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SCHLEICHER ASK-21 GLIDER (TG-9) STALL AND SPIN EVALUATION

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JULY 1989

FINAL REPORT

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This technical report (AFFTC-TR-89-27, Schleicher ASK-21 Glider (TG-9) Stall and Spin Evaluation) was submitted under Job Order Number 921ASK by the Commander, 6510 Test Wing, Edwards Air Force Base, California 93523-5000.

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REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY N/A	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution is unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) AFFTC-TR-89-27	5. MONITORING ORGANIZATION REPORT NUMBER(S) N/A
6a. NAME OF PERFORMING ORGANIZATION 6510 Test Wing	6b. OFFICE SYMBOL (If applicable) USAFTPS/DO
7a. NAME OF MONITORING ORGANIZATION N/A	
6c. ADDRESS (City, State, and ZIP Code) Edwards AFB, California 93523-5000	7b. ADDRESS (City, State, and ZIP Code) N/A
8a. NAME OF FUNDING/SPONSORING ORGANIZATION USAF Academy	8b. OFFICE SYMBOL (If applicable) CWOO
9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER N/A	
8c. ADDRESS (City, State, and ZIP Code) Colorado Springs, CO 80840	10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.
N/A	921ASK		

11. TITLE (Include Security Classification)
Schleicher ASK-21 Glider (TG-9) Stall and Spin Evaluation

12. PERSONAL AUTHOR(S)
Janzen, Doyle B. and Precourt, Charles J., Major

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM 27APR89 TO 31MAY89	1989 August 8	136

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	gliders, stalls, departures, sailplanes, flight testing, spin weight ballast, spins, spin modes
01/01	01/03/06		
01/02	01/03/08		

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This report documents the results of the Schleicher ASK-21 Glider (TG-9) Stall and Spin Evaluation. Testing included evaluation of the departure and spin susceptibility of the aircraft as a function of weight and cg, definition of spin modes and mode characteristics as well as the control effects on those modes. Stall and spin flight tests of the ASK-21 were conducted between 27 April and 31 May 1989 at the Air Force Flight Test Center (AFFTC), Edwards AFB, California.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL Precourt, Charles J., Major	22b. TELEPHONE (Include Area Code) (805) 277-8037 — 22c. OFFICE SYMBOL AFFTC/USAFTPS/DO

DD Form 1473, JUN 86 — Previous editions are obsolete.

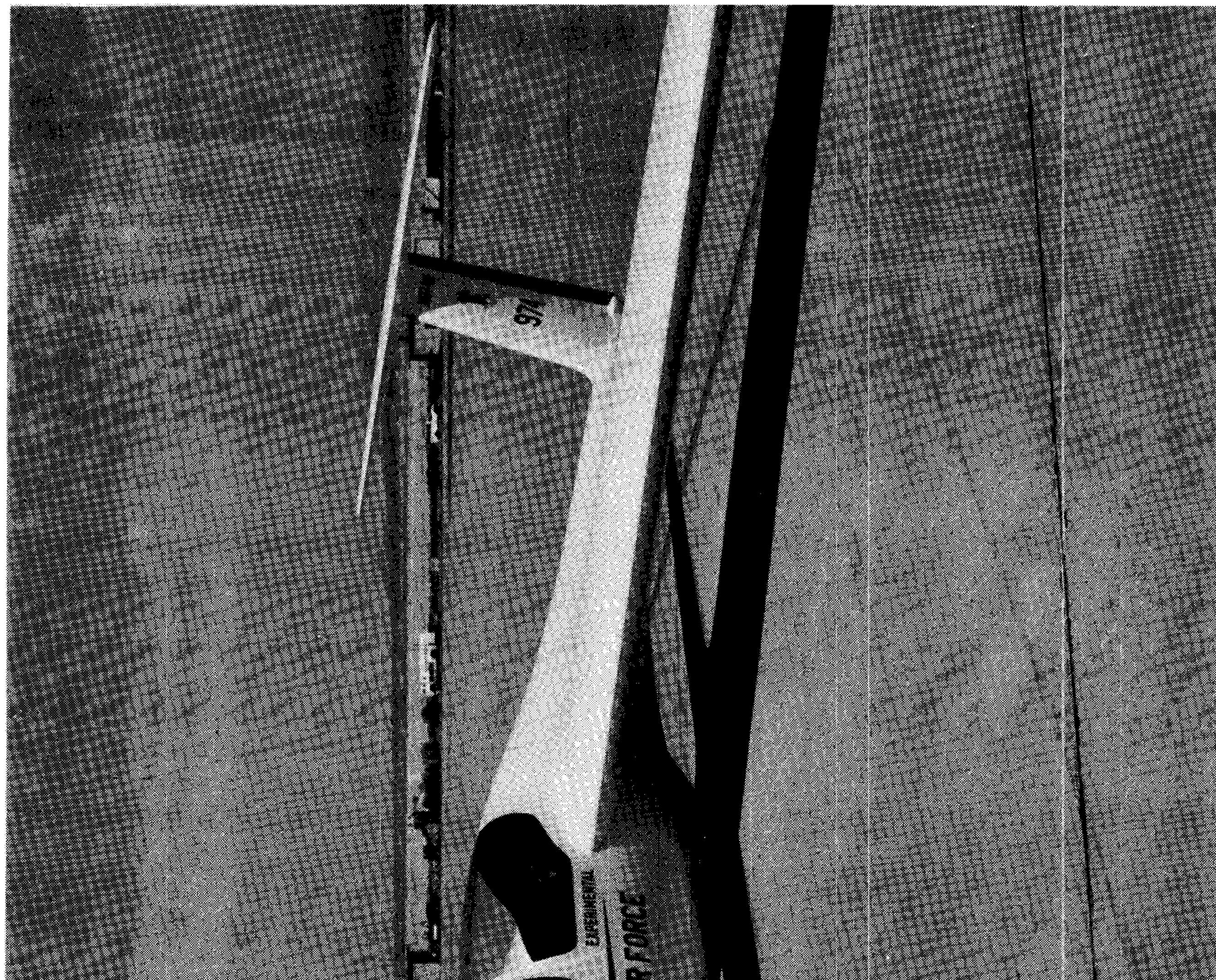
SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

PREFACE

This report documents the results of flight tests conducted to evaluate the stall, poststall, and spin characteristics of the Schleicher ASK-21 glider. These tests were requested by the Commandant of Cadets of the USAF Academy (USAFA). The objective of this test effort was to evaluate the effects of changing cg on the stall and spin characteristics.

Testing was conducted at the Air Force Flight Test Center (AFFTC), Edwards AFB, California, between 27 April and 31 May 1989. The flight test program consisted of 43 sorties totaling 30.5 flight hours. All tests were funded under Job Order Number 921ASK.

The test team expresses their sincere appreciation to the AFFTC organizations who participated in this evaluation. In particular, a special thanks to Robert E. Lee for providing technical expertise during this test. Thanks also goes to the Weight and Thrust Measurement Facility for painstaking efforts in acquiring critical weight and balance data, and to Barbara Jenner of the 6520 Range Squadron for providing 100 percent video coverage of the spins.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EXECUTIVE SUMMARY

This report documents the results of flight tests conducted to evaluate the stall, poststall, and spin characteristics of the Schleicher ASK-21 glider. These tests were requested by the Commandant of Cadets of the USAF Academy (USAFA) as a result of a Class A (fatal) mishap in November 1988. The investigation board recommended that the ASK-21 be tested prior to resumption of USAFA flight operations. The primary purpose of this program was to evaluate and document the effects of changing cg on the stall and spin characteristics. All test objectives were met.

Testing was conducted at the Air Force Flight Test Center (AFFTC), Edwards AFB, California, between 27 April and 31 May 1989. The flight test program consisted of 43 sorties totaling 30.5 flight hours.

The test aircraft was an Alexander Schleicher-manufactured ASK-21 glider, S/N 21235 and Registration Number N974AF. The aircraft had the USAF designation of the TG-9A, S/N 87-1974. It was owned by USAFA, 94th Airmanship Training Squadron. The glider was modified with an onboard video camera and a radar enhancing beacon (C-band) for this test. A thorough weight and balance was conducted, and the test aircraft was considered production representative.

The stall and spin characteristics of the ASK-21 were satisfactory and similar to those of other high performance sailplanes. The test team considered the aircraft to be an excellent spin trainer because cg could be accurately controlled using tail weights. This ensured that pilots of all weights could achieve the same spin results. Intentional stall and spin execution and recovery were safe and repeatable across the entire envelope of weight and cg.

The following eight major findings resulted from this test:

1. Stall warning indication was marginal, with only very light buffet, decreased cockpit noise, and very mild g-break at the stall.

2. The glider would spin at cg's forward of the manufacturer's flight manual reference value for spin entry.

3. The spin mode was oscillatory and, although it appeared flat at certain points in the oscillation, was easily recoverable. Spinning motions could be disorienting due to their oscillatory nature. Some spins terminated in spirals, requiring pilot attention to avoid excessive speeds during dive recoveries.

4. If forward stick was used without rudder to recover the aircraft from an out-of-control situation, recovery was sometimes significantly delayed.

5. The manufacturer's flight manual spin recovery procedure required up to 1 1/2 turns before rotation stopped. Using the manufacturer's flight manual procedure, the aircraft always recovered.

6. Spin entries occasionally occurred without rudder input if proper turn coordination was not exercised at speeds near stall.

7. Some spins continued indefinitely if controls were released during the developed spin.

8. Inverted spins were possible and occurred during inverted aerobatic maneuvers if cross-controlled inputs were maintained.

The current ASK-21 manufacturer's flight manual provided by the manufacturer does not accurately document spin susceptibility. Additionally, the manual does not adequately document the stall and spin characteristics. With appropriate flight manual revisions that reflect the major findings of this test, the ASK- 21 glider would be suitable for spin training.

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TABLE OF CONTENTS

Page No.

TABLE OF CONTENTS (Concluded)

LIST OF ILLUSTRATIONS

LIST OF TABLES

INTRODUCTION

BACKGROUND

This report documents the results of the Schleicher ASK-21 Glider Stall and Spin Evaluation conducted at the AFFTC, Edwards AFB, California. The test team flew 43 sorties, totaling 30.5 hours, between 27 April and 31 May 1989.

The primary purpose of this flight test program was to evaluate and document the stall and spin characteristics of the ASK-21 glider. The ASK-21 was designed to spin and was certified for spin training. These tests were requested by the Commandant of Cadets of the USAF Academy (USAFA). The flight manual currently provides a spin recovery procedure but no information on spin characteristics. This flight test program, therefore, emphasized stalls, departures, spins, and spin recoveries. The effects of changing cg on the stall and spin characteristics were determined. In accordance with manufacturer specifications, the cg was varied by using different aircrew weights and by the attachment of ballast in the tail and cockpit.

TEST OBJECTIVES

This flight test program had three general test objectives:

1. Determine the departure and spin susceptibility of the ASK-21 over its allowable range of cg.

2. Evaluate the stall, departure, and spin characteristics of the ASK-21 over its allowable range of cg.

3. Determine the effect of control inputs during fully developed spins.

The flight manual spin recovery procedure was also evaluated during this test. This was not a test objective but a natural fallout of the flight tests.

The flight test program was further organized in a phased approach to address specific test objectives. These flight test program phases were as follows:

1. Phase I: Departure and spin susceptibility evaluation, which required 15 sorties.

2. Phase II: Spin modes and spin characteristics determination.

3. Phase III: Determination of control effects on spin modes. Phases II and III were flown simultaneously and required 23 sorties.

4. Phase IV: Inverted spin mode evaluation, which required 5 sorties.

During the course of this flight test program, test results were compared to the requirements of Joint Aviation Regulations (JARs) Part 22 (Reference 1), which were used to certify the aircraft for use in the United States. An extract of the JAR Part 22 requirements for certification, with regard to stall and spin characteristics, is provided in Appendix F. Since the aircraft was not originally obtained under a military flight test program, the requirements of MIL-STD-1797 (Reference 2) do not apply to USAF procurement of this aircraft. However, MIL-STD-1797 was used as a guide during this test.

TEST ITEM DESCRIPTION

The test aircraft was an Alexander Schleicher-manufactured ASK-21 glider, S/N 21235 and Registration Number N974AF. It had the USAF designation of the TG-9A, S/N 87-1974. The aircraft, which was designed to meet the needs of modern sailplane training, consisted of an all fiberglass-foam, sandwich structure. It was a high performance sailplane with a mid-mounted wing, T-tail, tandem seating, conventional reversible flight controls, and airbrakes. The glider was also fully aerobatic with inverted flight capability. The glider had a +6.5 to -4.0 load factor limit at and below the maneuver speed of 97 KIAS. Above 97 KIAS, the load factor limit was +5.3 to -3.0. A three-view drawing of the aircraft is shown in Figure 1. A detailed description of the test

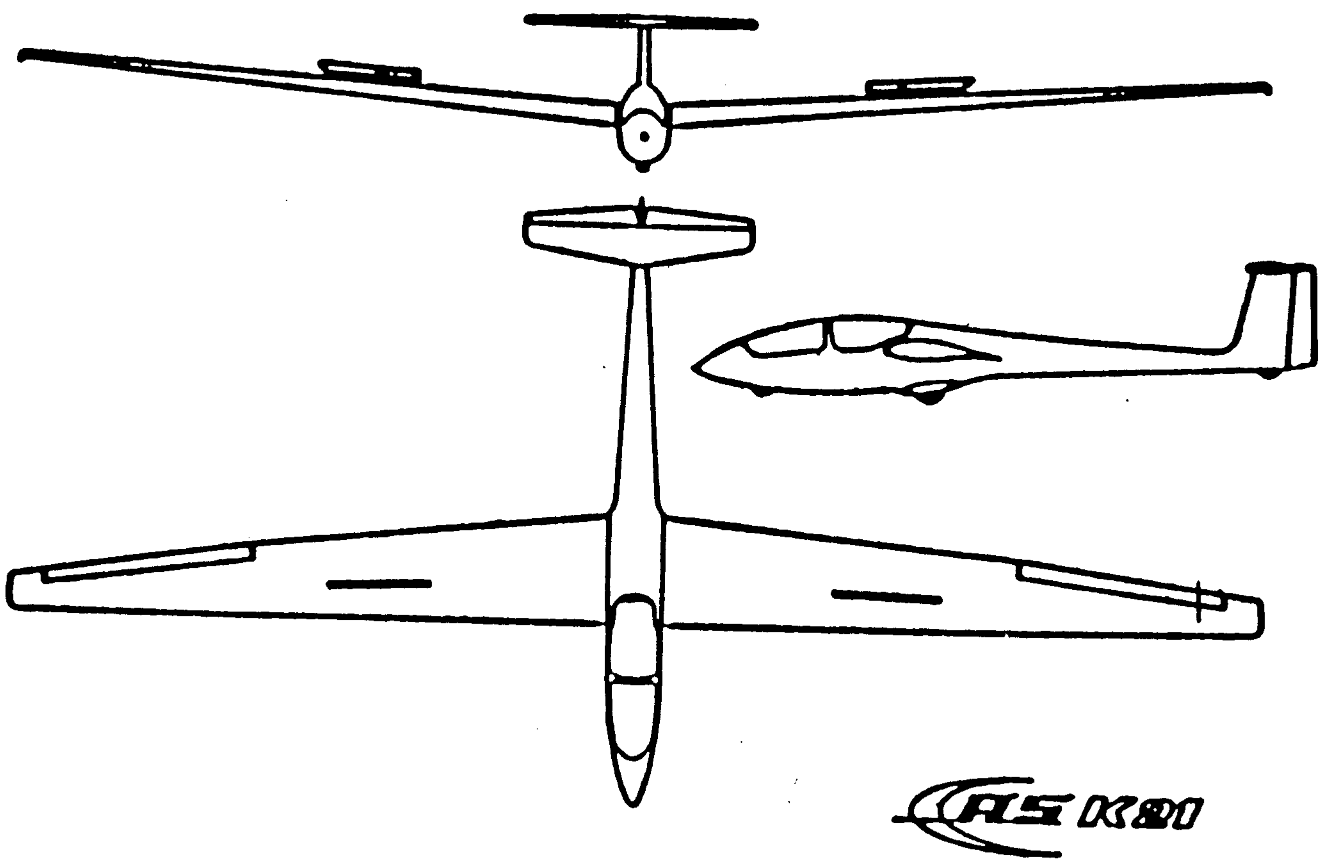

Figure 1 Schleicher ASK-21 Three View

aircraft is contained in Appendix B. A thorough weight and balance was performed on the test aircraft and the aircraft was considered production representative in configuration and mass properties.

CONSTRAINTS AND LIMITATIONS

Test instrumentation was limited to calibrated airspeed indicators, altimeters, G-meters, yaw strings, and a cockpit video camera. Point-to-point clearance for stall and spin test maneuvers was unnecessary since all test points were within the currently certified flight manual limitations. However, all testing followed a logical buildup from middle-of-the- envelope conditions to edge-of-the-envelope condi- tions.

The following restrictions applied to this flight test program:

1. The test aircraft was only flown in a designated spin area over the Rogers dry lakebed compass rose.

2. Project pilots were limited to current, qualified United States Air Force Test Pilot School (USAFTPS) spin instructors with Certified Flight Instructor - Glider (CFIG) ratings.

3. All testing had to be monitored on a real-time basis via VHF radio contact with project engineers and space positioning optical radar tracking (SPORT) flight vision cameras.

4. Maneuvers were only entered from above 4,000 feet above ground level (AGL).

5. In accordance with the flight manual limitations, no aerobatic or inverted entries to spins were flown with tail ballast weights installed.

6. The test team established the criteria of a maximum of two turns to complete recovery once initiated, or no more than one cycle oscillation in the oscillatory mode, as limits to halt the progression to more adverse points in the weight and cg envelope.

7. Minimum recovery altitude was 2,500 feet AGL to ensure straight and level flight by 2,000 feet AGL.

8. Maneuver entries up to 12,000 feet msl were required to duplicate the USAFA operational environment.

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TEST AND EVALUATION

TEST OBJECTIVES

The specific objectives for this flight test program were as follows:

1. Verify ASK-21 flight manual data for aircrew and tail ballast moment arms relative to the aircraft's weight and balance datum.

2. Determine the most forward cg where...

a. the aircraft will enter a spin, and

b. the aircraft will sustain a fully developed spin.

3. Evaluate the spin characteristics and spin recovery over the allowable range of cg where the aircraft will sustain a fully developed spin...

a. without tail ballast, and

b. with tail ballast.

4. Determine the acceptability of current cg/tail ballast envelopes used for spin training.

5. Evaluate inverted spin mode characteristics and spin recovery.

6. Develop an ASK-21 spin checkout program.
All test objectives were met.

The purpose of the first test objective was to determine that the test aircraft was production representative from a mass properties perspective. This would also ensure that weight and balance guidance given in the flight manual was accurate, repeatable, and applicable to this test. Finally, this objective was used to establish an accurate weight and balance data sheet for the test aircraft. This data sheet was then used to determine necessary loadings for flight tests throughout the permissible range of cg.

The second test objective (Phase I) was to determine the departure and spin susceptibility of the ASK-21 glider. In this process, the test team determined the most forward cg that would permit an incipient spin. This meant achieving a minimum of one turn. In the incipient spin, the aircraft self-recovered in spite of maintaining prospin inputs. The transition from forward cg, where even incipient spins were not possible to aft cg, where sustained spins were easily attainable, was not a thin line, but a broad band whose dimensions could only be determined by flight test. As the cg was moved aft, another boundary for ability to sustain a spin was defined. For the purposes of this test, a sustained spin was a spin that continued at least five turns, or indefinitely, as long as prospin inputs were maintained. Therefore, spins which achieved at least one, but less than five turns, and self-recovered in spite of maintaining prospin controls were classified as incipient spins.

For the purposes of this test, a departure was the event in poststall flight that precipitated entry into a poststall gyration or spin as defined in MIL-S-83691A (Reference 3). It was a momentary event indicated by uncommanded, divergent aircraft motions and was synonymous with complete loss of control. Since loss of control does not always result in spins with some aircraft, this evaluation was conducted to distinguish between departure susceptibility and spin susceptibility, which is customary in high angle-of-attack (AOA) testing at the Air Force Flight Test Center (AFFTC).

The definitions that described spins and spin modes for this test were also in compliance with MIL-S-83691A. In MIL-S-83691A, the incipient spin was defined as the initial phase of spinning motion, following a departure, in which it was still too soon to identify the spin mode. When the spin became developed, the mode of the spin could be recognized and characteristics of the spin from turn to turn were repeatable and easily described. For the purposes of defining the forward cg boundary for spinning, those spins which self-recovered never achieved a developed state by definition, and could only be classified as incipient. A spin mode was defined as a repeatable spin which had characteristic attitudes, rates, or oscillations which clearly distinguished it from other modes. Example modes included inverted versus upright or smooth versus oscillatory. The departure, incipient, developed, and recovery phases of a spin are illustrated in Figure 2.

