procedure may be proposed for the deep stall since this out-of-control mode is of a unique nature and may require recovery techniques (prolonged nose down

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pitch control, control stick pumping, asymmetric thrust, configuration changes, for example) that are significantly more extensive than normal stall recovery techniques and totally distinct from the out-of-control and spin recovery requirements.

6.3.18 Dive Pullout: the transition from the termination of recovery to level flight.

6.3.19 Total Recovery Altitude: the sum of the altitude losses during the recovery and dive pullout.

6.3.20 Recovery Rolls: uncommanded rolling motions near or below stall AOA that may occur during the recovery phase of the spin or PSG.

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Air Force - 12

Review Activities:

Preparing Activity:

Air Force - 12

Project No. 1500-F014

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APPENDIX II RELATED SECTIONS OF MIL-F-8785B (ASG)

MILITARY SPECIFICATION AMENDMENT-2 FLYING QUALITIES OF PILOTED AIRPLANES

This amendment is issued for use with Military Specification MIL-F-8785B(ASG) dated 7 August 1969.

Page 1, bottom of page: Delete "FOR OFFICIAL USE ONLY".

Page 2, paragraph 1.4: Reverse the order of the third and fourth sentences.

Page 4, paragraph 2.1: Delete "MIL-S-25015" and title thereto and add:

"MIL-S-83691A(USAF) Stall/Post-Stall/Spin Flight Test Demonstration Requirements for Airplanes

MIL-A-8861 Airplane Strength and Rigidity-Flight Loads".

Page 8, paragraph 3.1.8.4, item b: Delete and substitute: "The steady load factor corresponding to the minimum allowable value of lift coefficient for stall warning (3.4.2.1.1.2)".

Page 9, paragraph 3.1.9, third sentence: Between the words "Stalls," and "spins," insert "post-stall gyrations,".

Page 9, paragraph 3.1.10, fifth line: Delete "Flight Envelope," and substitute "Flight Envelope or".

Page 11, paragraph 3.1.10.3.3, last sentence: Delete and substitute: "The requirements on flight at high angle of attack, dive characteristics, dive recovery devices, and dangerous flight conditions shall also apply."

Page 11, add paragraph 3.1.11: "3.1.11 Interpretation of qualitative requirements. In several instances throughout the specification, qualitative terms such as "objectionable flight characteristics", "realistic time delay", "normal pilot technique" and "excessive loss of altitude or buildup of speed", have been employed to permit latitude where absolute quantitative criteria might be unduly restrictive. Final determination of compliance with requirements so worded will be made by the procuring activity (1.5)."

Pages 11 and 12, paragraph 3.2.1.1: Last line on page 11, delete sentence beginning on this line and substitute "Stable gradients mean that the elevator control deflection and force increments required to maintain straight, steady flight at a different speed are in the same sense as those required to

initiate the speed change, that is, airplane-nose-down control to fly at a faster speed, airplane-nose-up control to fly at a slower speed."

Page 18, paragraph 3.2.2.2: Delete and substitute: "In steady turning flight and in pullups at constant speed, the elevator control force, elevator control deflection, and elevator control surface deflection required to maintain a change in normal acceleration shall be in the same sense as those required to initiate the load factor change, that is, airplane-nose-up control inputs and surface travel to maintain an increase in normal acceleration, airplane-nose-down control inputs and surface travel to maintain a decrease in normal acceleration. These requirements apply to local gradients in constant-air-speed maneuvers throughout the range of service load factors defined in 3.1.8.4.

Page 21, paragraph 3.2.3.3.2, third sentence: Delete "For purposes of this requirement," and substitute "Here".

Page 24, paragraph 3.3.1.3, line 2: Delete "trim" and substitute "rolling moment".

Page 31, paragraph 3.3.5.1, line 3: Between the words "that" and "straight", insert "wings-level".

Page 36, paragraph 3.4.1: change title to: "Dangerous Flight Conditions." and delete last sentence of paragraph.

Page 36, paragraph 3.4.1.1 Delete last sentence.