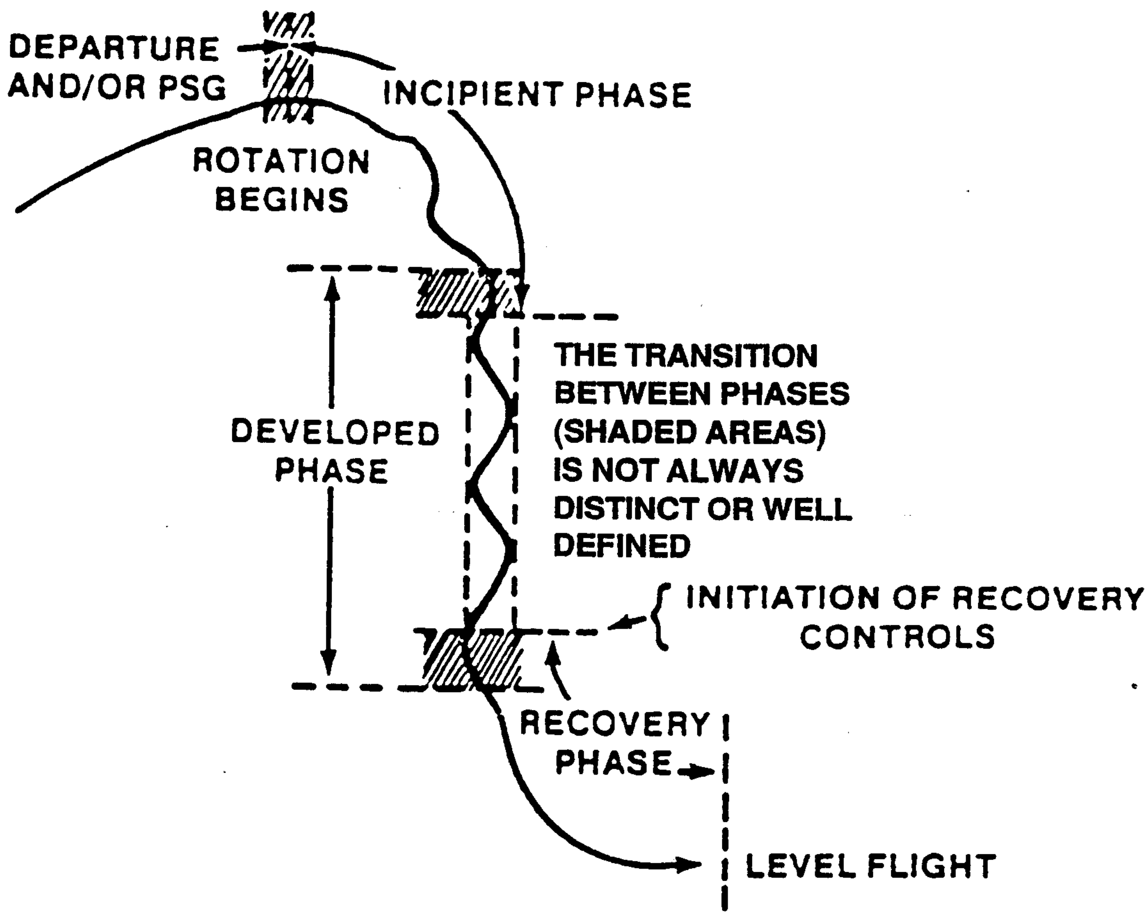

Figure 2 Spin Phases

The third test objective corresponded to Phase II flight testing. During this phase, the spin modes of the aircraft were evaluated qualitatively and quantitatively as the cg was progressively moved aft from the sustained spin boundary defined in Phase I. Weight and cg effects were identified and tail ballast effects were isolated. These results were then compared to the tail ballast loadings, presented in the flight manual, for spin training suitability.

The fourth test objective (Phase III flight testing) was to evaluate each identified spin mode for various control input effects. These tests were conducted to verify the primary recovery control and adequacy of the flight manual procedure. The tests were also used to identify any hazardous control inputs to be avoided during spin recovery and mandatory inputs required for spin recovery. The application of isolated control inputs during these spins simulated the spectrum of improper recovery controls which may be expected in the training environment.

The fifth test objective (Phase IV flight testing) was to test for the existence of an inverted spin mode. This test requirement met United States Air Force Academy (USAFA) needs for safely operating the glider as an aerobatic trainer, since glider aerobatics include prolonged inverted flight.

The final test objective was to develop an ASK-21 spin checkout program for USAFA flight operations. This was accomplished by producing video tapes showing various spin modes encountered during testing, entry techniques used to achieve spin entry, and the recovery techniques and characteristics applicable to the training environment. A spin training Phase Planning Guide was also written that outlines specific maneuvers, techniques, and procedures to be flown in accordance with the spin checkout program. This guide is presented in Appendix E.

TEST METHOD

The flight test techniques used in flight Phases I through IV involved various control inputs accomplished at stalls entered from both steady (static) and maneuvering (dynamic) flight conditions. The test maneuvers are detailed in Appendix A. These maneuvers followed the classic Phase A through D stall progression used in high AOA testing performed at the AFFTC as outlined in MIL-S-83691A.

Phase A through D type stalls are summarized as follows:

1. Phase A - Stalls with recovery at first indication

2. Phase B - Stalls with aggravated inputs

3. Phase C - Stalls with aggravated and sustained inputs

4. Phase D - Spin attempts

STALL CHARACTERISTICS

Approach to stall characteristics of the ASK-21 were evaluated on each flight prior to spin attempts. The approach to stall characteristics were similar to other high performance sailplanes. The following sections outline approach to stall and stall characteristics.

Approach to Stall Control Effectiveness:

At speeds below minimum sink speed in 1-g wings level flight, the controls were effective in all three axes. The elevator remained the most responsive control throughout this flight regime. The ailerons and rudder were slightly more sluggish but effective in the proper sense. The control forces were light and comfortable. Elevator forces remained stable up to the stall, as evidenced by an increasing stick force with increasing stick deflection.

Small aileron deflections produced adverse yaw (sideslip). Adverse yaw during approach to stall caused a nose slice away from the lateral stick input and occasionally a subsequent wing drop. This wing drop did not result in departure unless the aircraft was then forced into a full stall. In fact, application of lateral stick away from the wing drop would eventually return the aircraft to wings level. This indicated that up to stalled AOAs, aileron roll authority was sufficient to overpower adverse yaw.

Up to stall, large sideslip angles (up to full cross controls) could be flown without encountering a departure from controlled flight. As much as 50 degrees of sideslip angle was generated. In sideslips, however, the rudder forces lightened to zero. When the sideslip was large enough, the rudder locked out and required pilot input to recover. This was not objectionable as sideslips were fully controllable and the restoring pedal forces were very low. However, this contributed to the tendency found in spins for the aircraft to continue spinning when controls were released (see Hands Off section).

Warning Cues:

The most significant characteristic of the ASK-21 in approach to stall was the lack of any distinctive warning cues to the pilot that stall was imminent. With a cg aft of approximately 13 inches,[1] one cue was very slight airframe buffeting between 2 and 3 KIAS above the stall. If the cg was forward of 13 inches, full aft stick was achieved prior to any clear buffet onset, when approach to stall was performed from level flight. The only other cue of an impending stall, regardless of cg, was the diminished cockpit noise due to the slower speed of outside airflow. These cues were considered marginal for stall recognition. However, departures did not occur at stall unless aggravated inputs were prolonged more than 3 seconds (see Departure and Spin Susceptibility section).

During approach to stalls, airspeed indications were unreliable if sideslip was present. During full sideslips, indicated airspeed read zero or less, as evidenced by the needle unwinding and pointing at 160 KIAS. This resulted from the relative positions of the pitot and static pressure sensing ports, and was significant during spin and dive recoveries (see Spin Characteristics section).

Stall Indication:

During 1-g wings level flight, the stall was indicated by a very mild g-break (nose drop) of approximately 2 to 3 degrees. If the cg was forward of 13 inches, this g-break did not occur. Full aft stick was reached before stall, indicating a saturation of tail authority. If the stick was maintained full aft at stall, buffeting increased and a pitch bucking or slow oscillation in pitch attitude occurred as tail effectiveness returned at each nose drop and produced secondary stalls. Speeds at stall ranged from 33 to 38 KIAS depending on gross weight. These figures compared favorably with the 35 to 40 KIAS range documented in the flight manual. The use of spoilers had no significant effect on approach to stall, although the airframe buffet produced by the spoilers further masked the slight stall buffet of the airframe. Stall speeds with spoilers extended were generally 2 KIAS higher than without spoilers. This 2 KIAS difference was documented in the flight manual.

Dynamic entries to stall were flown using 30-degree, nose-high pitch attitudes and a more rapid onset rate. As expected, the dynamic effects produced a slower stall speed, as low as 20 KIAS, and a significant g-break of up to 40 degrees of nose drop. None of the dynamic entries to stall evaluated resulted in departure. The airspeed increased rapidly above stall during the g-break even if the stick was maintained at full aft. An altitude loss of approximately 100 feet was experienced during this type of maneuver.

Accelerated stalls were flown from 2-g turns in both directions. Slight airframe buffet was felt in the tail between 3 and 5 KIAS above the stall. If constant altitude was maintained during these turns, airspeed decreased and produced a mild g-break, as evidenced by a loss of pitch rate in the turn. Full aft stick was often reached with a stable turn condition, especially if a slight descent or thermal condition existed. This was due to obtaining maximum tail authority prior to stall. Accelerated stalls were characterized by mild warning cues in the approach to stall regime, similar to the 1-g stalls.

Stall Recovery:

Immediate recovery from all stalls was achieved by releasing back stick pressure and allowing the nose to fall, provided a wing drop had not occurred. Straight ahead stall recovery was achieved within a minimum altitude of 50 feet. Recovery was delayed if wing drop was present at the stall. This occasional wing drop was the result of stall from shallow bank turns, adverse yaw during shallow turns near the stall, or turbulence. If a wing drop occurred and forward stick was the only recovery input, the aircraft occasionally continued to rotate up to a turn or more depending on the timing of the control input. As much as 500 feet of altitude was

1 All cg distances are aft of datum.

required to obtain level flight. In the event of wing drop, opposite rudder was required to achieve the most expeditious recovery. This requirement is documented in the flight manual under the section entitled Wing Dropping and was verified by this test (see Appendix B). However, the flight manual also mentions "the glider is very harmless in low-speed flight," and that "with the stick back a distinct tail buffet is felt." Since these tests showed that tail and airframe buffeting in approach to stall was marginal for pilot warning cues, the flight manual should be revised to include the text provided in Appendix G. (R1)[2]

Inverted Stalls:

Inverted stalls were flown prior to inverted spin attempts. The characteristics in approach to stall at -1 g were essentially the same as normal 1-g flight. Stall speeds at -1 g were 38 to 40 KIAS for the cg's tested (15.8 to 18.4 inches). Very little airframe buffeting (even less than upright) was noticed during flight testing and the g-break was very mild, unless the stall was entered from a nose high attitude. Inverted stall testing was flown with the pitot probe extension installed, in accordance with flight manual instructions to reduce airspeed indicator error.

DEPARTURE AND SPIN SUSCEPTIBILITY

Phase I testing successfully defined the forward cg boundaries for both incipient and sustained spins. Dynamic maneuvers involving roll coupling, rudder reversals, multiple control inputs, and variations in input timing were all attempted to maximize the possibility of spin entry at the forward spinnable cg boundary determined during this flight test program.

Entry Techniques:

The ASK-21 was heavily wing loaded ($I_{xx} > I_{yy}$) as shown in Figure 3. Therefore, dynamic rolling maneuvers were ineffective in producing departures or spins. The most successful entry techniques were very simple. Wings level entries, with the pitch attitude maintained at 10 degrees nose high until stall while smoothly applying full rudder pedal and full aft stick, were the most effective. Another entry technique simulated a student error of an uncoordinated turn to enter a thermal condition. The nose of the aircraft was pulled up to 10 degrees nose high. While approaching 40 KIAS, the pilot initiated a full lateral stick turn without coordinated rudder. After a short pause, during which adverse yaw was generated, full rudder pedal was applied in the original direction of the intended turn. This action simulated a student's late recognition for the need to coordinate the turn. This generated more prospin yaw than the wings level entry noted above since the nose swung abruptly back from the initial sideslip angle caused by the adverse yaw. As the aircraft began to yaw in the originally intended turn direction, the stick was pulled aft to generate stall. The lateral stick position was then neutralized. This thermal entry technique was the most successful in producing repeatable spins.

Spin entry success was sensitive to entry pitch attitude conditions. For example, if the entry was too nose high, it resulted in a spiral dive. If the entry was too low, it resulted in a steep-banked sideslip. Spirals or sideslips occurred more frequently as the cg was moved forward. At 12.5 inches cg, no spinning motion could be produced.

Mass Properties Effects:

Spin entry success was not only sensitive to cg position, as expected, but also to inertia. The ASK-21 aircraft had the unique feature of tail ballasting, which meant that it could be loaded at both ends of the fuselage. Although the tail ballast weights were designed to control the cg, these weights significantly affected the inertia terms that govern aircraft response to flight maneuvers. Since the tail weights significantly increased the inertia of the aircraft longitudinal axis (see Appendix C), any initial yaw rotation resulted in a greater inertial pitching moment than without the tail weights. The increased inertial pitching moment forced the nose to a higher pitch attitude and thus sustained a stalled AOA. This greater moment resulted in achievable spins at cg's further forward than the low inertia loadings. Appendix H contains a detailed discussion of inertial effects on spin characteristics.

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2 Numerals preceded by an R within parentheses at the end of a paragraph correspond to the recommendation numbers tabulated in the Conclusions and Recommendation section of this report.

MOMENTS OF INERTIA

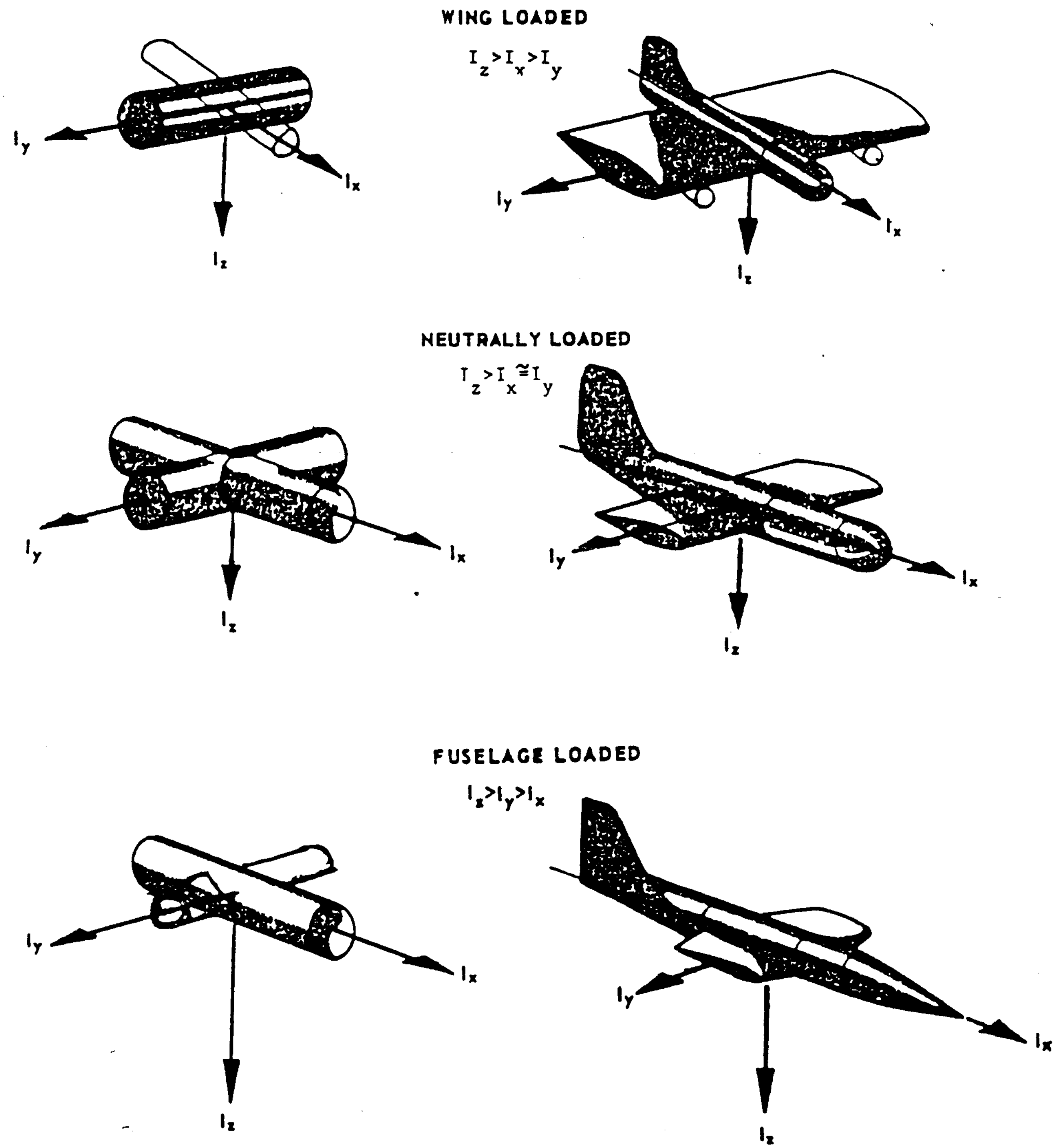

Figure 3 Aircraft Inertial Loadings

The flight manual stated that the aircraft would only spin at cg's aft of 0.4 meters or 15.75 inches (see Appendix B). The flight manual also does not differentiate between incipient and sustained spins. In these tests, incipient spins occurred as far forward as 12.9 inches. The variance between the test results and the information documented in the flight manual was due to both a difference in spin definition (incipient versus sustained) and the inertial effects of the tail weights. With low inertia loadings (solo, lightweight pilot without tail ballast), incipient spins could be achieved at cg's aft of 13.0 inches. Fully sustained spins were achieved aft of 15.0 inches, which was in close agreement with the flight manual value of 15.75 inches. With high inertia loadings (two pilots with tail ballast), incipient spins occurred aft of 12.5 inches and sustained spins occurred aft of only 13.5 inches. Figure 4 shows a summary of spin boundaries relative to cg for both low and high inertia loadings.

Figure 5 shows these spin boundaries by plotting cg versus pitching moment of inertia. Figure 5 also presents four example loadings which illustrate the effects of pilot weights and tail weights on the aircraft inertia. The results for spin entry success followed linear boundaries within the envelope of cg versus inertia. This brought a high degree of confidence in the data, and permitted accurate prediction of the kind of spin which may be produced for any configuration. The test team considered the aircraft to be an excellent spin trainer because cg could be accurately controlled using tail weights. This ensured that pilots of all weights could achieve the same spin results. It is extremely unlikely, but not impossible, that spin entry may be achieved for loadings which fall to the left of the incipient boundary line. Therefore, in accordance with MIL-S-83691A, the ASK-21 departure and spin resistance was classified as extremely resistant in the lower left corner of the envelope and progressively became less resistant as the loading moved to the upper right. The broad area between the two boundary lines was a region where only incipient spins were experienced. To the right of the sustained boundary line, spins could be sustained indefinitely as long as prospin controls were maintained. The flight log in Appendix E summarizes the flight maneuver results for Phase I testing.

The cg range tested in Phase I covered 12.4 to 14.0 inches aft of the datum. There were no tests flown forward of 12.4 inches because spin entry was highly unlikely in this area. Although no spins were encountered at 12.4 inches cg, this does not imply a spin forward of that cg is impossible. In accordance with MIL-S-83691A, the aircraft can only be classified as extremely resistant to departures and spins forward of 12.4 inches cg.

Based on the data in Figure 5, the test team determined that 16.0 inches was the best cg for spin training. Figure 6 shows how to achieve 16.0 inches cg in any ASK-21 glider using all combinations of pilot weights and tail weights. Figure 7 shows how to compute cg for any loading of any ASK-21.

Some operators may feel a false sense of security about the spin resistance of the glider when operating forward of the flight manual reference cg of 15.75 inches. For reference, Appendix B contains the current flight manual discussions regarding high AOA flight and spins. Since spins were achieved well forward of the cg referenced in the flight manual, it should be revised to include the text provided in Appendix G. (R1)

No Rudder Spin Entry:

Spin entry attempts without using rudder inputs were flown as a result of the adverse yaw seen during approach to stall. The test team suspected a wing drop would generate sufficient yaw to cause the rudder to float to the prospin position. Test pilots felt this was the most likely inadvertent spin scenario. For this test, the aircraft was flown in a shallow bank with the nose approximately 5 to 10 degrees above the horizon. This simulated a pilot failing to recognize approach to stall. As the airspeed approached 40 KIAS, a small lateral stick input was made in an attempt to level the wings. This input resulted in adverse yaw in the direction of the low wing. As the yaw developed, the pilot neutralized the lateral stick and pulled aft on the longitudinal stick. This simulated switching the pilot's attention to the direction of yaw and finding higher than expected terrain.