Pages 36 through 38, paragraphs 3.4.1.2 through 3.4.3: Delete and substitute: "3.4.1.2 Devices for indication, warning, prevention, recovery. It is intended that dangerous flight conditions be eliminated and the requirements of this specification met by appropriate aerodynamic design and mass distribution, rather than through incorporation of a special device or devices. Such devices may be used only if the procuring activity approves the need, the design criteria, possible Special Failure States (3.1.6.2.1), and the devices themselves. As a minimum, these devices shall perform their function whenever needed, but shall not limit flight within the Operational Flight Envelope. Neither normal nor inadvertent operation of such devices shall create a hazard to the airplane. For Levels 1 and 2, nuisance operation shall not be possible. Functional failure of the devices shall be indicated to the pilot.

3.4.2 Flight at high angle of attack. The requirements of 3.4.2 through 3.4.2.2.2 concern stall warning, stalls, departure from controlled flight, post-stall gyrations, spins, recoveries and related characteristics. They apply at speeds and angles of attack which in general are outside the Service Flight Envelope. They are intended to assure safety and the absence of mission limitations due to high angle of attack characteristics.

3.4.2.1 Stalls. The stall is defined in terms of airspeed and angle of attack in 6.2.2 and 6.2.5 respectively. It usually is a phenomenon caused by airflow separation induced by high angle of attack, but it may instead (3.1.9.2.1) be determined by some limit on usable angle of attack. The stall requirements apply for all Airplane Normal States in straight unaccelerated flight and in turns and pullups with attainable normal acceleration up to n_L . Specifically, the Airplane Normal States associated with the configurations, throttle settings, and trim settings of 6.2.2 shall be investigated; also, the requirements apply to Airplane Failure States that affect stall characteristics.

3.4.2.1.1 Stall approach. The stall approach shall be accompanied by an easily perceptible warning. Acceptable stall warning for all types of stalls consists of shaking of the cockpit controls, buffeting or shaking of the airplane, or a combination of both. The onset of this warning shall occur within the ranges specified in 3.4.2.1.1.1 and 3.4.2.1.1.2 but not within the Operational Flight Envelope. The increase in buffeting intensity with further increase in angle of attack shall be sufficiently marked to be noted by the pilot. The warning shall continue until the angle of attack is reduced to a value less than that for warning onset. At all angles of attack up to the stall, the cockpit controls shall remain effective in their normal sense, and small control inputs shall not result in departure from controlled flight. Prior to the stall, uncommanded oscillations shall not be objectionable to the pilot. These requirements apply whether V_S is as defined in 6.2.2 or as allowed in 3.1.9.2.1.

3.4.2.1.1.1 Warning speed for stalls at l_g normal to the flight path. Warning onset for stalls at l_g normal to the flight path shall occur between the following limits when the stall is approached gradually:

| <u>Flight Phase</u> | <u>Minimum Speed for Onset</u> | <u>Maximum Speed for Onset</u> |
|---------------------|--|---|
| Approach | Higher of $1.05V_S$ or $V_S + 5$ knots | Higher of $1.10V_S$ or $V_S + 10$ knots |
| All Other | Higher of $1.05V_S$ or $V_S + 5$ knots | Higher of $1.15V_S$ or $V_S + 15$ knots |

3.4.2.1.1.2 Warning range for accelerated stalls. Onset of stall warning shall occur outside the Operational Flight Envelope associated with the Airplane Normal State and within the following range of percentage of lift at stall at that airspeed, in that Airplane State, when the stall is approached gradually:

| <u>Flight Phase</u> | <u>Minimum Lift at Onset</u> | <u>Maximum Lift at Onset</u> |
|---------------------|------------------------------|------------------------------|
| Approach | 82% C_{Lstall} | 90% C_{Lstall} |
| All Other | 75% C_{Lstall} | 90% C_{Lstall} |