On flights configured with low inertia and cg just forward of 15.75 inches (flight manual reference cg for spins), up to 3 1/2 turn spins were achieved.

Wing drop at stall was very similar to other spins with rudder. Within the first 90 degrees of turn, the rudder began to float in the direction of the spin. For these spins, a stalled condition had to be maintained for 3 to 5 seconds (Phase C stall) in order to achieve

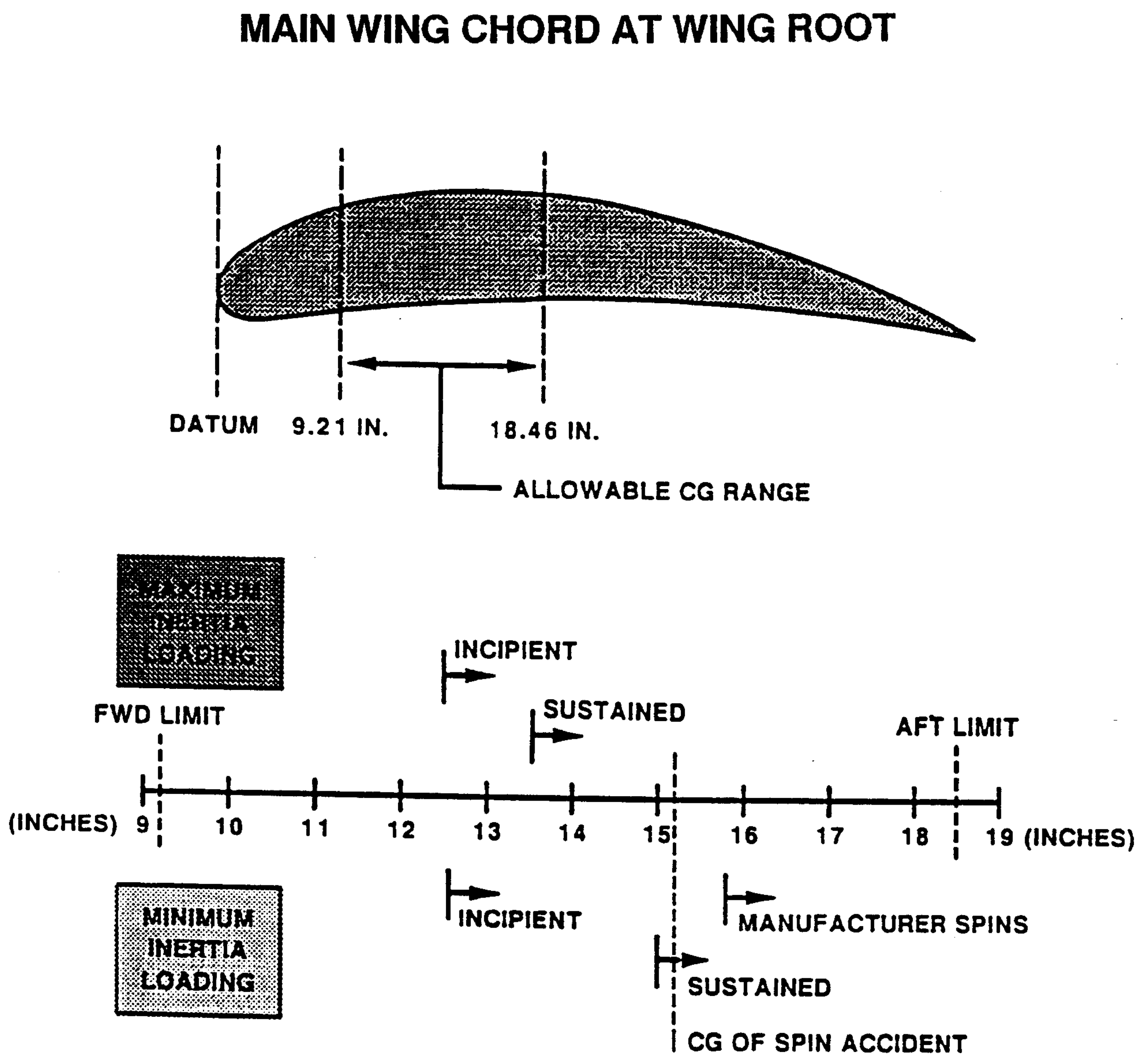

Figure 4 ASK-21 Spin Boundaries

ASK-21 Spin Susceptibility

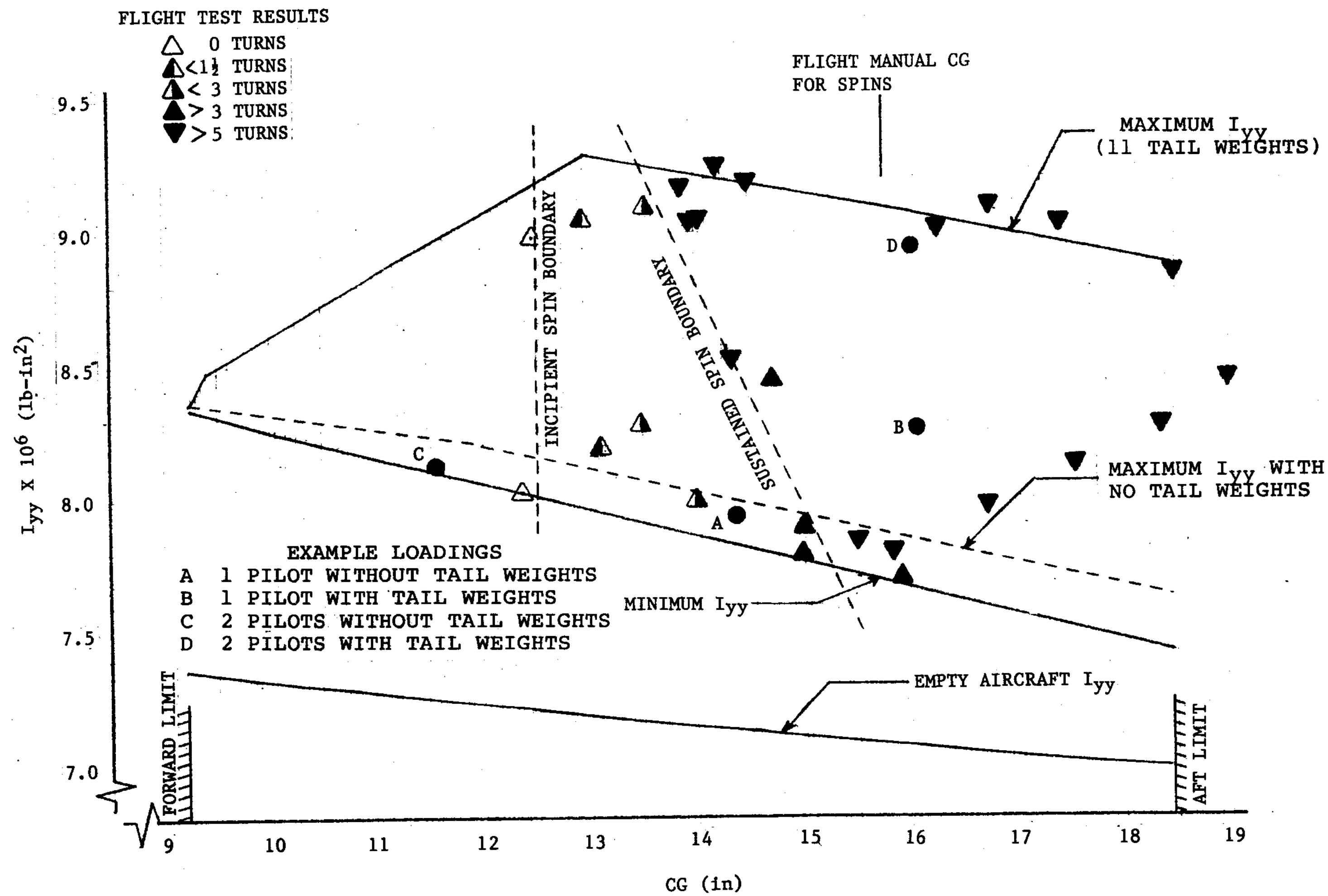

Figure 5 ASK-21 Center of Gravity Versus Pitch Inertia

ASK-21 Spin Training
Number of Tail Weights Necessary to Achieve 16 Inches Center of Gravity

NOTES: 1. Number of tail weights is sum of increment for empty aircraft plus increment due to front and rear seat weights (rounded to nearest whole).
2. Maximum number of tail weights allowed is 11.
3. No cockpit ballast.

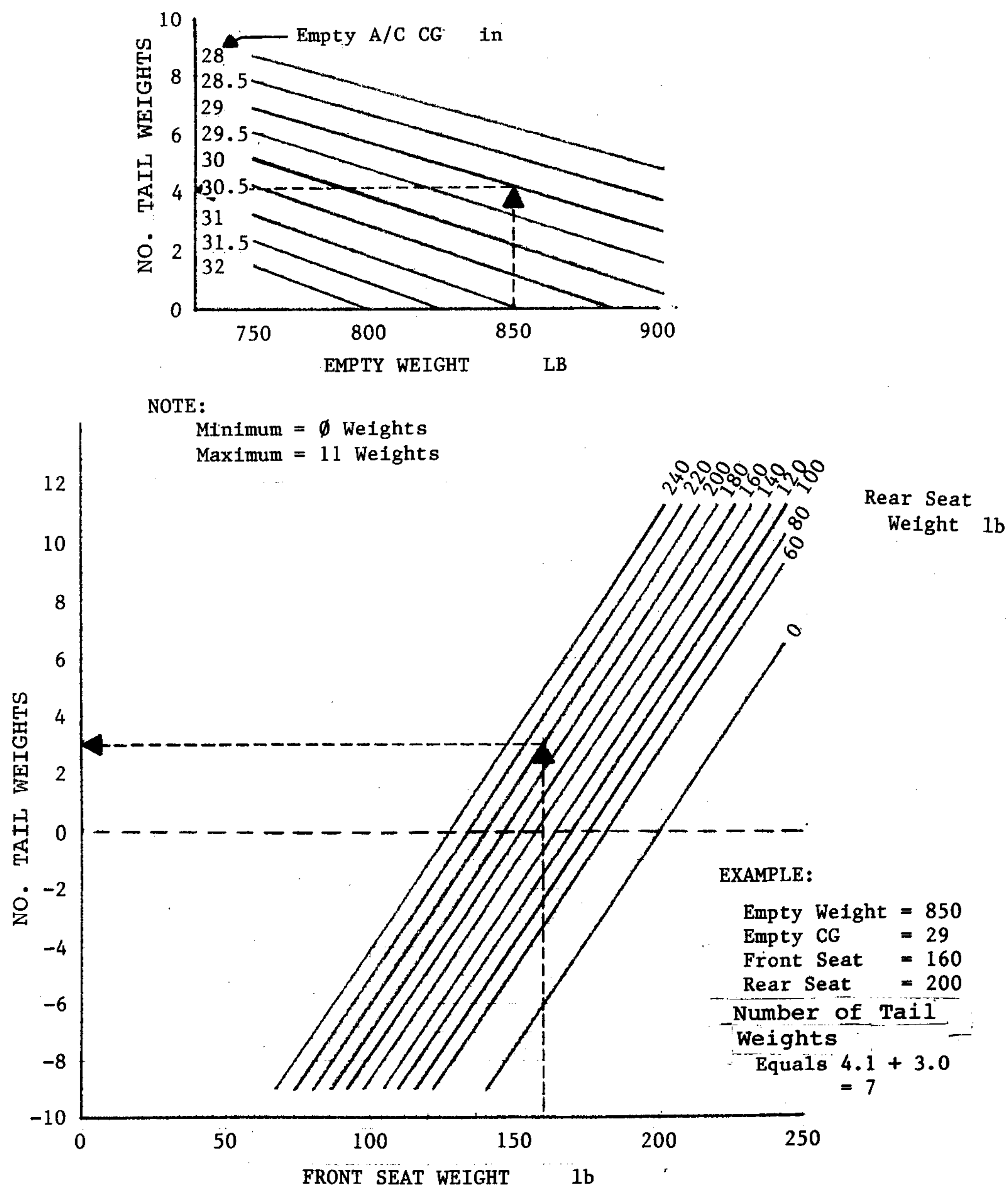

Figure 6 ASK-21 Loading Chart for Spins

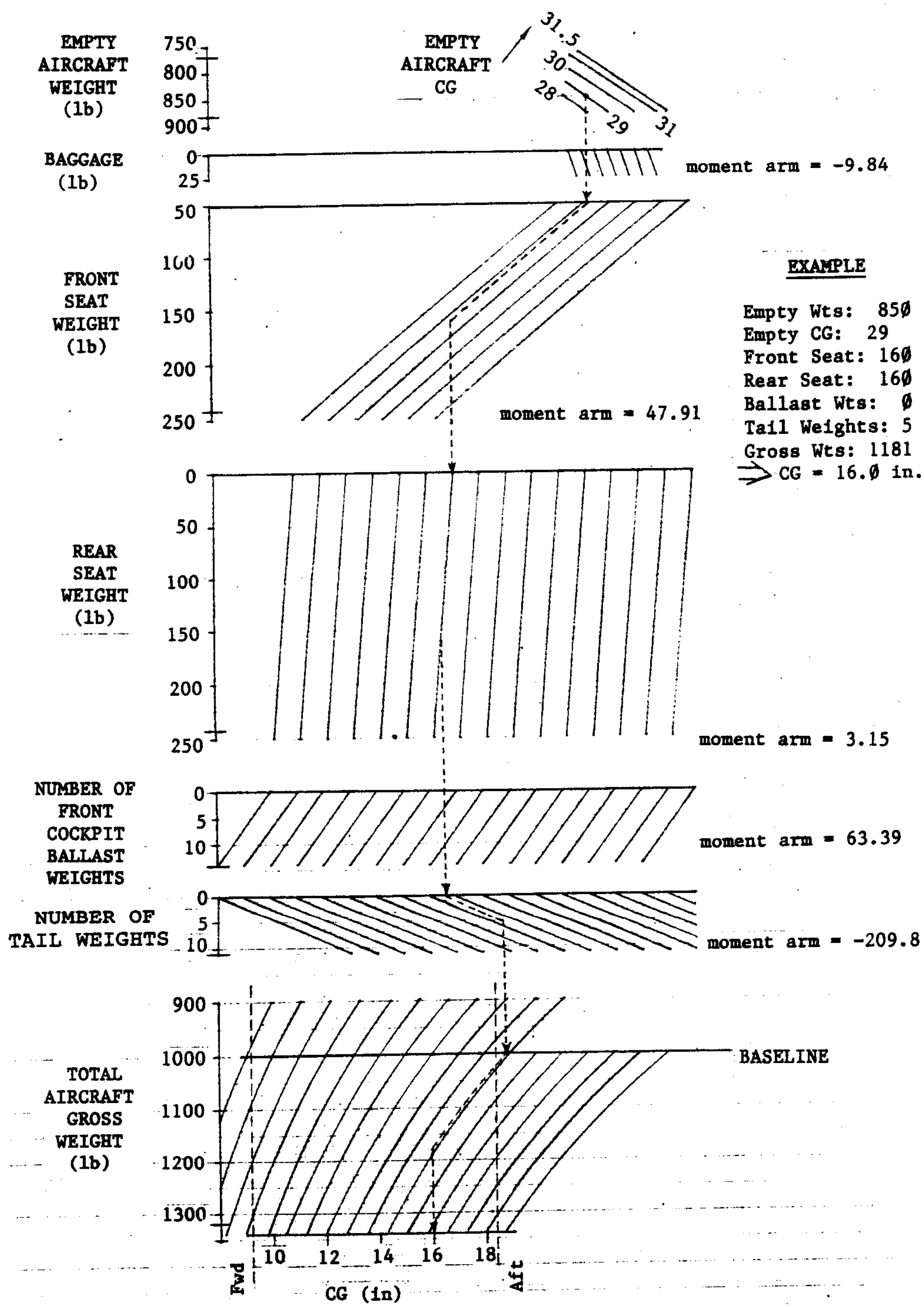

Figure 7 ASK-21 Center of Gravity Chart

required a minimum of 500 feet of altitude. This was still classified as resistant to spin in accordance with MIL-S-83691A. However, since spins were achieved without pilot rudder input, the manufacturer's flight manual should be revised to include the text provided in Appendix G. (R1)

SPIN CHARACTERISTICS

With Phase I testing completed, Phase II spin tests progressed to examining the sustained spin throughout the remainder of the weight and balance envelope. The cg and inertia combinations tested in this phase are shown in Appendix A (Table A1). The aircraft manufacturer's data indicated the aircraft had two upright spin modes, one smooth and the other oscillatory. Copies of the manufacturer's test reports are provided in Appendix I. The reports also indicated the ASK-21 does not have an inverted spin mode.

Spin Modes:

The test team used Table 1 to analyze ASK-21 spin data for defining spin modes. Table 1, obtained from MIL-S-83691A, provided the commonly accepted modifiers for distinguishing one or more spin modes from flight test data. The appropriate modifiers of the ASK-21 upright spin mode were erect, fast, and oscillatory. These modifiers were based on average values of AOA and body axis yaw rate, in accordance with MIL-S-83691A. The oscillation of this spin mode caused variances in pitch attitude ranging from extremely steep to flat. Therefore, a single modifier for attitude did not readily apply to this mode. The average attitude value was classified as steep.

Pilots found that the aircraft had only one upright mode which was oscillatory. However, this mode appeared to be smooth if the spin was only examined for three turns or less. This was because the inertial pitching moment in developed spins varied as a function of cg and ballast loading. This variance changed the period and frequency of the oscillation. Variations from one oscillation per turn to one oscillation every three turns were observed, depending on loading. Despite this variation, the spin always developed an oscillation in pitch attitude, resulting in essentially one upright mode.

The attitude of the ASK-21 erect spin mode did not stabilize because the pitch axis moments never reached equilibrium. Appendix H provides a detailed discussion on the dynamics of the oscillatory mode.

Spin Parameters:

The pitch attitude during ASK-21 upright spins averaged between 40 and 50 degrees nose low. The steep phase of the oscillation was as much as 70 degrees nose low and the flat phase was as high as the horizon (zero degrees). The flat phase never resulted in an unrecoverable situation. Occasionally, the spin attitude was steep enough that the AOA was momentarily less than stall, resulting in recovery as the aircraft pitched down out of the spin.

In general, as the cg was moved aft, the oscillation occurred more frequently, while increases in inertia resulted in a larger amplitude of the oscillation. For example, at the forward cg boundary of the sustained spin envelope (Figure 4), the oscillation was seen once every third turn. At the aft cg limit, it occurred every 3/4 to 1 turn. At low inertia values, the pitch attitude oscillated typically ±15 degrees about 50 degrees nose low. At high inertias, the pitch attitude oscillated ±30 degrees about 40 degrees nose low.

The rotation rate of the spin was as fast as 140 degrees per second, or approximately one turn every 2.5 seconds. This rate occurred at the steep phase of a spin oscillation. During the flat phase, the rotation rate slowed to approximately 80 degrees per second, or one turn every 4.5 seconds. The average rotation rate was greatest at forward cg and at high inertia, where the oscillations occurred least frequently. Toward the aft cg limit, with oscillations to flat attitudes occurring more frequently, the average rotation rate was least. This was a favorable situation because as the cg was more aft (more adverse), the rotation rates were slower (less adverse). The sensitivity of both the pitch attitude and rotation rate to variations of inertia was surprising, since the inertia of the glider could only be varied approximately 18 percent in pitch, 4 percent in yaw, and 1 percent in roll. Pitch inertia was less than one-third that of roll or yaw (see Appendix C).

In all spins, the altitude loss was approximately 200 feet per turn, with a variance of 150 feet minimum to 250 feet maximum. This indicated that in spite of the oscillatory nature of the spin mode, the descent rate remained relatively constant. Altitude loss during recovery was 200 to 300 feet until the rotation stopped. An additional 300 feet was required to achieve straight and level flight from a 4-g dive pullout.

The transition from steep to flat phases of the spin oscillation occurred over approximately 1/2 to 1 turn. During this transition, approximately 30 degrees of

Table 1

SPIN MODE MODIFIERS[1]

Sense	Attitude	Rate	Oscillations[2]
Erect (positive AOA)	Extremely Steep Average AOA between stall and 35 degrees	Slow Up to 60 degrees per second	Smooth
or	Steep Average AOA between 35 degrees and 70 degrees	Fast 60 to 120 degrees per second	Mildly Oscillatory
Inverted (negative AOA)	or	or	Oscillatory
	Flat Average AOA 70 degrees or greater	Extremely Rapid 120 degrees per second or greater	Highly Oscillatory or Violently Oscillatory

Notes: [1]Table was extracted from MIL-S-83691A.
[2]These terms are qualitative only.

sideslip angle developed and the bank angle varied between 5 and 10 degrees from wings level. During the phases when pitch attitude was momentarily constant, bank angle and sideslip both returned to near zero.

Airspeed indications during the spin oscillated along with pitch attitude. In most cases, airspeed oscillated between 30 and 40 KIAS. During larger oscillations with higher sideslip angles present, airspeed erroneously read zero or unwound to less than zero (pointer at 160 KIAS on dial). This was particularly noticeable during spin recoveries (see Control Effect section). Since the manufacturer's flight manual does not document spin characteristics, it should be revised to include the text provided in Appendix G. (R1)

Pilot Comments:

Pilots reported that spins in the ASK-21 were not particularly uncomfortable or disorienting, but that prior knowledge of several unique characteristics was necessary to avoid dangerous situations. The following section outlines these characteristics.

Occasionally, spin attempts resulted in spiral dives. Therefore, pilots had to be alert to the cues distinguishing spins from spirals. The primary cue for making this distinction was airspeed. However, the airspeed indicator at high sideslip angles was often pegged at zero or less when actual speed was 60 KIAS or more. Therefore, cockpit noise was the only reliable cue. Pilots generally agreed that a speed of 60 KIAS resulted in high enough cockpit noise to cue the pilot that the aircraft was not in a spin. If noise continued to increase as the maneuver progressed, the pilot had to recover immediately with opposite rudder pedal and relaxed longitudinal stick pressure to avoid excessive speeds. This was particularly true with tail weights installed since limiting speed in that configuration was 200 kilometers per hour (108 KIAS). Recovery initiated at 60 KIAS with a subsequent 4-g dive pullout was successful in keeping maximum dive speeds below approximately 100 KIAS. Since delayed recoveries and late recognition of spirals are likely in the training environment, the manufacturer's flight manual should be revised to include the text provided in Appendix G. (R1)

Pilots also commented that changes in cockpit noise were noticeable during sustained spin oscillations. During the steep phase of a sustained spin, the airspeed was between 30 and 40 KIAS and the cockpit noise level allowed conversation between front and back seat occupants without difficulty. In a spiral, the noise level began to inhibit voice communications. During the flat phase of the sustained spin, the noise level became noticeably quieter. This was attributed to a change in AOA in the flat phase, when the relative wind was not along the canopy but moving more vertical. One pilot commented that the flat phase sometimes became so slow and quiet that it felt like the aircraft was flying itself out of the spin into a level attitude.

The changes in cockpit noise in combination with the characteristic oscillatory mode of the ASK-21 spin resulted in some disorientation. Test pilots felt that, compared to other spin trainers, the oscillatory pitch attitude superimposed over a sustained yaw rate could confuse pilots who have not had much spin training. Since the rotation rate was also varying, the potential existed to misinterpret the flight situation and make incorrect recovery inputs. During the steep phase, the spin was fast enough that a pilot with minimum experience may become disoriented by the rotation rate. Test pilots felt these characteristics were not dangerous to ASK-21 operators provided they were adequately informed. Therefore, the manufacturer's flight manual should be revised to include the text provided in Appendix G. (R1)

During the spin, the pilot was not subjected to any abnormal or uncomfortable forces as a consequence of the spinning motion. Cockpit g forces remained near 1.0 in the vertical axis and zero in both the lateral and longitudinal axes.

Forces on the controls during spins were light. Aft stick forces were the same during the spin as at stall except during the steep phase when the longitudinal stick force required to maintain full aft stick decreased to zero. This was accompanied by a tendency for the stick to move laterally to the direction of the spin with approximately 5 to 10 pounds of force. Rudder pedal forces for full prospin deflection also decreased to zero in the sustained spin. If the controls were released at the steep phase of a spin oscillation, ailerons and rudder would move fully into the spin and the stick would remain full aft.

CONTROL EFFECTS

The various control inputs tested during sustained spins are listed in Appendix A (Table A5). The Phase III flight test maneuvers isolated the effect of each control surface on the sustained spin. The hands-off tests further provided information about control surface air loads as well as the sustainability of a spin.

Rudder Effects:

After achieving a sustained spin, the rudder was abruptly applied opposite the spin while the longitudinal stick was maintained full aft and lateral stick neutral. When opposite rudder was initiated at a slow point or flat phase of the spin oscillation, the rotation rate stopped within 1/4 to 1/2 turn and the aircraft recovered. In most cases, even at a high rotation rate, opposite rudder recovered within 1/2 to 3/4 of a turn from the point of input. However, with cg's of 14 to 16 inches and high inertias, recovery required up to 1 1/2 additional turns when opposite rudder was applied while the rotation rate was accelerating. Since this was 1/2 turn greater than the one turn maximum required by Joint Aviation Regulations (JARs) Part 22 certification, the test team further investigated these delayed recoveries using the manufacturer's flight manual spin recovery procedure. The manufacturer's flight manual procedure is provided in the Flight Manual Excerpts section of Appendix B.

The difference between the opposite rudder isolated input test and the manufacturer's flight manual spin recovery procedure was that the pilot eased the stick forward shortly after applying rudder for the manufacturer's flight manual procedure. On several occasions, the same tendency for the delay in recovery seen in the rudder effects tests was noted using the manufacturer's flight manual procedure. For example, on flight 15, with the cg at 14.03 inches and the fuselage inertia at 9.048 x 10^6 lb-in^2 (high inertia), 1 1/3 turns occurred after initiating recovery until rotation stopped. Delayed recoveries only occurred if recovery was initiated when the spin rate was greatest (nose low oscillation). The delayed recovery never exceeded 1 1/2 turns and in most cases, when the manufacturer's flight manual procedure was used, recovery was achieved in less than one additional turn from point of initiation.

A recovery of 1 1/2 turns required up to five seconds which may seem excessively long to an inexperienced pilot. The manufacturer's flight manual procedure had a 100 percent success rate if given sufficient time. It should be noted that the standard for U.S. manufactured aircraft is Federal Aviation Regulation (FAR) Part 23, which states a 1 1/2 turn maximum. Since the occasional delayed recovery slightly exceeded the one turn requirement of JAR Part 22, the manufacturer's flight manual should be revised to include the text provided in Appendix G. (R1)

Aileron Effects:

The aileron effects on the spin characteristics of an aircraft are generally well documented in spin theory literature, and the ASK-21 test results were typical of a wing loaded aircraft design. A detailed discussion of aileron effects on spin characteristics is contained in Appendix H.

For the ASK-21 spin tests, lateral stick against the spin achieved a noticeable bank angle away from the spin as well as a nose down pitch rate. Most of these spins resulted in recovery as the yaw rate decreased, roll rate increased, and the nose pitched down leaving the aircraft in a steep sideslip to terminate the spin. In a few cases, the aircraft remained in a spin with the bank angle away from the spin direction. Therefore, lateral stick against the spin was not a reliable contributor to spin recovery.

Lateral stick with the spin increased rotation rate, but this effect was masked by the oscillatory characteristics of the spin. In the majority of tests flown, lateral stick into the spin achieved a slightly higher rotation rate and a more sustainable spin. The results of testing isolated lateral stick inputs indicated that neutral lateral stick was the best position for recovery.

Elevator Effects:

Isolated longitudinal stick inputs were made during sustained spins with lateral stick neutral and full rudder pedal in the prospin direction. These tests were used to determine the ability of the elevator to break the stall during the spin. Inputs up to full forward stick were made at various points in the oscillation cycle of the spin.

The most significant finding of the elevator effects tests was a continued spin at full forward stick. During the incipient phase of the spin or at the start of a nose up oscillation, full forward stick produced up to three more turns before recovery. These tests proved the degree to which recovery can be delayed if only forward stick without rudder was used. The manufacturer's flight manual emphasizes the need for opposite rudder to recover from stalls if a wing drop occurs. Since spin recovery may be delayed up to three additional turns if forward stick is applied without first applying opposite rudder, the manufacturer's flight manual should be revised to include the text provided in Appendix G. (R1)

The second effect found in testing isolated longitudinal stick inputs was that full elevator effectiveness returned immediately when recovery occurred. This caused an excessive unload and a potential for exceeding limit speeds during dive recovery. The test team determined that spoilers were extremely effective in preventing excessive speeds in the ensuing dive. Since the manufacturer's flight manual does not suggest the use of spoilers to control speed in dive recoveries, it should be revised to include the text provided in Appendix G. (R1)

Hands Off:

At various points during the oscillation of a sustained spin, the pilot completely released the controls and removed his feet from the rudder pedals. This test was accomplished in all configurations that experienced sustained spins.

In the majority of these tests, the aircraft self-recovered. The stick moved laterally in the direction of the spin when the controls were released. The stick usually reached full lateral deflection and then started forward toward neutral longitudinal deflection. The aircraft pitch attitude steepened followed by the rudders returning to neutral. At this point, the aircraft self-recovered in a steep attitude and unloaded to approximately zero g unless the pilot grasped the stick and applied controls for dive pullout. When this test was initiated during the flat phase of a spin (slowest rotation rate), the stick started forward with little lateral movement but the aircraft still self-recovered.

Under certain circumstances, the aircraft did not self-recover when controls were released. If the controls were released just after the pitch attitude had cycled nose low and the rotation rate was high, the stick moved abruptly into the spin and remained at the full aft and full lateral position. The rudder also remained at full prospin deflection and the spin continued indefinitely until the pilot forced the controls to the recovery position. Of particular interest was the cg range where this was most prevalent. Aft of 16 inches cg, the aircraft always recovered hands off. However, between 14 and 16 inches cg with higher inertias, this characteristic was easily repeatable. This was attributed to the high average rotation rates in these configurations. These rates, accompanied by high inertia, resulted in greater momentum and a corresponding higher airload and hinge moment on the elevator, ailerons, and rudder. This caused them to lock out at a full prospin setting.

This tendency was not objectionable since control forces for recovery from a hands-off sustained spin were low. However, since this tendency occurred in the cg range where most spin training would be conducted, the manufacturer's flight manual should be revised to include the text provided in Appendix G. (R1)

INVERTED SPINS

The main purpose of Phase IV testing was to verify if an inverted spin mode existed. This verification was important to operators at USAFA since their aerobatic training in the ASK-21 involved extended inverted flight maneuvering. Manufacturer test data (see Appendix I) indicated inverted spins were impossible.

For these tests, manufacturer's flight manual instructions required the pitot probe extension be installed and no tail ballast be used. Without tail ballast and with the lightest weight test pilot, the most aft cg achieved was 15.84 inches. However, since other ASK-21 gliders have a more aft empty cg and other pilots are lighter in weight, aerobatics could be flown in the ASK-21 with more aft cg's. Therefore, the aircraft was configured with special ballast in the front seat and flown solo from the rear seat. There were four flights flown with this front seat ballast. A fifth flight was flown solo from the front seat. These combinations produced cg's between 15.84 inches and the aft limit of 18.46 inches (see Table A1). Inverted spins were achieved at each of these cg's.

Susceptibility:

For the most forward cg tested at 15.84 inches, an inverted spin could only be achieved if lateral stick was maintained opposite the yaw (cross controls). In reference to the equations of motion in Appendix H, lateral stick against the spin was a prospin input for inverted spins. Aft of 17 inches cg, sustained inverted spins were possible without maintaining lateral stick against the spin. This indicated that inverted spins were less likely to occur at cg's forward of 15.8 inches since control positions were more critical. Overall, the ASK-21 was extremely resistant to inverted spins since only Phase D inverted stalls resulted in inverted spins, regardless of cg. Although results indicated increased resistance forward of 15.8 inches, this does not imply inverted spins at more forward cg's are impossible.

Characteristics:

Inverted spin entry was not achieved forward of 17 inches cg from static maneuvers such as straight ahead, inverted, and wings level stalls. The dynamic entry maneuver in Appendix A (Table A6) was designed to simulate a student's overcontrolled inputs when attempting a slow roll aerobatic maneuver.The aircraft was pulled to a 20-degree nose high attitude from a 90 KIAS cruise condition (shallow dive). A roll was then initiated with full lateral stick and rudder pedal. When passing through 90 degrees of bank, forward stick pressure was applied to keep the attitude above the horizon. This produced negative g, requiring opposite rudder pedal for coordination. These inputs were intentionally exaggerated to full forward stick, full lateral stick, and full opposite rudder pedal, which produced significant yaw rate at the 180-degree bank angle point in the roll. This also produced some roll coupling which assisted spin entry. Full cross-control inputs were held until spin entry was achieved.

The ensuing departure and spin entry was similar to the upright spin. The nose fell to approximately 60 degrees nose low and then hesitated. Cockpit g forces built up to -2 g and then the nose oscillated up to 40 degrees nose low. The spin was developed after approximately 180 degrees of rotation and was oscillatory. Altitude loss was 200 to 300 feet per turn and the rotation rate was one turn every 3 to 3 1/2 seconds. At the cg's tested, the inverted spin oscillations occurred every 3/4 to 1 turn. Once the spin developed, g forces oscillated between -1 and -1.5 g, although as much as -2.3 g was observed during the departure for one spin entry before that spin developed. Airspeed oscillated near 40 KIAS and remained stalled throughout. Cockpit g forces were uncomfortable but other spin characteristics were comparable to the upright case.

Inverted spin recovery was immediate (1/4 to 1/2 turn) when controls were neutralized. Altitude loss from initiating recovery to level flight was 400 to 500 feet. Since the spin included a component of roll rate as well as yaw rate, the aircraft rolled to an upright attitude, without further pilot input. This resulted in a more pleasant recovery than was expected. Pilots felt that high-speed dives would be a problem if a roll to upright were required since this would force a delay in initiating dive recovery. Since the roll to upright occurred as a natural response to neutralizing controls in the inverted spin, high speeds during dive recovery were not encountered. Airspeeds were typically between 90 and 100 KIAS during inverted spin recoveries. Because these spins have not been previously documented and occurred in a typical training scenario, the manufacturer's flight manual should be revised to include the text provided in Appendix G. (R1)

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CONCLUSIONS AND RECOMMENDATION

The stall and spin characteristics of the ASK-21 were satisfactory and similar to those of other high performance sailplanes. The test team considered the aircraft to be an excellent spin trainer because cg could be accurately controlled using tail weights. This ensured that pilots of all weights could achieve the same spin results. Intentional stall and spin execution and recovery were safe and repeatable across the entire envelope of weight and cg.

The following eight major findings resulted from this test:

1. Stall warning indication was marginal, with only very light buffet, decreased cockpit noise, and very mild g-break at the stall.

2. The glider would spin at cg's forward of the manufacturer's flight manual reference value for spin entry.

3. The spin mode was oscillatory and, although it appeared flat at certain points in the oscillation, was easily recoverable. Spinning motions could be disorienting due to their oscillatory nature. Some spins terminated in spirals, requiring pilot attention to avoid excessive speeds during dive recoveries.

4. If forward stick was used without rudder to recover the aircraft from an out-of-control situation, recovery was sometimes significantly delayed.

5. The manufacturer's flight manual spin recovery procedure required up to 1 1/2 turns before rotation stopped. Using the manufacturer's flight manual procedure, the aircraft always recovered.

6. Spin entries occasionally occurred without rudder input if proper turn coordination was not exercised at speeds near stall.

7. Some spins continued indefinitely if controls were released during the developed spin.

8. Inverted spins were possible and occurred during inverted aerobatic maneuvers if cross-controlled inputs were maintained sufficiently long.

The current ASK-21 manufacturer's flight manual does not accurately document spin susceptibility. Additionally, the manual does not adequately document the stall and spin characteristics. With appropriate flight manual revisions that reflect the major findings of this test, the ASK-21 glider would be suitable for spin training.

1. The manufacturer's flight manual should be revised to include the text provided in Appendix G (pages 9, 11, 16, 18, 19, 20, and 21).

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2. Flying Qualities of Piloted Vehicles, Military Standard MIL-STD-1797, 31 March 1987.

3. Stall/Post-Stall/Spin Flight Test Demonstration Requirements for Airplanes, Military Standard MIL-S-83691A, 15 April 1972.

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APPENDIX A

TEST MANEUVERS

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TEST MANEUVERS

The stall, spin entry, and developed spin characteristics of the ASK-21 were evaluated for various cg's, moments of inertia, pitch attitudes, bank angles, sideslip angles, aileron positions, rudder positions, and spoiler positions. Testing began with both project pilots and no ballast weights, which yielded a cg of 12.4 inches. The ASK-21 manufacturer's flight manual stated that the glider would not enter a spin at cg's forward of 15.7 inches. However, spins have previously been documented at 15.2 inches cg (Reference 4). Table A1 shows test points that moved the cg to the aft limit. For most cg's, the minimum and maximum pitching moment of inertia was tested as shown in Table A1. For a given cg, the lightest pilot weights and fewest tail weights possible yield the minimum pitching moment of inertia. Likewise, the heaviest pilot weights and most tail weights possible yield the maximum pitching moment of inertia.

The departure and spin susceptibility of the glider was determined in Phase I. Phase A, B, C, and D stalls were flown as shown in Figure A1. The entry conditions for these stalls are in Table A2 and the pilot inputs are in Table A3. Table A4, which was adapted from MIL-S-83691A, contains the flight test demonstration maneuvers which define Phase A, B, C, and D stalls. The entry conditions in Table A4 were used to develop Table A2 for this test. Figure A1 shows that the cg was moved forward or aft to determine the most forward cg where the glider entered a spin (12.5 inches), and the most forward cg where it sustained a spin (13.5 inches). When both cg's were determined, Phase II began at 13.5 inches cg.

Phase II determined the spin modes and associated characteristics. The manufacturer has documented two known spin modes in the ASK-21 (see Appendix I). One has a smooth yaw rate with a stabilized pitch attitude of 45 to 60 degrees nose low. The other has an oscillatory yaw rate with the pitch attitude oscillating between 0 and 60 degrees nose low. Figure A2 shows that initially, Phase D stalls were flown for each entry from Table A2 and each input from Table A3. When the test team determined that the ASK-21 had only one spin mode, Phase D stalls at the remaining cg's in Table A1, were flown using only the entries and inputs which gave repeatable spins. Phase II proceeded to the manufacturer's flight manual aft cg limit of 18.46 inches per Table A1.

Phase III determined what impact control inputs (effectors), which differ from manufacturer's flight manual spin recovery procedures, had during fully developed spins. Table A5 shows the various effectors that were evaluated during fully developed spins. All spin recoveries were manufacturer's flight manual procedure and were initiated at or above 3,500 feet AGL.

Phase IV evaluated inverted spin modes and consisted of five flights at the end of the program. This was necessary since USAFA uses its ASK-21 fleet for aerobatic training. Manufacturer tests indicated the glider would not spin inverted (see Appendix I). No aerobatic maneuvers were accomplished with tail weights on the glider. Table A6 shows the entry conditions and pilot inputs that were used. These were accomplished from 15.84 inches cg to the aft cg limit of 18.46 inches. To reach 15.84 inches cg, the glider was flown solo from the front seat with no ballast weights. To reach the aft cg limit without tail weights, the glider was flown solo from the back seat with 65 pounds of parachutes and ballast strapped in the front seat (see Table A1).