"3.4.2.1.2 Stall characteristics. In the unaccelerated stalls of 3.4.2.1, the airplane shall not exhibit rolling, yawing, or downward pitching at the stall which cannot be controlled to stay within 20 degrees for Classes I, II and III, or 30 degrees for Class IV airplanes. It is desired that no pitch-up tendencies occur in unaccelerated or accelerated stalls. In unaccelerated stalls, mild nose-up pitch may be acceptable if no elevator control force reversal occurs and if no dangerous, unrecoverable, or objectionable flight conditions result. A mild nose-up tendency may be acceptable in accelerated stalls if the operational effectiveness of the airplane is not compromised and:

- a. The airplane has adequate stall warning
- b. Elevator effectiveness is such that it is possible to stop the pitch-up promptly and reduce the angle of attack, and
- c. At no point during the stall, stall approach, or recovery does any portion of the airplane exceed structural limit loads.

The requirements apply for all stalls, including stalls entered abruptly.

"3.4.2.1.3 Stall prevention and recovery. It shall be possible to prevent the stall by moderate use of the elevator control alone at the onset of the stall warning. It shall be possible to recover from a stall by simple use of the elevator, aileron, and rudder controls with cockpit control forces not to exceed those of 3.4.5.1, and to regain level flight without excessive loss of altitude or buildup of speed. Throttles shall remain fixed until speed has begun to increase when an angle of attack below the stall has been regained unless compliance would result in exceeding engine operating limitations. In the straight-flight stalls of 3.4.2.1, with the airplane trimmed at an airspeed not greater than $1.4V_S$, elevator control power shall be sufficient to recover from any attainable angle of attack.

"3.4.2.1.3.1 One-engine-out stalls. On multiengine airplanes, it shall be possible to recover safely from stalls with the critical engine inoperative. This requirement applies with the remaining engines at up to

Flight Phase

Thrust

TO
CL
PA
WO

Takeoff
Normal climb
Normal approach
Waveoff

"3.4.2.2 Post-stall gyrations and spins. The post-stall gyration and spin requirements apply to all modes of motion that can be entered from upsets, decelerations and extreme maneuvers appropriate to the Class and Flight Phase Category. Entries from inverted flight shall be included for Class I and IV airplanes. Entry angles of attack and sideslip up to maximum control capability and under dynamic flight conditions are to be included, except as limited by structural considerations. For all Classes and Flight Phase Categories, thrust settings up to and including MAT shall be included, with and without one critical engine inoperative at entry. The requirements hold for all Airplane Normal States and for all States of stability and control augmentation systems except approved Special Failure States. Store release shall not be allowed during loss of control, spin or gyration, recovery, or subsequent dive pullout. Automatic disengagement of augmentation systems, however, is permissible if it is necessary and does not prevent meeting any other requirements; reengagement shall be possible in flight following recovery."

"3.4.2.2.1 Departure from controlled flight. All Classes of airplanes shall be extremely resistant to departure from controlled flight, post-stall gyrations and spins. The airplane shall exhibit no uncommanded motion which cannot be arrested promptly by simple application of pilot control. In addition, the procuring activity may designate that certain training airplanes shall be capable of a developed spin and consistent recovery."

"3.4.2.2.2 Recovery from post-stall gyrations and spins. For airplanes which according to MIL-A-8861 must be structurally designed for spinning, the following requirements apply. The proper recovery technique(s) must be readily ascertainable by the pilot, and simple and easy to apply under the motions encountered. Whatever the motions, safe, consistent recovery and pullout shall be possible without exceeding the control forces of 3.4.5.1 and without exceeding structural limitations. A single technique shall provide prompt recovery from all post-stall gyrations and incipient spins, without requiring the pilot to determine the direction of motion and without tendency to develop a spin. The same technique used to recover from post-stall gyrations and incipient spins, or at least a compatible one, is also desired for spin recovery. For all modes of spin that can occur, these recoveries shall be attainable within:

| <u>Class</u> | <u>Flight Phase</u> | <u>Turns for Recovery</u> |
|---------------|---------------------|---------------------------|
| I | Category A, B | 1 1/2 |
| I | PA | 1 |
| Other Classes | PA | 1 |
| Other Classes | A & B | 2 |

of the initiation of recovery action. Avoidance of a spin reversal or an adverse mode change shall not depend upon precise pilot control timing or deflection. It is desired that all airplanes be readily recoverable from all attainable attitudes and motions. The post-stall characteristics of those airplanes not required to comply with this paragraph shall be determined by analysis and model tests."