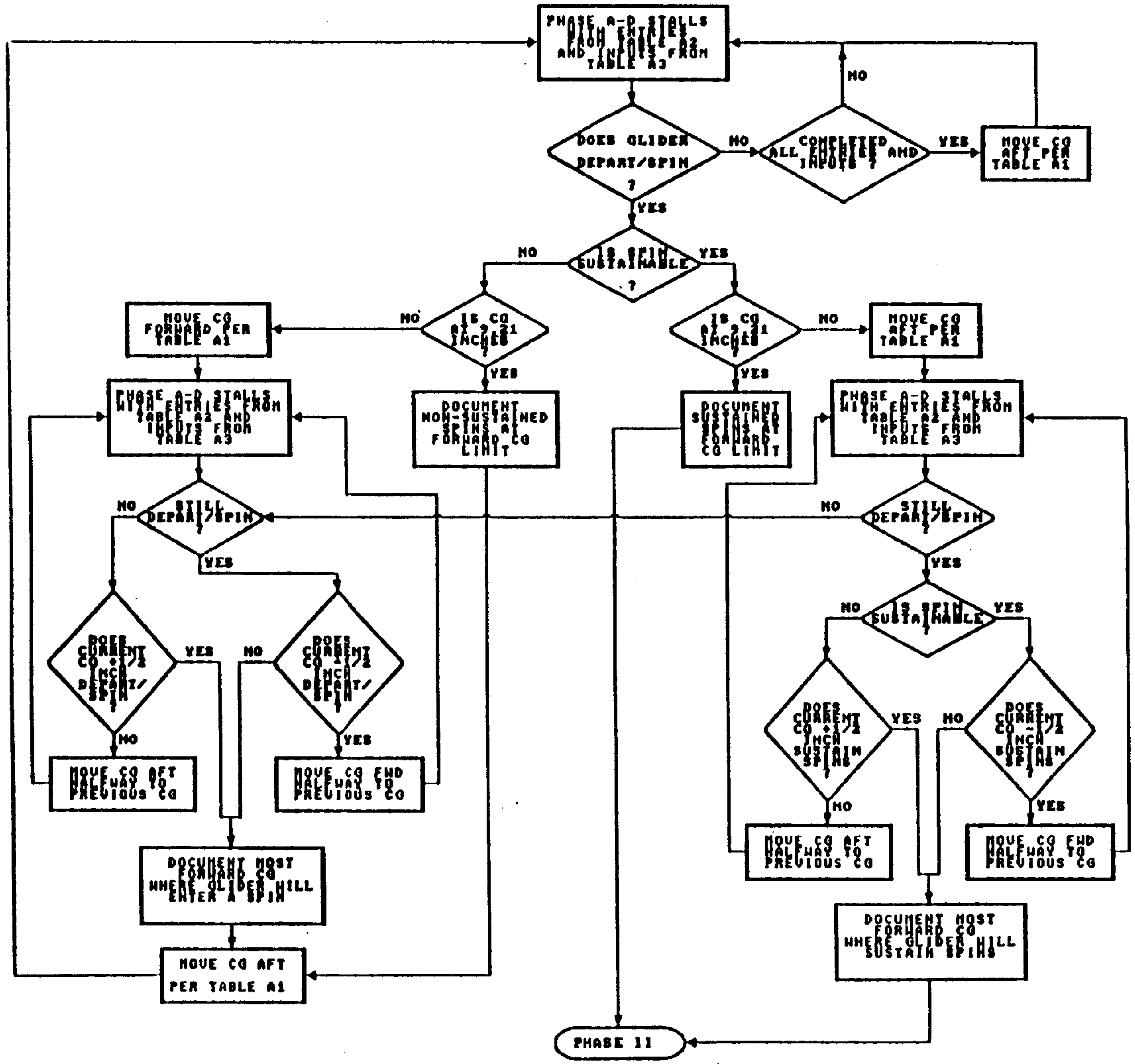

Figure A1 Phase I Departure and Susceptibility Decision Tree

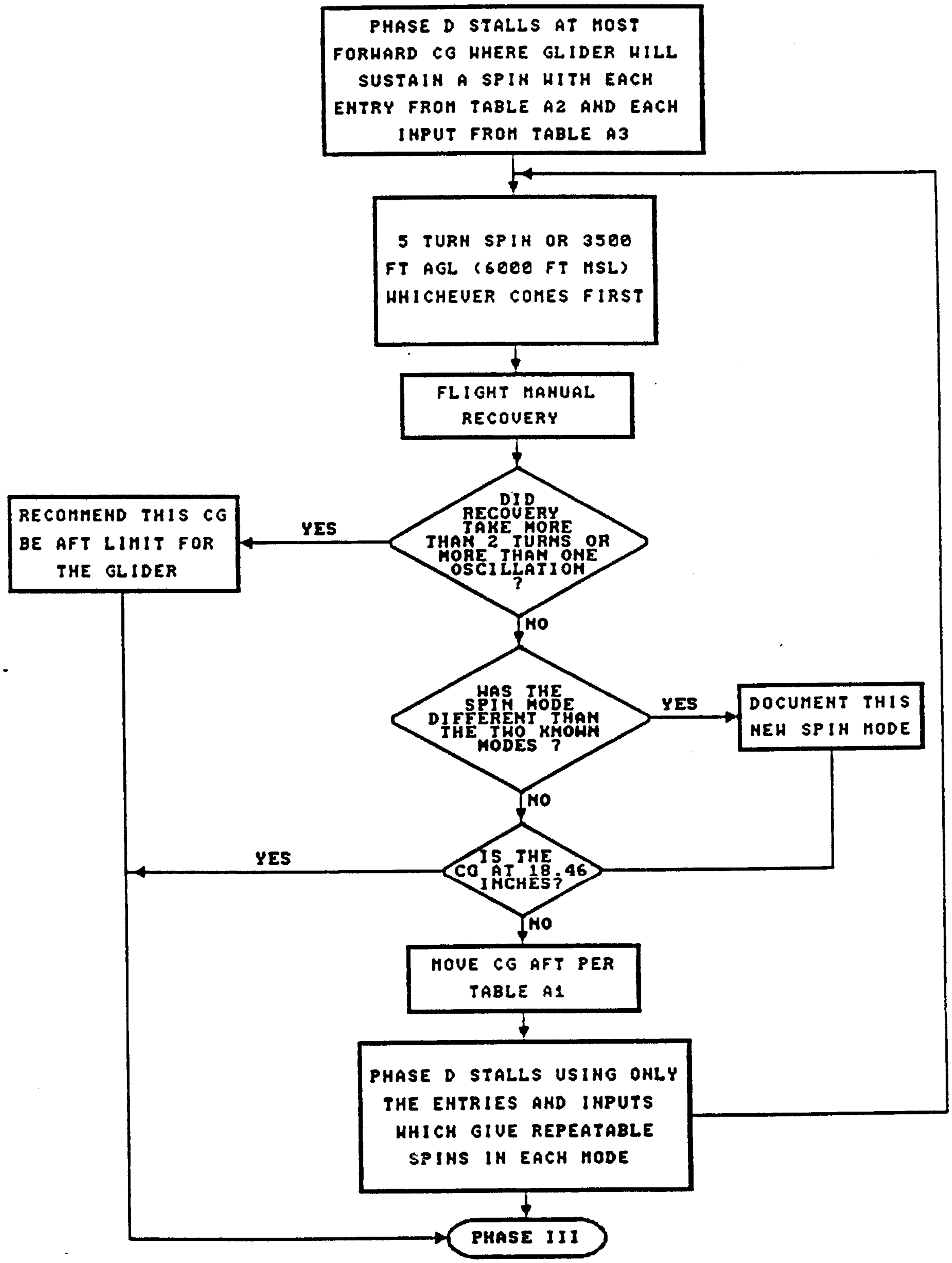

Figure A2 Phase II Spin Mode Characteristics Decision Tree

Table A1

TEST LOADINGS

cg (inches aft of datum)	Front Cockpit Weight (lb)	Rear Cockpit Weight (lb)	Number of Tail Weights (2.20 lb each)	Number of Cockpit Weights (2.20 lb each)	Gross Weight (lb)	I_{yy} (lb-in2 x 106)
12.36	176	230	0	0	1257	8.021
12.47	230	176	8	6	1288	8.980
12.94	230	176	9	5	1288	9.046
13.11	176	230	2	0	1262	8.197
13.46	176	230	3	0	1264	8.277
13.49	176	217	3	1	1253	8.280
13.53	230	176	10	3	1286	9.097
13.87	230	176	11	3	1288	9.176
13.96	176	230	10	14	1310	9.045
14.01	176	0	0	11	1051	7.986
14.03	217	176	10	4	1275	9.048
14.20	230	176	12	3	1290	9.256
14.34	176	230	6	1	1273	8.530
14.49	217	230	12	0	1325	9.194
14.71	176	122	5	7	1176	8.444
14.99	139	176	0	0	1166	7.791
15.00	176	0	0	5	1038	7.891
15.50	176	0	0	2	1031	7.843
15.84	176	0	0	0	1027	7.811
15.92	122	176	0	0	1149	7.702
16.16[1]	65	230	0	14	1177	7.664
16.27	176	217	12	3	1277	9.019
16.74	176	0	2	0	1032	7.978
16.78	230	0	12	4	1117	9.101
17.09[1]	65	176	0	14	1123	7.608
17.42	230	0	12	0	1108	9.035
17.56	176	0	4	0	1036	8.129
17.84[1]	65	230	0	3	1153	7.484
18.37	176	0	6	0	1041	8.279
18.38[1]	65	176	0	6	1105	7.474
18.49	176	0	11	11	1076	8.843
19.00[2]	176	0	8	1	1047	8.446

Notes:

- Maximum weight in either cockpit (including ballast) = 242 pounds (Flight Manual weight limit)
- Basic aircraft weight (including radio, video camera, C-band beacon, and batteries) = 851 pounds
- Basic aircraft I_{yy} = 6,721,000 lb-in^2 (estimated)
- Maximum gross weight = 1,320 pounds
- Parachute = 18 pounds

[1]Phase IV configurations (front seat arm = -46.10 inches)

[2]This cg was beyond the aft limit of 18.46 inches due to a weighing error of the tail weights

Table A2

STALL AND SPIN ENTRY CONDITIONS

Entry Number	Pitch Angle (deg)	Roll Angle (deg)	Sideslip Angle (deg)	Normal Load Factor (g's)	Spoiler Position
1	0	0	0	1	Closed
2	0	0	0	1	Open
3	0	45	0	1.4	Closed
4	0	45	0	1.4	Open
5	0	As Required[1]	Maximum Rudder	1	Closed
6	0	As Required[1]	Maximum Rudder	1	Open
7	30	45	0	2	Closed
8	30	45	0	2	Open
9	5[2]	60	0	2	Closed

Notes: • All entry conditions were evaluated to establish the most forward cg where the ASK-21 would enter a spin, and, the most forward cg where the ASK-21 would sustain a spin. For cg's more aft, only selected entries were used.

[1]Lateral stick, as required, for steady-heading sideslip.

[2]A maximum command coordinated bank-to-bank roll (60-degree bank angle) was initiated. At the opposite bank angle, full aft stick and full lateral stick and rudder pedal were input.

Table A3

PILOT INPUTS AT IMMINENT STALL

1. Aft stick.

2. Aft stick + rudder pedal.

3. Aft stick + lateral stick with the spin.

4. Aft stick + lateral stick against the spin.

5. Aft stick + rudder pedal + lateral stick with the spin.

6. Aft stick + rudder pedal + lateral stick against the spin.

Notes:
- Lateral stick was used to sustain a spin if an incipient spin developed.
- All pilot inputs were used to establish the most forward cg where the ASK-21 would enter a spin, and, the most forward cg where the ASK-21 would sustain a spin. For cg's more aft, only selected inputs were used.

Table A4

FLIGHT TEST DEMONSTRATION MANEUVERS
(Adapted from MIL-S-83691A)

Test Phase	Maneuver Requirements					
	Control Application	Entry Number from Table A2[1]				
		Smooth AOA Rate[3]		Arupt AOA Rate[4]		
		One g	Accelerated[2]	One g	Accelerated[2]	Tactical[5]
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 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.	1, 5	3, 7	2, 6	4, 8	9
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,[6] intentionally or in response to unscheduled airplane motions, before recovery attempt is initiated.	1, 5	3, 7	2, 6	4, 8	9

Table A4

FLIGHT TEST DEMONSTRATION MANEUVERS (Continued)
(Adapted from MIL-S-83691A)

Test Phase	Maneuver Requirements					
	Control Application	Entry Number from Table A2[1]				
		Smooth AOA Rate[3]		Arupt AOA Rate[4]		
		One g	Accelerated[2]	One g	Accelerated[2]	Tactical[5]
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,[6,8] intentionally or in response to unscheduled airplane motions, and held for 3 seconds[7,8] before recovery attempt is initiated.	1, 5	3, 7	2, 6	4, 8	9
D Poststall Gyration, Spin, and Deep Stall Attempts[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 applied in the most critical[11] manner to attain each possible mode of poststall 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]	1, 5	3, 7	2, 6	4, 8	9

Notes:

[1]The airplane was trimmed at settings consistent with the maneuver task. The effects of each designated flight test variable was determined individually in each required test phase or until such effects were definitely established and predictable for succeeding test phases. Variables were 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 airspeeds, dynamic pressure, and allowable load factor, included windup turns, constant-altitude turns, and wings-level pullouts from dives appropriate to the ASK-21 glider.

[3]Smooth, 1-g entries were approached using a slow control rate which produced a speed deceleration of approximately 1 knot per second for normal stalls (+1 g). Smooth, accelerated entries were approached using a control rate, which achieved an AOA rate of approximately 1/2 degree per second.

[4]In the required abrupt entries, the entry AOA rate was at least 4 degrees per second except when limited by maximum available control deflection and rate. The magnitudes of the abrupt entry rates were graduated in Test Phases A through C, commensurate with the increasing severity of the control requirements, but the stated minimum AOA rates were achieved in Test Phase C.

[5]These entries were initiated from maneuvers associated with the capability and class of the ASK-21. The maneuvers were conducted with a suitable AOA rate and included:

(a) inverted stalls and aborted vertical reversements,loops, or immelmanns 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); and

(d) head-out-of-cockpit maneuvering.

[6]Misapplied controls consisted of moving controls in the most critical directions an amount significantly greater than that expected during operational use. This generally required full deflection.

[7]This time requirement was increased when there was no clear indication to the pilot of impending loss of control.

[8]The test pilot ensured that routine familiarity with stalls, poststall gyrations, and spins did not negate the intent of the delay/misapplication simulation and did not result in premature application of spin recovery controls before a developed spin had been attained.

[9]Recovery was also demonstrated from a fully developed spin if such a spin was attainable within a limited number of turns after spin entry.

[10]In addition to the demonstration of a satisfactory spin recovery procedure, the effect of delayed application of the out-of-control recovery procedures was investigated briefly during the final phase of testing. The effects of premature application of the spin recovery procedures under consideration, if different from the out-of-control recovery procedure, were also determined.

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

Table A5

PHASE III EFFECTORS

1. Hands off.

2. Opposite rudder pedal.

3. Lateral stick with the spin.

4. Lateral stick against the spin.

5. Longitudinal stick full forward.

Notes:
- Only the entries from Table 2 and inputs from Table 3, which gave repeatable spins, were used.
- Flight manual recovery was accomplished after five turns or at 3,500 feet AGL (6,000 feet msl), whichever came first.
- Dive recovery was initiated when any effector produced a spiral dive.

Table A6

PHASE IV INVERTED SPIN MODE EVALUATION STALL AND SPIN ENTRY CONDITIONS

Pitch Angle (deg)	Roll Angle (deg)	Sideslip Angle (deg)	Normal Load Factor (g's)	Spoiler Position	Entry Airspeed
5	180[1]	0	-1	Closed	1.05 Vs (52 knots)
10	90[2]	0	-1.5	Closed	1.4 V_S (70 knots)

Notes:
- These maneuvers were flown with the pitot tube extension installed.

[1]At stall, full forward stick and full rudder pedal was input.

[2]A maximum command coordinated roll was initiated. At 90 degrees of bank, full forward stick and opposite rudder pedal was input.

APPENDIX B

TEST ITEM DESCRIPTION

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TEST ITEM DESCRIPTION

AIRCRAFT

The test aircraft was an Alexander Schleicher-manufactured ASK-21 glider, S/N 21235 and Registration Number N974AF. It was owned by USAFA, 94th Airmanship Training Squadron. The aircraft was designed to meet the needs of modern sailplane training. It had an all fiberglass-foam, sandwich structure. This aircraft was a high performance sailplane with a mid-mounted wing, T-tail, tandem seating, conventional reversible flight controls and airbrakes. The glider was fully aerobatic with inverted flight capability. It was maintained and registered under FAA procedures since USAFA maintenance was a contract arrangement with FAA-certified airframe and powerplant mechanics.

The ASK-21 was certified for use in the United States under JAR Part 22 (see Appendix F). The FAA Type Certificate Data Sheet covering the ASK-21 was G47EU 1.10.83.

The ASK-21 was not prone to spin when the cg was in the forward part of its allowable range. This would occur with two average size adults in the cockpit. For spin training under these circumstances, the aircraft was designed to permit the attachment of ballast in the tail, near the bottom of the vertical stabilizer. These weights were used to shift the cg aft to an appropriate point within the allowable range where the glider would spin. The aircraft also had provisions for cockpit ballast to control cg location for solo flight by lightweight pilots.

MODIFICATIONS

In order to document test results, the test aircraft had a video camera mounted in the cockpit to record cockpit instruments, intercom and radio transmissions, and the front cockpit view of test maneuvers. A C-band beacon was also mounted in the test aircraft to enhance tracking by ground cameras used to document test results. Figures B1 and B2 show the cockpit video camera and C-band beacon installations, respectively. Figure B3 illustrates the cockpit of the ASK-21 glider.

Modifications to the glider were accomplished under FAA procedures (similar to the USAF Class II modification process). To accomplish this, the current airworthiness certificate was supplemented by an experimental certificate, for this test only, in the research and development category. FAA inspectors from the local Flight Standards District Office/Maintenance Inspection District Office in Van Nuys, California, issued this certificate.

FLIGHT MANUAL EXCERPTS

The following excerpts cover the total current discussion on low-speed flight, wing dropping, stalls, and spins documented in the ASK-21 flight manual.

II.7 IN-FLIGHT CENTER OF GRAVITY RANGE

The approved in-flight cg range is from 9,21 (234 mm) - 18,46 inches (469 mm) behind the datum line; equivalent to 20 percent - 41,1 percent of the MAC = 44,13 inches (1121 mm). With a 0,31 inches (8 mm) behind leading edge center part of the wing.

II.8 WEIGHT AND BALANCE INFORMATION

Maximum payload front seat (pilot including parachute):

242 lbs = 110 daN

Minimum payload front seat (pilot including parachute):

154 lbs = 70 daN

Caution: Short weight in the front seat must be compensated by ballast (installation of lead discs in the nose; 1 lead disc = 2,76 pounds pilot weight).

Number of lead discs	Min. payload front seat daN = kg	lbs
0	70,0	154,32
1	68,75	151,57
2	67,5	148,81
3	66,25	146,06
4	65,0	143,30
5	63,75	140,54

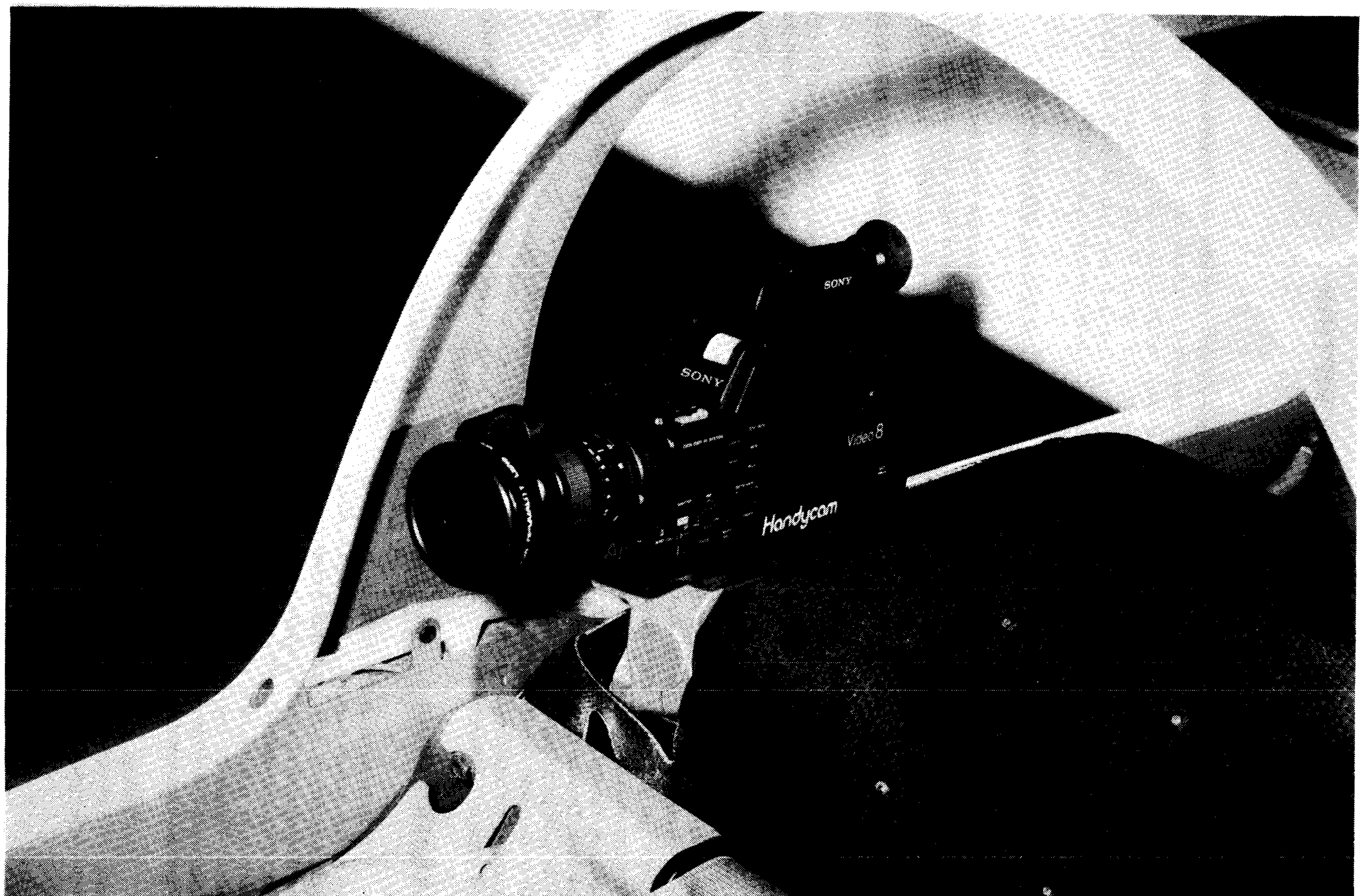

Figure B1 Cockpit Video Camera Installation

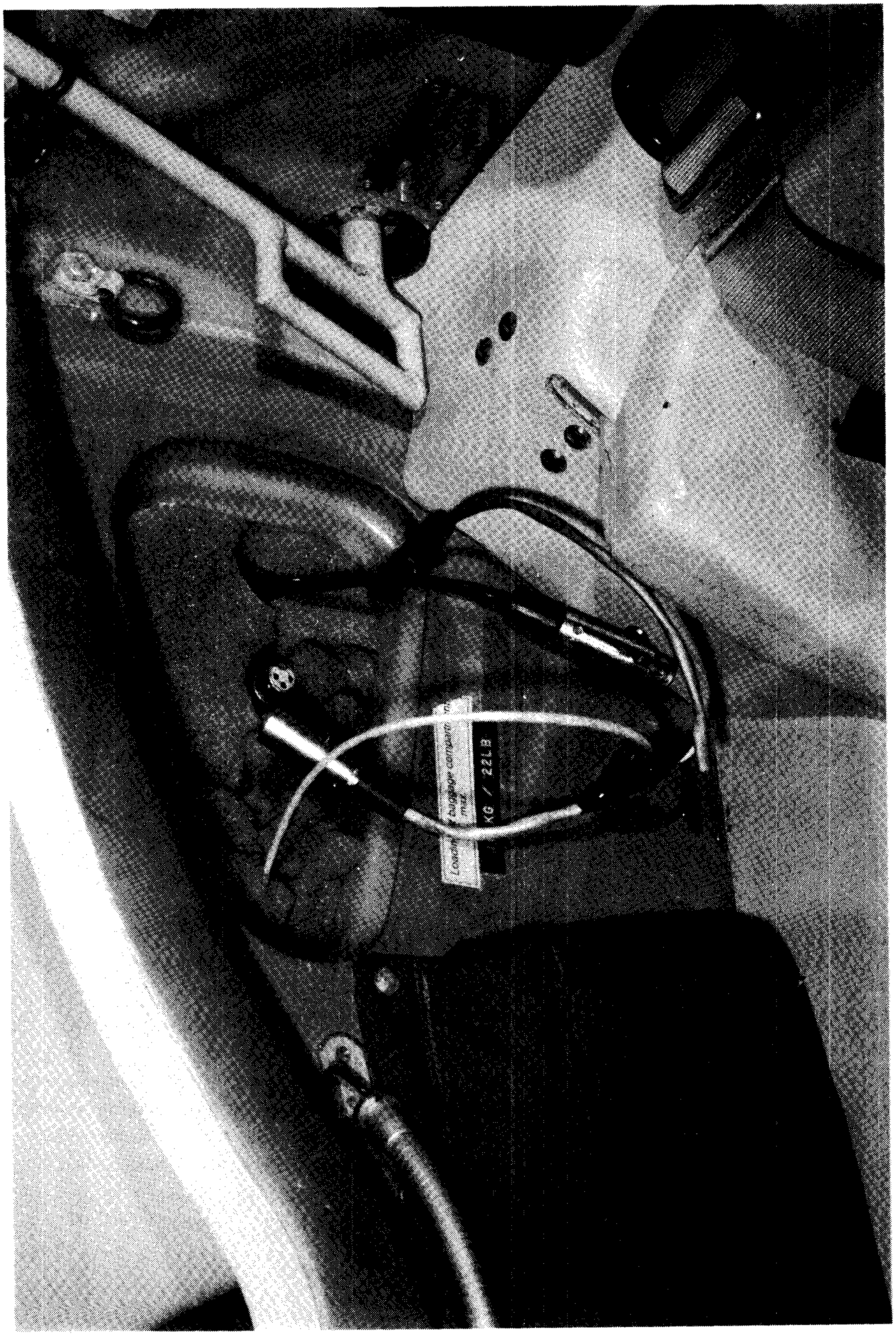

Figure B2 C-Band Beacon Installation

Figure B3 ASK-21 Glider Cockpit

Number of lead discs	Min. payload front seat daN = kg	lbs
6	62,5	137,79
7	61,25	135,03
8	60,0	132,28
9	58,75	129,52
10	57,5	126,77
11	56,25	124,01
12	55,0	121,25

Maximum payload rear seat (pilot including parachute):

242 lbs = 110 daN

1 kg = 2,2046223 lbs

III. EMERGENCY PROCEDURES

III.1 RECOVERY FROM SPIN

According to the standard procedure, spinning is terminated as follows:

a. Apply opposite rudder; i.e., apply rudder against the direction of rotation of the spin.

b. Short pause.

c. Release stick; i.e., give in to the pressure of the stick, until the rotation stops and sound airflow is established again.

d. Centralize rudder and allow glider to dive out.

The altitude loss, from the beginning of the recovery until normal flight attitude is established, is about 260 ft = 80 m.

III.4 WING DROPPING

The glider is extremely harmless. Nevertheless, one always has to face the possibility of wing dropping because of turbulence. In that case, push stick forward immediately and apply opposite rudder until normal flight attitude is regained.

IV.6 LOW-SPEED FLIGHT AND WING DROPPING

With the stick back a distinct tail buffet is felt. The glider is very harmless in low-speed flight. By use of normal aileron deflections, the wing may be kept level up to minimum speed, even with aft cg positions.

With normal rudder deflections no wing dropping is found. Yaw angles of up to 5 degrees have no significant influence on the wing dropping attitude.

Also, rapid pulling up into 30 degrees pitch does not cause wing dropping, but only a gentle nose drop. The same applies for stalling out of a 45-degree turn.

But one has to point out that even the most harmless glider needs speed in order to be controllable. In turbulence this is especially important.

The speed at which the stall takes place depends on the payload; the following standard values are applicable:

Single

All up weight 1034 lbs = 470 daN

without airbrakes 35 KIAS = 40 mph = 65 km/h

with airbrakes 37 KIAS = 42 mph = 68 km/h

Dual

All up weight 1320 lbs = 600 daN

without airbrakes 40 KIAS = 46 mph = 74 km/h

with airbrakes 42 KIAS = 48 mph = 77 km/h

ASK21 Technical Note #4 (14 Nov 1980): Trim Ballast for Spin Instruction

The glider can be made to enter a spin only with in-flight cg of r=400 mm and more. Particularly when flown by two occupants, some ballast is necessary in the tail.

Spin Instruction:

The glider can be made to enter a spin with in-flight cg positions of 400 mm and more. With cg positions before this point, which is usually the case when flown by two occupants, some ballast must be carried in the tail for spinning. On accomplishment of the ASK-21 Technical Note #4, ballast up to 12 kilograms can be carried at the bottom of the fin. This is sufficient for occupant weights of about twice 95 kilograms (209 lbs).

With spin ballast installed, aerobatics are not allowed and the maximum speed Vne is restricted to 200 kilometers per hour.

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APPENDIX C

WEIGHT AND BALANCE AND MOMENTS OF INERTIA

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WEIGHT AND BALANCE AND MOMENTS OF INERTIA

Following delivery of the ASK-21 and prior to flight test, the aircraft was weighed in the AFFTC weight and balance hangar. The baseline mass properties were then used to calculate the necessary aircrew, tail ballast, and cockpit ballast combinations for the desired cg's and moments of inertia.

The empty weight cg of the ASK-21 was determined by placing the glider on two pair of scales; one at the nose and one at the tail skid. The Datum Line (DL) is situated at the leading edge of the straight center part of the wing (Figure C1). The glider was leveled by placing a 52/1000 slope wedge on the rear top edge of the fuselage. Figure C1 shows the formula for calculating empty weight cg. For the test aircraft, the empty weight was 851 pounds and the empty weight cg was 29.02 inches aft of datum. These values included the radio, C-band beacon, cockpit video camera, and batteries. The empty weight and empty weight cg values fell within the ranges of a production aircraft, as listed in the manufacturer's flight manual.

Table C1 shows the moment arms that were used to calculate the cg's in Table A1. As Table C1 shows, there were small discrepancies between the manufacturer's flight manual moment arms and the actual moment arms for the test aircraft. The manufacturer's flight manual numbers were used to calculate the test points in Table A1 in order to correspond to values an operational pilot would determine using the manufacturer's flight manual. Variations between the actual cg and the manufacturer's flight manual derived cg for the test aircraft were less than 0.5 inches for all loadings flown.

The inertia values of the glider were also needed since experience has shown that spin characteristics are sensitive to inertia values as well as cg. The inertias were mathematically derived, using known aircraft component weights and dimensions, because the actual inertia values for the ASK-21 were unavailable. This derivation is detailed in Figure C2.

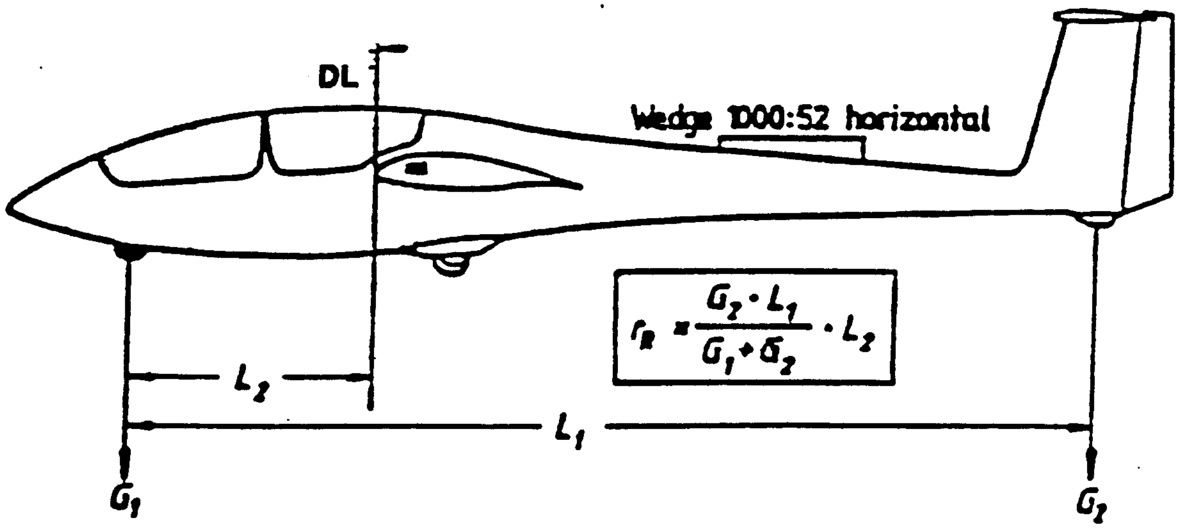

Figure C1 ASK-21 Weight and Balance

Table C1

ASK-21 MOMENT ARMS

Item	Weight (lb)	Arm (in)		Moment (lb-in)
		Flight Manual	Test Aircraft	
Basic Aircraft (including radio, C-band beacon, cock-pit video camera, and batteries)	851	---	29.02	24,696.02
Front Pilot with 18.0 lb Parachute	---	-47.91	-47.10	---
Rear Pilot with 18.0 lb Parachute	----	3.15	-2.02	---
Tail Ballast (Nut + Bolt = 0.4 lb, Each Weight = 2.2 lb)	---	209.80	210.96	---
Cockpit Ballast (Each Weight = 2.2 lb)	--- ---	-63.39	-59.09	---

EMPTY AIRCRAFT MASS PROPERTIES FOR THE TEST AIRCRAFT (S/N 21235):

Empty Weight = 851 pounds
Empty cg = 29.02 inches
Empty Moment = 24,696 in-lb

The pitch, roll, and yaw inertias of the empty aircraft were estimated using the methods outlined in Reference 5. The wings were the dominant components in computing the roll and yaw inertias. Therefore, the pitch inertia was most significantly affected by aircraft loading. For an average empty aircraft weighing 840 pounds and an empty cg of 30.0 inches, the estimated moments of inertia were:

$I_{xx} = 30.2 \times 10^6$ lb-in^2
$I_{yy} = 6.7 \times 10^6$ lb-in^2
$I_{zz} = 34.3 \times 10^6$ lb-in^2

The following equation was derived to translate the empty aircraft pitch inertia to the in-flight cg:

Iyy_0(translated to in-flight cg) = $7{,}872{,}641 - 65{,}061 \bullet cg + 889 \bullet cg^2$

IN-FLIGHT AIRCRAFT MASS PROPERTIES:

The front seat pilot, cockpit weights, and tail weights were the predominant factors which varied the pitch inertia up to 18 percent. The tail weights, in particular, had a large effect on pitch inertia due to their location (long moment arm). The following equations were used to estimate in-flight pitch inertias:

Front Seat Pilot:

W_f = pilot weight + parachute weight
Moment Arm = -47.91 inches
Iyy_f (translated to in-flight cg) = $(400 \bullet W_f) - 20{,}000 + W_f \bullet (47.91 + cg)^2$

Rear Seat Pilot:

W_r = pilot weight + parachute weight
Moment Arm = 3.15 inches
Iyy_r (translated to in-flight cg) = $(400 \bullet W_r) - 20{,}000 + W_r \bullet (3.15 + cg)^2$

Tail Weights:

Each Weight = 2.2 pounds (nut + bolt = 1.0 pounds)
$W_t = 2.2 \bullet$ (number of tail weights) + 1.0, ($W_t = 0$ for no tail weights)
Moment Arm = 209.8 inches
Iyy_t (translated to in-flight cg) = $W_t \bullet (209.8 - cg)^2$

Figure C2 Aircraft Mass Properties Derivation

Cockpit Weights:

Each Weight = 2.2 pounds
$W_c = 2.2 \bullet$ (number of cockpit weights)
Moment Arm = -63.39 inches
Iyy_c (translated to in-flight cg) $= W_c \bullet (63.39 + cg)^2$

Aircraft (S/N 21235):
Gross Weight $= 851 + W_f + W_r + W_t + W_c$
$cg = (24{,}696 - 47.91 \bullet W_f - 3.15 \bullet W_r + 209.8 \bullet W_t - 63.39\ W_c)/\text{Gross Weight}$
$Iyy = Iyy_o + Iyy_f + Iyy_r + Iyy_t\ Iyy_c$

Figure C2 Aircraft Mass Properties Derivation (Concluded)

APPENDIX D

FLIGHT LOG

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Table D1

FLIGHT LOG

Flight Number	Date	Phase	Front Cockpit Weight (lb)	Rear Cockpit Weight (lb)	Number of Tail Weights	Number of Cockpit Weights	Gross Weight (lb)	cg (in)	Iyy ($lb\text{-}in^2 \times 10^6$)	Remarks
1	27 Apr 89	I	176	230	0	0	1257	12.36	8.021	Phase A-C Stalls: No tendency to depart
2	27 Apr 89	I	176	230	0	0	1257	12.36	8.021	Phase D Stalls: Spirals out every time
3	1 May 89	I	176	230	3	0	1264	13.46	8.277	9 Phase C Stalls: 1 showed a tendency to spin, no departures
4	1 May 89	I	176	230	3	0	1264	13.46	8.277	10 Phase D Stalls: 1 entered a spin which rotated 2 turns, entry techniques are improving
5	1 May 89	I	176	230	3	0	1264	13.46	8.277	11 Phase D Stalls: 2 incipient spins (flight manual recovery after 1 turn due to altitude)
6	1 May 89	I	176	230	10	14	1310	13.96	9.045	9 Phase C Stalls: 1 produced an incipient spin; 6 Phase D Stalls: 3 incipient spins, 2 3/4 turns at most

Table D1

FLIGHT LOG (Continued)

Flight Number	Date	Phase	Front Cockpit Weight (lb)	Rear Cockpit Weight (lb)	Number of Tail Weights	Number of Cockpit Weights	Gross Weight (lb)	cg (in)	I_{yy} (lb-in^2 x 10^6)	Remarks
7	2 May 89	I	176	230	2	0	1262	13.11	8.197	15 Phase D Stalls: 4 incipient spins for 1/2 turn, had several tuck unders to negative g
8	2 May 89	I	230	176	10	3	1286	13.53	9)978	Phase D Stalls: 5 incipient spins: Up to 3 turns, flight manual recovery took a full turn, best entry technique: 10^o nose high and input rudder at 40 knots
9	2 May 89	I	176	230	10	14	1310	13.96	9.0453	Phase D Stalls: 2 incipient and 1 sustained which went 5 turns, flight manual recovery took a full turn, pitch oscillations during spin of 40^o - 60^o nose low, 1 oscillation every 2-3 turns
10	3 May 89	I	176	230	0	0	1257	12.36	8.021	25 Phase D Stalls: 5 incipient spins - 3/4 turn at most, no sustained rotations

Table D1

FLIGHT LOG (Continued)

Flight Number	Date	Phase	Front Cockpit Weight (lb)	Rear Cockpit Weight (lb)	Number of Tail Weights	Number of Cockpit Weights	Gross Weight (lb)	cg (in)	I_{yy} (lb-in^2 x 10^6)	Remarks
11	3 May 89	I	230	176	9	5	1288	12.94	9.046	18 Phase D Stalls: 15 incipient spins, 1 1/2 turns at most, best entry technique was ailerons with the turn once autorotation started
12	3 May 89	I	230	176	8	6	1288	12.47	8.980	20 Phase D Stalls: 2 incipient spins for 1/2 turn at most
13	3 May 89	I	176	230	2	0	1262	13.11	8.197	19 Phase D Stalls: 9 incipient spins, never obtained more than 1 turn
14	4 May 89	I	176	217	3	1	1253	13.49	8.280	14 Phase D Stalls: 10 incipient spins - 2 1/2 turns at most, always self-recovered

Table D1

FLIGHT LOG (Continued)

Flight Number	Date	Phase	Front Cockpit Weight (lb)	Rear Cockpit Weight (lb)	Number of Tail Weights	Number of Cockpit Weights	Gross Weight (lb)	cg (in)	Iyy (lb-in^2 x 10^6)	Remarks
15	4 May 89	I	217	176	10	4	1275	14.03	9.048	9 Phase D Stalls: 7 incipient spins and 2 sustained spins - 2 went 5 full turns and 2 self-recovered after 4 turns, pitch oscillations were 20^o- 60^o nose low, flight manual recovery took up to 1 1/3 turns, these spins are very sensitive to entry conditions
16	8 May 89	II/III	230	176	12	3	1290	14.20	9.256	5 Phase D Stalls: 4 sustained spins, hands off took 2 turns to recover, ailerons with the turn increased turn rate and sustained the spin, ailerons against the turn recovered in 1 1/2 turns, opposite rudder took 1/2 turn to recover

Table D1

FLIGHT LOG (Continued)

Flight Number	Date	Phase	Front Cockpit Weight (lb)	Rear Cockpit Weight (lb)	Number of Tail Weights	Number of Cockpit Weights	Gross Weight (lb)	cg (in)	I_{yy} (lb-in^2 x 10^6)	Remarks
17	8 May 89	II/III	230	176	12	3	1290	14.20	9.256	5 Phase D Stalls: 2 incipient and 3 sustained spins, forward stick pitched it out in 3/4 turn, ailerons with the turn increased turn rate and produced larger pitch oscillations (20^0 - 60^0 nose low), ailerons against the turn self recovered in 2 turns
18	8 May 89	II/III	176	0	0	11	1051	14.01	7.986	8 Phase D Stalls: 6 incipient spins - up to 2 turns and self-recovered each time
19	9 May 89	II/III	176	230	6	1	1273	14.34	8.530	5 sustained spins out of 5 attempts, hands off did not recover - stick and rudder went full into the turn and remained, repeated hands off and it recovered in 2 turns, ailerons with the turn sustained the spin, ailerons against the turn recovered in 1/2 turn

Table D1

FLIGHT LOG (Continued)

Flight Number	Date	Phase	Front Cockpit Weight (lb)	Rear Cockpit Weight (lb)	Number of Tail Weights	Number of Cockpit Weights	Gross Weight (lb)	cg (in)	I_{yy} (lb-in^2 x 10^6)	Remarks
20	9 May 89	II/III	176	230	6	1	1273	14.34	8.530	13 Phase D Stalls: 13 incipient spins of which only 3 rotated more than 1 1/2 turns - not consistent with the last flight, hands off recovered two times in 1 1/2 turns or less, it did not recover the third time, the glider will recover hands off from the smooth spin mode but not the oscillatory mode
21	9 May 89	II/III	176	0	0	5	1038	15.00	7.891	13 Phase D Stalls: 13 incipient spins - 4 1/2 turns at most, all of them self-recovered
22	11 May 89	II/III	217	230	12	0	1325	14.49	9.194	4 Sustained Spins: 5 turns, 1 oscillation every 2 turns, spin rate was slower with this loading, hands off took 3 full turns to recover, ailerons with the turn sustained the spin, flight manual recovery was no problem