Page 40; paragraph 3.5.2, line 4: Between the words "for" and "these," insert "some of".

Page 42, paragraph 3.5.4.2, second sentence: Delete and substitute: "In particular, this requirement shall be met during rapid large-amplitude maneuvers, during operation at high angle of attack (3.4.2 through 3.4.2.2.2), and during flight in the atmospheric disturbances of 3.7.3 and 3.7.4."

Page 43, paragraph 3.5.5.2: In line 1, between the words "The" and "control," insert "change in"; in line 2, delete "zero".

Page 43 paragraph 3.5.6.2: In line 1, between the words "The" and "control," insert "change in"; in line 2, delete "zero".

Page 52, paragraph 3.7.5, third equation: Delete and substitute: $r_g = \frac{-\partial v_g}{\partial x}$.

Page 53, paragraph 4.1, first sentence: Delete and substitute: "Compliance with all requirements of section 3 shall be demonstrated through analysis. In addition, compliance with many of the requirements will be demonstrated by simulation, flight test, or both."

Page 56, table XV: Delete entries in all seven columns pertaining to requirements 3.4.2.2 through 3.4.3 and substitute the following:

| " Req'mt No. | Title | Critical Loading (4.2.1, 4.2.2) | Load Factor | Altitude (4.3.1) | Flight Phase |
|--|--------------------------------|---|-------------|------------------|--------------|
| 3.4.2 | Flight at high angle of attack | | | | |
| 3.4.2.1 (3.4.2.1.1 Through 3.4.2.1.3.1) | Stalls | | | | |
| 3.4.2.2 (3.4.2.2.1, 3.4.2.2.2) | Post-stall gyrations and spins | | | | |
| | | See MIL-S-83691 or MIL-D-8708, whichever is applicable for flight demonstration. More severe conditions generally will be investigated by analysis and model testing. | | | |

Page 58, delete paragraph 4.4 and add:

"4.4 Tests at specialized facilities. Certain tests, by their nature, can be conducted only at specialized facilities which are not accessible to either the procuring activity or the contractor except at the option of a third organization. In such cases, when an agreement of test support at the specialized facility is obtained by the procuring activity, an analysis of results obtained in the tests is a necessary part of the analytical compliance demonstration."

Page 61, paragraph 6.2.2, definition V_S : Delete item b and substitute:

"b. Speed at which uncommanded pitching, rolling, or yawing occurs (3.4.2.1.2)".

Page 67, paragraph 6.2.5, definition α_S : Delete item b and substitute the following:

"b. Angle of attack, for a given speed or Mach number, at which uncommanded pitching, rolling, or yawing occurs (3.4.2.1.2)".

Page 67, paragraph 6.2.5: add the following:

$C_{L_{stall}}$ - lift coefficient at α_S defined above

Page 71, paragraph 6.2.6: Delete the definition for $\Delta\beta_{max}$ and substitute: "maximum change in sideslip occurring within 2 seconds or one half-period of the Dutch roll, whichever is greater, for a step aileron-control command (figures 9 and 10).

Page 74, add:

"6.2.8 Terms used in high-angle-of-attack requirements.

Post-stall - The flight regime involving angles of attack greater than nominal "stall" angles of attack. The airplane characteristics in the post-stall regime may consist of three more or less distinct consecutive types of airplane motion following departure from controlled flight: post-stall gyration, incipient spin, and developed spin.

Post-stall gyration (PSG) - Uncontrolled motions about one or more airplane axis following departure from controlled flight. While this type of airplane motion involves angles of attack higher than stall angle, lower angles may be encountered intermittently in the course of the motion.

Spin - That part of the post-stall airplane motion which is characterized by a sustained yaw rotation. The spin may be erect or inverted, flat (high angle of attack) or steep (low but still stalled angle of attack) and the rotary motions may have oscillations in pitch, roll, and yaw superimposed on them. The incipient spin is the initial, transient phase of the motion during which it is not possible to identify the spin mode, usually followed by the developed spin, the phase during which it is possible to identify the spin mode."