Table D1

FLIGHT LOG (Continued)

Flight Number	Date	Phase	Front Cockpit Weight (lb)	Rear Cockpit Weight (lb)	Number of Tail Weights	Number of Cockpit Weights	Gross Weight (lb)	cg (in)	Iyy ($lb\text{-}in^2 \times 10^6$)	Remarks
23	11 May 89	II/III	217	230	12	0	1325	14.49	9.194	4 Sustained Spins: Ailerons against the turn slowed the turn rate slightly but kept on spinning, opposite rudder recovered in 1/2 turn, forward stick recovered in 1 turn, hands off recovered in 1/2 turn
24	12 May 89	II/III	176	0	0	2	1031	15.50	7.843	7 Phase D Stalls: 1 incipient and 6 sustained spins, 5 turns, hands off recovered in 2 turns, ailerons with the turn smoothed out and sustained the spin with increased turn rate, flight manual recovery worked in 1/2 turn
25	12 May 89	II/III	176	0	0	2	1031	15.50	7.843	6 Phase D Stalls: 1 incipient and 5 sustained spins, ailerons against the turn recovered in 2 turns, opposite rudder required 1 1/4 turns to recover, forward stick wrapped up the spin and recovered in 2 turns, hands off recovered immediately

Table D1

FLIGHT LOG (Continued)

Flight Number	Date	Phase	Front Cockpit Weight (lb)	Rear Cockpit Weight (lb)	Number of Tail Weights	Number of Cockpit Weights	Gross Weight (lb)	cg (in)	I_{yy} (lb-in^2 x 10^6)	Remarks
26	12 May 89	II/III	176	217	12	3	1277	16.27	9.019	4 Sustained Spins: It did not recover hands off this time, pitch oscillations were 10^o - 60^o nose low - it would have spun to the ground, ailerons with the turn damped the oscillations and increased the turn rate, forward stick recovered in 1 1/2 turns - not effective in pitching the nose down
27	15 May 89	II/III	176	0	0	0	1027	15.84	7.811	9 Phase D Stalls: 2 incipient and 7 sustained spins hands off recovered in 1 1/2 turns at most, ailerons with the turn increased the oscillations to 1 turn and sustained the spin, ailerons against the turn recovered in 1 turn, opposite rudder recovered in 1/2 turn, forward stick smoothed out the oscillations and sustained the spin

Table D1

FLIGHT LOG (Continued)

Flight Number	Date	Phase	Front Cockpit Weight (lb)	Rear Cockpit Weight (lb)	Number of Tail Weights	Number of Cockpit Weights	Gross Weight (lb)	cg (in)	Iyy (lb-in^2 x 10^6)	Remarks
28	15 May 89	II/III	176	0	2	0	1032	16.74	7.978	7 Sustained Spins: Hands off recovered in 1 turn at most, forward stick recovered in 1 1/2 turns at most, opposite rudder took less than 1/2 turn to recover, ailerons with the turn sustained the spin, ailerons against the turn recovered in 1 1/4 turns
29	22 May 89	II/III	176	0	4	0	1036	17.56	8.129	5 Sustained Spins: Pitch oscillations are every turn now, hands off recovered in 1 1/2 turns, forward stick smoothed out the oscillations and recovered in 2 1/2 turns ailerons with the turn increased the turn rate and sustained the spin, flight manual recovery took 1/2 turn

Table D1

FLIGHT LOG (Continued)

Flight Number	Date	Phase	Front Cockpit Weight (lb)	Rear Cockpit Weight (lb)	Number of Tail Weights	Number of Cockpit Weights	Gross Weight (lb)	cg (in)	I_{yy} (lb-in^2 x 10^6)	Remarks
30	22 May 89	II/III	176	0	6	0	1041	18.37	8.279	4 Sustained Spins: Pitch oscillations are now 10^o - 60^o nose low and 1 turn, forward stick recovered in 2 turns at most, flight manual recovery worked immediately
31	22 May 89	II/III	176	0	8	1	1047	*19.00	8.446	4 Sustained Spins: It spun with stick only, hands off recovered in 1 1/2 turns, forward stick recovered in 1 1/2 turns, ailerons against the turn almost recovered in 1 1/2 turns but it stayed in the spin, flight manual recovery worked well, *cg was inadvertently out of limits due to a weighing error of the tail weights
32	23 May 89	II/III	230	0	12	4	1117	16.78	9.101	6 Sustained Spins: Spun with stick only, hands off recovered in 3 turns, ailerons with the turn accelerated the spin and increased the oscillations, forward stick took a full turn to recover

Table D1

FLIGHT LOG (Continued)

Flight Number	Date	Phase	Front Cockpit Weight (lb)	Rear Cockpit Weight (lb)	Number of Tail Weights	Number of Cockpit Weights	Gross Weight (lb)	cg (in)	I_{yy} (lb-in^2 x 10^6)	Remarks
33	23 May 89	II/III	230	0	12	0	1108	17.42	9.035	4 Sustained Spins: Did not spin without rudder, overall spin rate is slower because the oscillations are so frequent, nose comes up to the horizon on each oscillation, hands off recovered in 2 turns, ailerons with the turn sustained the spin, forward stick damped the oscillations and recovered in 3 turns
34	24 May 89	II/III	139	176	0	0	1166	14.99	7.791	10 Phase D Stalls: 7 incipient spins, achieved 1 1/2 turns with stick only, most turns sustained was 4 3/4, pitch oscillation every 2-3 turns again, forward stick recovered in 1 turn, flight manual recovery worked in 1/4 turn

Table D1

FLIGHT LOG (Continued)

Flight Number	Date	Phase	Front Cockpit Weight (lb)	Rear Cockpit Weight (lb)	Number of Tail Weights	Number of Cockpit Weights	Gross Weight (lb)	cg (in)	I_{yy} ($lb\text{-}in^2 \times 10^6$)	Remarks
35	24 May 89	II/III	176	0	11	11	1076	18.49	8.843	3 Sustained Spins: 1 oscillation every turn, spin rate stays slow, ailerons with the turn slightly damped the oscillations, easing the stick forward (1 inch off the aft stop) did damp the oscillations and self-recovered after 7 turns
36	25 May 89	II/III	122	176	0	0	1149	15.92	7.702	8 Incipient Spins: 4 1/4 turns at most, spun with stick only - very successful in duplicating the USAFA accident conditions, hands off recovered in 1/2 turn, forward stick pitched out immediately, ailerons with the turn recovered in 1 turn

Table D1

FLIGHT LOG (Continued)

Flight Number	Date	Phase	Front Cockpit Weight (lb)	Rear Cockpit Weight (lb)	Number of Tail Weights	Number of Cockpit Weights	Gross Weight (lb)	cg (in)	I_{yy} (lb-in^2 x 10^6)	Remarks
37	25 May 89	II/III	176	122	5	7	1176	14.71	8.444	5 Incipient Spins: Did not spin without rudder, 4 1/2 turns at most without effectors, hands off took 1 1/2 turns to recover, forward stick recovered in 1 1/2 turns, moving the stick forward and aft at the appropriate points in the oscillations kept the spin going indefinitely
38	25 May 89	II/III	230	176	11	3	1288	13.87	9.176	6 Sustained Spins Out of 9 Attempts: Did not spin without rudder, 5 turns sustained, hands off recovered in 1 1/2 turns, ailerons with the turn increased the oscillations to 1/turn and recovered in 3 turns, forward stick recovered in 3/4 turn, flight manual recovery took 1/2 turn

Table D1

FLIGHT LOG (Continued)

Flight Number	Date	Phase	Front Cockpit Weight (lb)	Rear Cockpit Weight (lb)	Number of Tail Weights	Number of Cockpit Weights	Gross Weight (lb)	cg (in)	I_{yy} (lb-in^2 x 10^6)	Remarks
39	30 May 89	IV	65	230	0	14	1177	16.16	7.664	2 Incipient Inverted Spins Out of 4 Attempts: 1/2 turn each, it wanted to roll off into a big sideslip
40	30 May 89	IV	65	176	0	14	1123	17.09	7.608	6 Inverted Phase D Stalls: 2 incipient spins - recovered after 2 1/2 turns due to altitude, spin parameters are similar to up-right spins, hands off recovery worked immediately, best entry technique was forward stick and full rudder at inverted
41	30 May 39	IV	65	230	0	3	1153	17.84	7.484	5 Inverted Phase D Stalls: 4 incipient spins - at least 3 turns and recovered due to negative g buildup, very oscillatory - from -1 to -2 g's, flight manual recovery worked immediately

Table D1

FLIGHT LOG (Concluded)

Flight Number	Date	Phase	Front Cockpit Weight (lb)	Rear Cockpit Weight (lb)	Number of Tail Weights	Number of Cockpit Weights	Gross Weight (lb)	cg (in)	I_{yy} (lb-in^2 x 10^6)	Remarks
42	30 May 89	IV	65	176	0	6	1105	18.38	7.474	6 Inverted Phase D Stalls: 2 incipient and 1 sustained spin for 5 turns, 1 oscillation every 1 1/2 turns, -1 g to -2 g, pitch varies from 40°- 70° nose low, inverted spins are a reality in the ASK-21
43	31 May 89	IV	176	0	0	0	1027	15.84	7.811	3 Inverted Phase D Stalls: 3 incipient spins for 3 1/2 turns at most, very oscillatory spins, it spins easier when ailerons are held into the spin

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APPENDIX E

SPIN TRAINING CHECKOUT PROGRAM

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SPIN TRAINING CHECKOUT PROGRAM

This appendix contains the recommended spin training checkout program for USAFA.

SPIN TRAINING

(BASIC 1 SORTIE/0.5 HOURS, ADVANCED 4 SORTIES/2.0 HOURS)

GENERAL

This block of training is to orient pilots to spins and departures from controlled flight during sailplane flight.

Ground instruction for the basic spin orientation sortie may be accomplished by a qualified cadet spin instructor or assigned staff instructor.

Ground instruction for the advanced spin training will be accomplished by a staff spin evaluation pilot.

Spin training will be accomplished prior to ASK-21 pilot in command (PIC) qualification being awarded.

Basic spin orientation training in the ASK-21 will be given to all sailplane instructors prior to their instructor check ride.

PREREQUISITES

At least four sorties of the advanced sailplane checkout must have been flown satisfactorily or the trainee must be in the SGS 2-33 basic instructor upgrade program.

The trainee will have a thorough knowledge of spins, manufacturer's flight manual recovery procedure, appropriate flight envelope, and ASK-21 operating limits.

Upgrades to cadet spin instructor will be considered, in conjunction with Aerobatic Instructor upgrade, and require the same minimum time and experience requirements.

Upgrades to staff spin evaluator pilot will be limited to the minimum required to keep a qualified cadre of staff pilots who are highly proficient in teaching all aspects of high angle-of-attack (AOA) flight to other sailplane instructors.

DEFINITIONS

Cadet spin instructor: A cadet Aerobatic Instructor who has also been designated and trained to give the basic spin orientation instruction to upgrade instructors and advanced sailplane trainees. Authorized to conduct spin and departure training within or forward of the basic spin orientation envelope.

Staff spin evaluation pilot: A highly experienced staff assigned soaring instructor who has been designated and trained to instruct all aspects of high AOA flight. The only spin instructor authorized to instruct spins and departures aft of the basic spin orientation center of gravity (cg) envelope.

Basic spin orientation sortie: Stall, departure, and spin training within the basic spin orientation envelope designed to provide the trainee with the knowledge and ability to minimize loss of controlled flight; recognize and recover with minimum loss of altitude from stalls, departures, and spins; and have confidence in their ability to fly and instruct high AOA flight.

Advanced spin orientation training: Spin and departure training of upgrade advanced sailplane instructors within and outside of the basic spin orientation envelope to provide the knowledge and ability to recognize and safely recover from stalls, departures, and spins with minimum loss of altitude throughout the entire aircraft envelope; understand the results of various control inputs during spins and the effects of improper recovery techniques on recovery; and confidently fly and instruct advanced sailplane maneuvers.

Departure: Uncommanded aircraft motion occurring after stall that results in extra loss of altitude. Loss of basic aircraft control.

Spin: Sustained natural yawing and rolling motion of an aircraft above stall AOA, requires extra altitude and positive control inputs by the pilot to minimize altitude loss during recovery. The requirement for a spin to occur is a stall accompanied with yaw rate.

Basic spin orientation cg envelope: cg and inertia loading envelope allowed for basic spin orientation training flights. Provided in each aircraft's forms and is approximately 14 to 16 inches aft of the datum. Allows for consistent spin characteristics to be observed. Obtained by a certain combination of front and back seat pilot weights, front cockpit and tail ballast weights. Must be checked by the PIC prior to each flight that basic spin orientation training is to be accomplished.

RESTRICTIONS

Basic spin orientation instruction will be given by designated soaring cadets and staff instructors who have spun within the last 60 days.

Instructor upgrade spin instructional flights will only be given by designated staff spin evaluation pilots.

Spins will be entered at a minimum of 3,000 feet above ground level (AGL) and manufacturer's flight manual recovery initiated by 2,500 feet AGL to ensure a return to level flight by 2,000 feet AGL.

No aerobatic maneuvers will be flown during flights with any tail weights installed.

Inverted spin attempts are prohibited.

Spins are a dual only maneuver.

PROCEDURES

Spin training is considered aerobatic flight and the PIC will ensure all applicable aerobatic flight procedures are followed, including the use of parachutes.

Pilot weights (including parachutes) and required ballast will be briefed to the Safety Officer prior to flight to ensure that the flight is conducted within the applicable spin training envelope.

Preflight:

The specific flight profile, including planned pilot inputs and expected aircraft response and altitude loss, will be briefed prior to flight.

Discuss unusual attitude recovery techniques, potential areas for aircraft over-g or overspeed, maximum airspeed for flight with tail weights attached, false airspeed indications during flight with high sideslips, and exchange of aircraft control.

Flight:

The instructor will demonstrate straight ahead and turning stalls, including techniques for minimum loss of altitude during recovery, and the trainee will demonstrate proficiency prior to spins.

The instructor will demonstrate spin entry, a three-turn spin, and the manufacturer's flight manual recovery prior to trainee spin attempts. The instructor will emphasize recovery controls followed by minimum loss of altitude during dive pullout.

The trainee will practice spin entry and recovery until good proficiency in spin recognition and recovery is obtained. Various entry methods, including turning flight, turn reversals, and adverse yaw (no rudder), will be instructed and practiced by the trainee. Emphasis will be placed on possible entry maneuvers that are similar to maneuvers that may occur during student training and normal sailplane flight.

More than one flight may be required to attain a good level of proficiency in basic spin recognition and recovery. Between spins, thermalling may be accomplished to increase altitude for additional spins to be flown.

The trainee may accomplish the landing if the trainee is in the advanced sailplane upgrade program, otherwise the instructor will land the aircraft.

Additional advanced spin orientation flights at high and low inertia loadings, and forward and aft cg's, will be flown to demonstrate ASK-21 departure and spin characteristics to advanced sailplane upgrade cadet and staff instructors. Additionally, aileron inputs and incorrect recovery control inputs will be demonstrated during these advanced rides when instructed by staff spin evaluation pilots.

Postflight:

Fill out a grade card for all maneuvers practiced and make any retypes on the back of the card, as required.

Discussion and Critique: Weak areas, special emphasis on situational awareness at all times, including cg and expected aircraft handling qualities.

Cadets may be recommended for advanced spin training and spin instructor check ride after or during the Aerobatic Instructor recommendation. Advanced spin training, in conjunction with Aerobatic Instructor upgrade, will be flown from both front and rear seats. Proficiency and instruction ability in the basic spin orientation events are required for the spin instructor check ride and is considered a separate qualification.

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APPENDIX F

JOINT AVIATION REGULATIONS PART 22

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JOINT AVIATION REGULATIONS PART 22

The certification basis for the use of the ASK-21 glider in the United States was Federal Aviation Regulation (FAR) Parts 21 and 29, effective February 1965. This included amendments 21-1 through 21-53. Original certification in West Germany was under "Airworthiness Requirements for Sailplanes and Powered Sailplanes" (LFSM), dated 1975. Also referenced was Section 5 (e) (g) of FAA Advisory Circular 21.23-1, dated 12 January 1981. The transition from West German Airworthiness to certification with the FAA was accomplished by the JAR for sailplanes and powered sailplanes (JAR Part 22), dated 1 April 1980. This included Amendment 1, dated 18 May 1981. The type certification data sheet covering airworthiness certification of the ASK-21 in the United States was G47EU, dated 10 January 1983. Excerpts from the JAR which apply to this flight test program follow.

JAR 22.207 STALL WARNING

There must be a clear and distinctive stall warning with airbrakes, wing flaps, and landing gear in any normal position, both in straight and in turning flight.

The stall warning may be furnished either through the inherent aerodynamic qualities of the sailplane (e.g., buffeting) or by a device that will give clearly distinguishable indications.

ACJ222.207(b) (Interpretative Material)

A visual stall warning alone is not acceptable.

The stall warning must begin at a speed between 1.05 V_{S1} and 1.1 V_{S1} and must continue until the stall occurs.

A sailplane which does not give warning of the approach to the stall may, however, be acceptable provided that when a stall occurs from straight flight:

(1) it is possible to produce and correct roll by using the ailerons, the rudder being held neutral; and

(2) no appreciable wing dropping occurs when both ailerons and rudder are held neutral.

SPINNING

JAR 22.221 GENERAL

Compliance with the following requirements must be shown in all configurations, including unavoidable asymmetric water ballast.

The sailplane must be able to recover from spins of at least five turns or such lesser number at which the spin turns into a spiral dive. Tests must be conducted with wing flaps and airbrakes neutral (see ACJ 22.335) and with:

(1) controls held in the position normal for spins;

(2) ailerons and rudder used in opposite directions;

(3) ailerons applied in the direction of rotation.

In addition, tests must be conducted in critical combinations of airbrake extension and wing flap deflection.

ACJ22.221(b) (Acceptable Means of Compliance)

It will normally be sufficient to conduct a number of spins of about two turns in each of the conditions of JAR 22.221(b) and subsequently to conduct spins of five turns in the most adverse cases.

The sailplane must be able to recover from any point in a spin as defined in JAR 22.221(b) in not more than one additional turn by applying the controls in a manner normal for recovery and without exceeding either the limiting airspeed or the limiting positive maneuvering factor for the sailplane. The loss of altitude from the point at which recovery is initiated to the point at which horizontal flight is first regained must be determined. For wing flap positions for which a V_{FE} limitation is established, the flap position may be adjusted during recovery after the autorotation has stopped.

ACJ22.221(c) (Acceptable Means of Compliance)

The procedure normally considered as a standard procedure to recover from a spin is established as follows:

(1) Apply opposite rudder (i.e., against the direction of rotation of the spin).

(2) Short pause.

(3) Ease the control column forward until the rotation ceases.

(4) Centralize rudder and allow sailplane to dive out.

It must be impossible to obtain uncontrollable spins with any use of the controls.

JAR 22.223 SPIRAL DIVE CHARACTERISTICS

If there is any tendency for the spin to turn into a spiral dive, the stage at which this tendency occurs must be determined. It must be possible to recover from the condition without exceeding either the limiting airspeed or the limiting positive maneuvering factor for the sailplane. Compliance with this requirement must be shown without the use of airbrakes.

APPENDIX G

FLIGHT MANUAL REVISIONS

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FLIGHT MANUAL REVISIONS

The U.S. Air Force is planning to write a technical order flight manual for the ASK-21 (TG-9).The following discussion is the recommended writeup for Section VI (Flight Characteristics) of the flight manual. The information is also appropriate for the manufacturer's flight manual.

STALL CHARACTERISTICS

The approach to stall characteristics of the ASK-21 are similar to other high performance sailplanes. Flight in this regime can be made safely and routinely provided these characteristics are well understood.

Control Effectiveness on Approach to Stall:

At speeds below minimum sink speed in 1-g wings level flight, the controls are effective in all three axes. The elevator is the most responsive control throughout this flight regime. The ailerons and rudder are slightly more sluggish, but effective in the proper sense.

Small aileron deflections produce adverse yaw. Adverse yaw during approach to stall causes a nose slice away from the input and a subsequent wing drop. Unless the aircraft is then forced into a full stall, this wing drop does not result in departure and is controllable. Prolonged aft stick (stall) in the presence of wing drop may result in departure or spin. Departure can be prevented by coordinating with rudder (opposite the wing drop).

Up to stall, large sideslip angles (up to full cross controls) can be flown without departure from controlled flight. In sideslips, however, the rudder forces lighten to zero. When the sideslip is sufficiently great, the rudder "locks out" and has to be pushed back by pilot input. Restoring pedal forces are light and the aircraft is easily returned to coordinated flight.