Page 76, paragraph 6.5, second sentence: Delete and substitute: "Among these considerations are: the influence of engine gyroscopic moments on airframe dynamic motions; the effects of engine operation (including flameout and intentional shutdown) on characteristics of flight at high angle of attack (3.4.2); and the reduction at low rpm of engine-derived power for operating the flight control system."

Page 79, paragraph 6.8: Under "PUBLICATION," delete "USAF" and "HIAD-Handbook of Instructions for Airplane Designers" and add:

"AFSC Design Handbooks

DH 1-0 General
DH 2-0 Aeronautical Systems"

"AFFDL Technical Report

TR 69-72 Background Information and User Guide for MIL-F-8785B(ASG), Military Specification - Flying Qualities of Piloted Airplanes, August 1969".

Page 81, Numerical Index: Add the following:

"3.1.11 Interpretation of qualitative requirements.....11

Page 85, Numerical Index: Delete paragraphs 3.4.2 through 3.4.3 and titles thereto and substitute:

- "3.4.2 Flight at high angle of attack
- 3.4.2.1 Stalls
- 3.4.2.1.1 Stall approach
- 3.4.2.1.1.1 Warning speed for stalls at lg normal to the flight path
- 3.4.2.1.1.2 Warning range for accelerated stalls
- 3.4.2.1.2 Stall characteristics
- 3.4.2.1.3 Stall prevention and recovery
- 3.4.2.1.3.1 One-engine-out stalls
- 3.4.2.2 Post-stall gyrations and spins
- 3.4.2.2.1 Resistance to loss of control
- 3.4.2.2.2 Recovery from post-stall gyrations and spins."

Page 88, Numerical Index: Delete title to paragraph 4.4 and substitute:
"Tests at specialized facilities."

BIBLIOGRAPHY

Stall/spin flight testing deserves more than the cursory review of reference material that would normally satisfy preparation for conventional flying qualities test programs. When the post-stall flight regime is addressed, the accomplishment of accurate predictions of dynamic behavior becomes much more difficult. This difficulty is two-fold. Past stall/spin programs obviously did not necessarily constitute reliable precedents for the conduct of tests on future airplanes. Even more important, predictive studies for a specific airplane may actually yield misleading conclusions if indiscriminantly applied toward the subsequent flight test program without an understanding of how predictive study constraints and ground rules can color results. Why then make an issue of vigorous research when stall/spin testing proves to be so exploratory and the predictive studies as much or more so speculative than indicative?

Basically, extensive stall/spin research should indicate the myriad operational circumstances, or motions, or maneuvers that can possibly be experienced in flight test. This is not a "what do we do after tomorrow's five inverted spins" approach; it is a "what can happen" viewpoint for every entry. The research can reveal the surprises inflicted upon previous programs and eliminate over confidence (which is a hazard itself within a hazardous program). The research can reveal pitfalls of test conduct in which seemingly innocuous differences in the method of achieving identical objectives produces entirely different results (the three F-4 post-stall programs are an illustration of this). The research may provide a clue to explore one more area before finishing the job, thereby reducing the chance of inexplicable losses in the field. And since USAF post-stall terminology has only been standardized by the current demonstration specification, the research can disclose the common behavior of past-tested airplanes that only appears to be different because of the words selected to describe it. Finally, if project personnel make it a policy to review each bit of predictive information, whether simulation, wind tunnel analysis or dynamic model test, they can provide helpful feedback to contractor and government agencies when flight test results confirm or deny the predictions.

The following bibliography, therefore, is included to provide concepts, not details. This bibliography is not deemed inclusive or necessarily representative of the best work in the stall spin area. In fact, some of the selections report the very worst in testing. But the poorer documents are not going to disappear; they can still be enlightening in negative aspects. Again, this emphasizes the responsibility of project personnel to research aggressively but interpret and apply judiciously. Those personnel who apply or have an interest in the subject specification are solicited to forward bibliography additions to the preparing activity.

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