Warning Cues:

The most significant characteristic in approach to stall is the lack of any distinctive warning cues that stall is imminent. With a cg aft of approximately 13 inches, there is only very slight airframe buffet at 2 to 3 knots indicated airspeed (KIAS) above the stall. If the center of gravity (cg) is forward of 13 inches, full aft stick is reached prior to any clear buffet onset when approach to stall is made from level flight. The only other cue to the pilot of an impending stall, regardless of cg, is the diminished cockpit noise due to the slower speed of outside airflow.

During approach to stalls, airspeed indications are unreliable if sideslip is present. In full sideslips, indicated airspeed is zero or less (needle unwinds and points to 160 KIAS). This is due to the relative positions of the pitot and static pressure sensing ports.

Stall Indication:

In 1-g wings level flight, the stall is marked by a very mild g-break (nose drop) of 2 to 3 degrees or less. If the cg is forward of approximately 13 inches, this g-break does not occur. Full aft stick is reached first, indicating a saturation of tail authority. If the stick is held full aft at stall, buffeting increases and a pitch "bucking" or slow oscillation in pitch attitude occurs as tail effectiveness returns at each nose drop and produces secondary stalls. Speeds at stall range from 33 to 38 KIAS depending on gross weight.

Spoilers have no significant effect on stall characteristics, although the airframe buffet they produce further masks the natural stall buffet of the airframe. Stall speeds with spoilers are generally 2 KIAS higher than without.

Dynamic entries to stall can be flown using higher pitch attitudes and a more rapid onset rate. The dynamic effects produce a slower stall speed and a much more pronounced g-break of up to 40 degrees of nose drop, even at forward cg. Dynamic entries to stall do not result in departure. The airspeed increases rapidly above stall during the g-break even if the stick is held full aft. Approximately 100 feet of altitude loss can be expected in this type of maneuver.

During accelerated stalls, slight airframe buffet is felt in the tail at 3 to 5 KIAS above the stall. If constant altitude is maintained during turns, airspeed decreases sufficiently to produce a mild g-break. Full aft stick can be achieved in a stable turn condition, however, if slight descent or thermal conditions exist. This is due to reaching maximum tail authority prior to stall. Accelerated stalls are characterized by little warning cues in the approach to stall regime, similar to the 1-g stall.

Stall Recovery:

Recovery from all stalls is immediate by releasing back stick pressure and allowing the nose to fall, provided a wing drop has not occurred. Straight ahead stall recovery requires as little as 50 feet altitude. Recovery can be delayed if wing drop is present at the stall. Wing drop can be caused by stall from a shallow bank turn, adverse yaw during shallow turns near the stall, or turbulence.

WARNING

If a wing drop occurs at stall and forward stick is the only recovery input, the aircraft may depart controlled flight and enter an incipient spin. Opposite rudder will prevent departure in all cases if applied opposite the wing drop prior to applying forward stick. A departure at stall can require more than 500 feet of altitude to recover to level flight.

Inverted Stalls:

The characteristics in approach to stall at -1 g are essentially unchanged from normal 1-g flight. Stall speeds at -1 g are 38 to 40 KIAS (pitot tube extension installed). Very little buffeting (even less than upright) of the airframe is noticed and the g-break is very mild unless the stall is entered from a nose high attitude. The aircraft tends to roll, seeking an upright attitude, during the g-break at stall.

DEPARTURE AND SPIN SUSCEPTIBILITY

Entry Techniques:

The simplest spin entry is accomplished from wings level with the pitch attitude held constant at 10 degrees nose high until stall, while smoothly applying full rudder and full aft stick. Proper timing of aileron inputs prior to stall can generate additional yaw (adverse yaw due to aileron) to assist spin entry. This is particularly true at more forward cg when rudder and elevator alone fail to produce spin entry.

Spin entry is sensitive to entry conditions. If the entry attitude is too nose high, it results in a spiral dive. If the entry attitude is too shallow, it results in a steep-banked sideslip. The spiral or sideslip occur more frequently as the cg is moved forward. Spin entry is unlikely with the in-flight cg forward of 12.4 inches. In this case, entry attempts result in spirals or sideslips regardless of control input techniques.

Mass Properties Effects:

Spin entry success is also sensitive to inertia loading. The ASK-21 aircraft has the unique feature of tail ballasting, meaning that it can be loaded at both ends of the fuselage. Although the tail weights were designed to control cg, they greatly effect the inertia terms that govern aircraft response to flight maneuvers. Since the tail weights significantly increase the inertia of the longitudinal axis of the aircraft, any initial yaw rotation results in more angular momentum than without tail weights. This greater momentum results in achievable spins at cg's further forward than the low inertia case.

Flight testing has produced spins at cg's as far forward as 12.9 inches. With minimum inertia loadings (solo, lightweight pilot without tail ballast), incipient spins can be achieved at cg's aft of 13.0 inches and sustained spins aft of 15.0 inches. With higher inertia loadings (two pilots and tail ballast), incipient spins can occur aft of 12.5 inches and sustained spins aft of only 13.5 inches. Therefore, the tail weights cause the target cg where spins can be expected to move progressively more forward as pilot weights increase.

Figure G1 shows flight test results by plotting cg against inertial loading. The results for spin entry and number of turns achieved follow linear boundaries within the envelope. It is extremely unlikely, but not impossible, that spin entry can be achieved to the left of the incipient boundary line. Therefore, the ASK-21 departure and spin resistance is classified as "extremely resistant" in the lower left corner of the envelope and progressively becomes less resistant as the loading is moved to the upper right. The broad area between the two boundary lines is a region where spins are only incipient (self-recover in spite of holding prospin controls). To the right of the sustained boundary line, spins can be sustained indefinitely as long as prospin controls are held.

In reference to test results shown in Figure G1, the best cg for spin training is 16.0 inches. Figure G2 shows how to load any ASK-21 glider to obtain 16.0 inches cg. Figure G3 shows how to compute cg for any loading of any ASK-21. The maximum number of tail weights permitted is 11. If pilot weights call for more than 11 tail weights when using Figure 2, use 11 tail weights which will result in a cg slightly ahead of 16.0 inches.

ASK-21 Spin Susceptibility

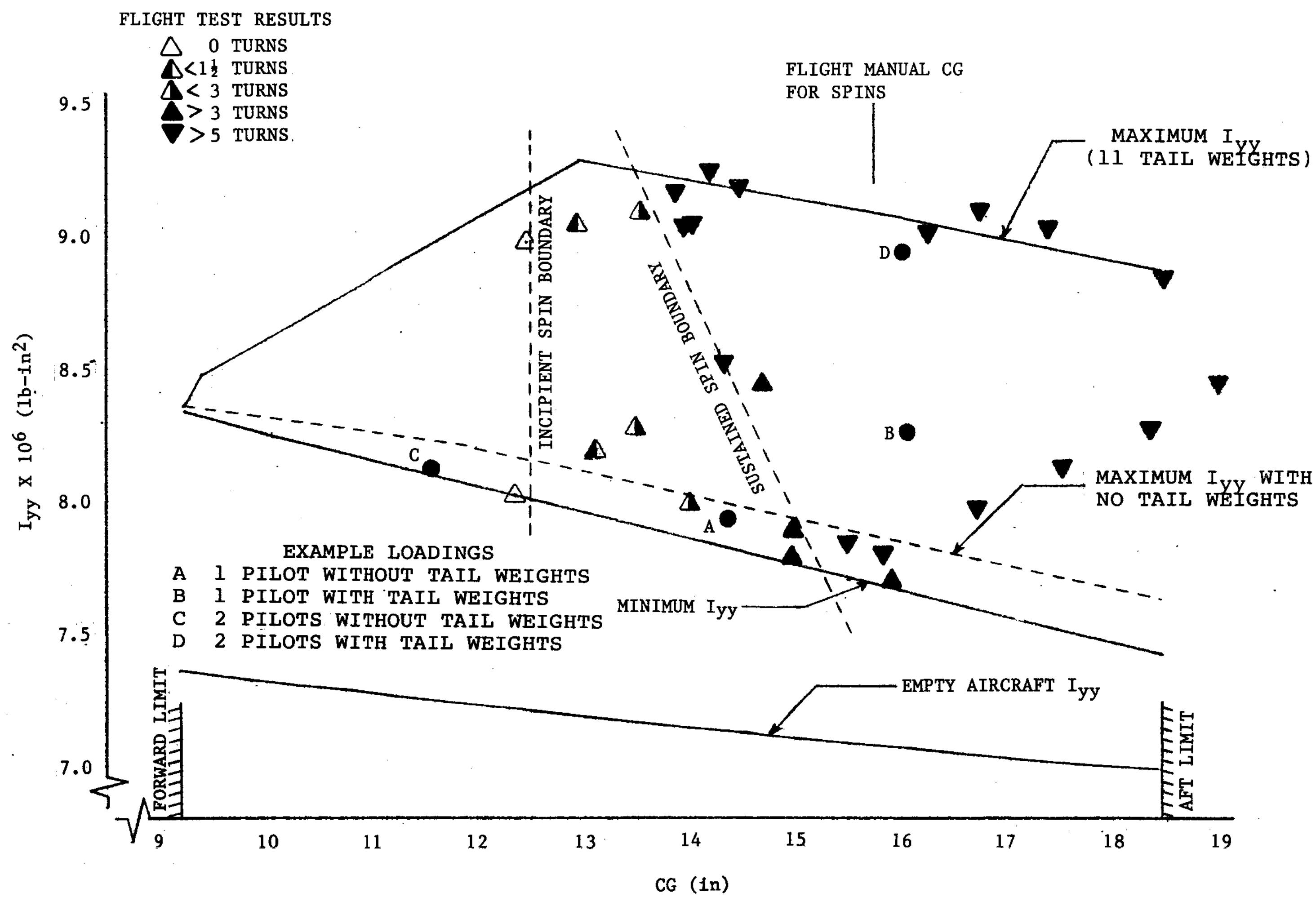

Figure G1 ASK-21 Center of Gravity Versus Pitch Inertia

ASK-21 Spin Training
Number of Tail Weights Necessary to Achieve 16 Inches Center of Gravity

NOTES: 1. Number of tail weights is sum of increment for empty aircraft plus increment due to front and rear seat weights (rounded to nearest whole).
2. Maximum number of tail weights allowed is 11.
3. No cockpit ballast.

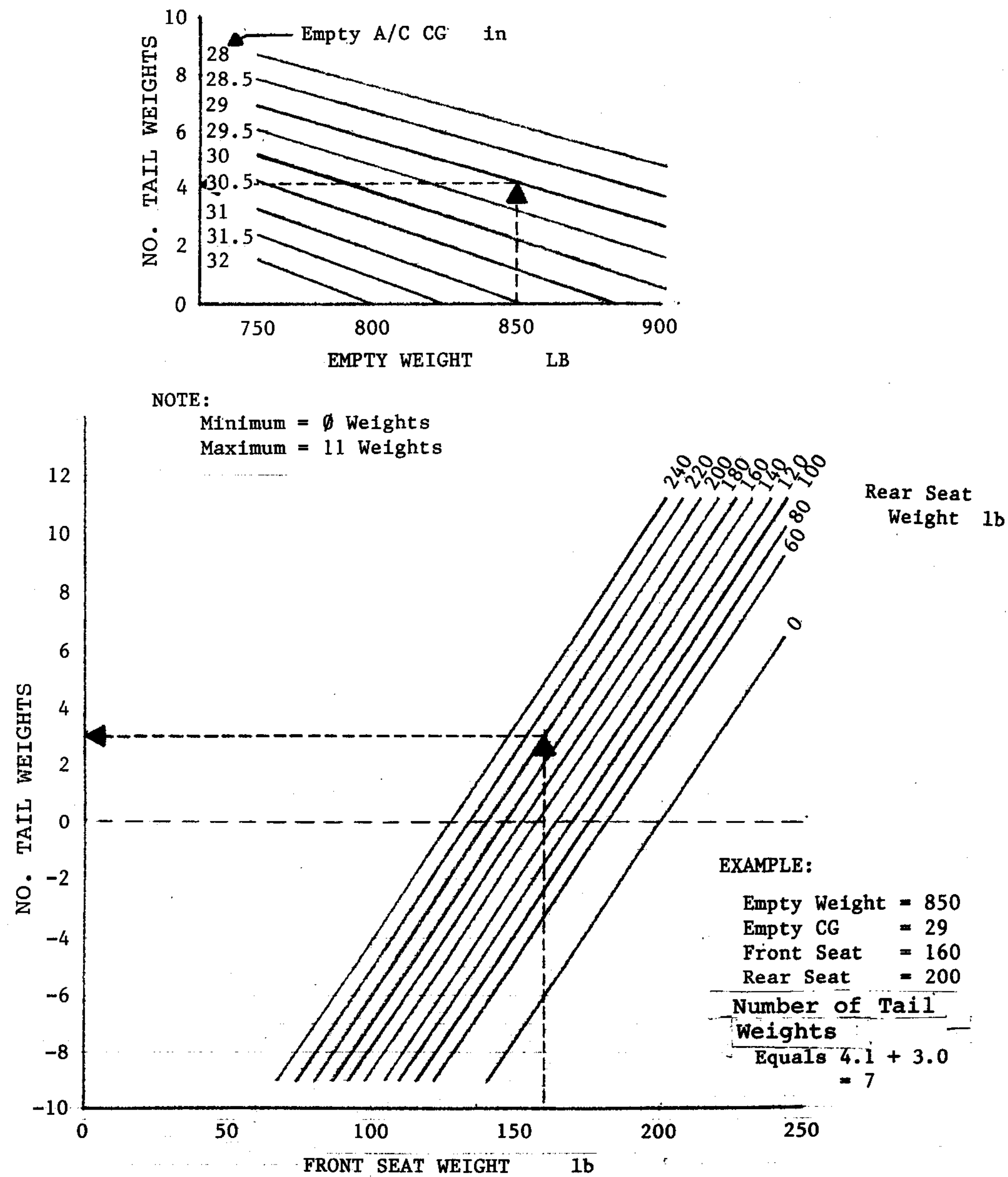

Figure G2 ASK-21 Loading Chart for Spins

ASK-21 Center of Gravity

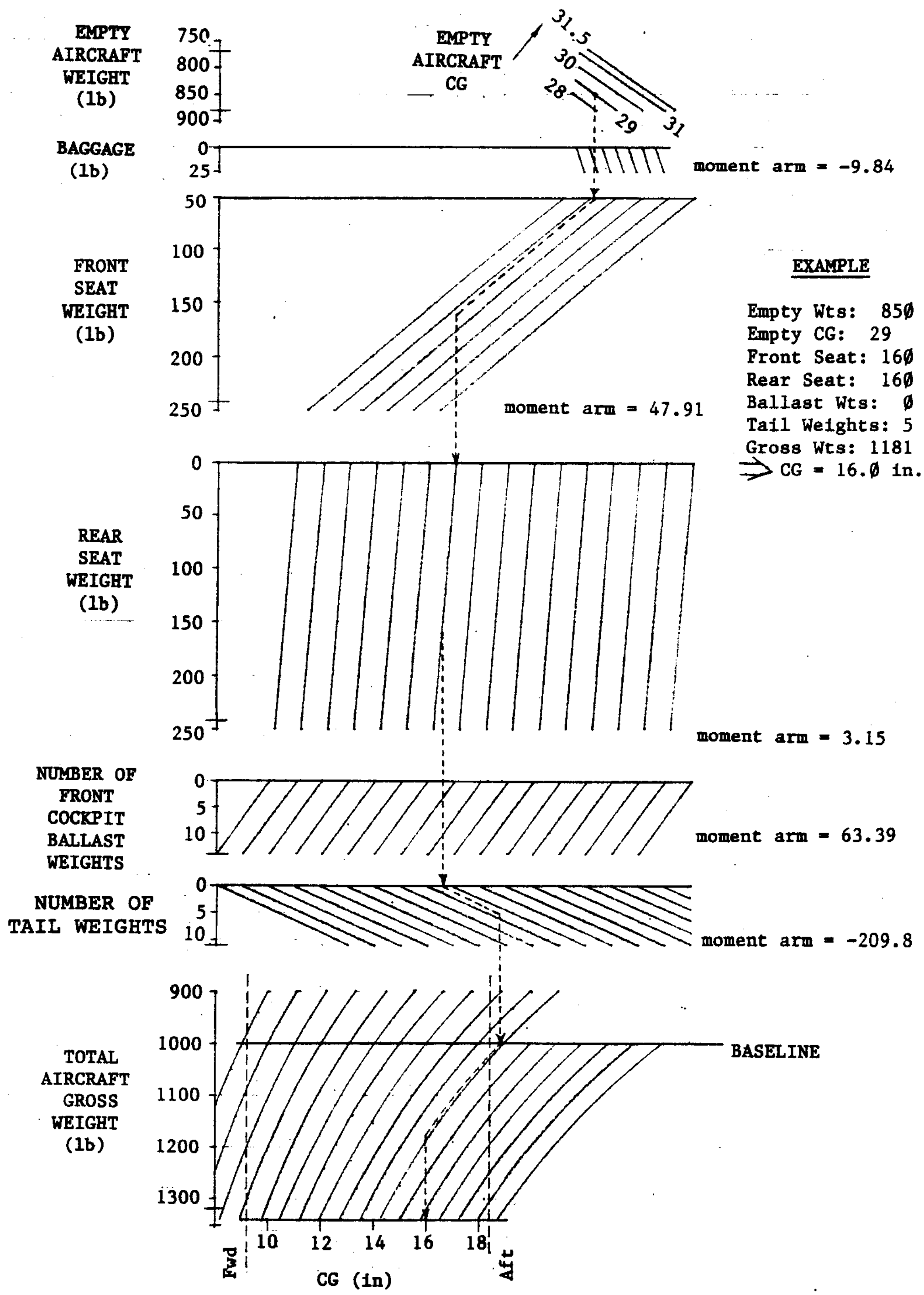

Figure G3 ASK-21 Center of Gravity Chart

Due to the higher inertia of this case, the aircraft will still spin easily for training.

No Rudder Spin Entry:

Spin entry without using rudder input can occur under certain conditions. A wing drop at stall can generate sufficient yaw to cause the rudder to float to the prospin position. Wing drop can occur due to adverse yaw from uncoordinated aileron inputs near stall or turbulence. In this case, if recovery is not initiated by applying rudder opposite the wing drop and then breaking the stall with forward stick, a spin can develop.

WARNING

If proper turn coordination is not exercised near stall, a departure or spin may occur with only stick inputs.

SPIN CHARACTERISTICS

Spin Modes:

The ASK-21 has two spin modes, one upright and one inverted. Both are classified as fast, steep, and oscillatory, However, the oscillation of the spin causes a variance in pitch attitude that can range from extremely steep to nearly flat. The average attitude value is classified as steep. The spin modes may also appear smooth instead of oscillatory if they are only examined for three turns or less. This is because the period and frequency of the pitch oscillation vary as a function of cg and inertia loading. Variations from one oscillation per turn to one oscillation every three turns can be seen, depending on loading.

Spin Parameters:

The pitch attitude during ASK-21 upright spins averages 40 to 50 degrees nose low. The steep phase of the oscillation is as much as 70 degrees nose low and the flat phase as high as the horizon. In no case does the flat phase tend toward an unrecoverable situation. On some occasions, the spin attitude is steep enough that the AOA is momentarily less than stall, resulting in recovery as the aircraft pitches down out of the spin.

The oscillation occurs more frequently as the cg is moved aft, while increases in inertia loading result in a larger amplitude of the oscillation. For example, at a forward cg, the oscillation is seen every third turn. At the aft cg limit, the oscillation occurs every 3/4 to 1 turn. At low inertia values, the pitch attitude oscillates typically ±15 degrees about 50 degrees nose low, while at high inertia the oscillation is ±30 degrees about 40 degrees nose low.

The rotation rate of the spin is as fast as 140 degrees per second, or one turn every 2.5 seconds. This rate occurs at the steep phase of a spin oscillation. During the flat phase, the rotation rate is as slow as 90 degrees per second or one turn every 4.5 seconds. The average rotation rate is fastest at forward cg's and high inertias, where oscillations occur least frequently. Toward the aft cg limit, where oscillations to flat attitudes are more frequent, the average rotation rate is slowest.

In all spins, the altitude loss is approximately 200 feet per turn with a variance of 150 feet minimum to 250 feet maximum. This indicates that in spite of the oscillatory nature of the spin mode, the descent rate remains relatively constant.

Airspeed indications during the spin oscillate along with pitch attitude. In most cases, airspeed oscillates between 30 and 40 KIAS. During larger oscillations in pitch attitude, higher sideslip angles are present and airspeed erroneously reads zero or less (pointer unwinds to 160 KIAS).

Since airspeed indications can be unreliable during spins, particular attention is necessary to recognize the transition to a spiral. If cockpit noise due to outside airflow continues to increase to the point that conversation between crewmembers is difficult, or if the airspeed indicator is increasing through 60 KIAS, the aircraft is no longer spinning but is likely in a spiral. Opposite rudder and relaxed back stick pressure should be used immediately to avoid potential overspeed or overstress situations associated with high-speed spirals. Spoilers should be used as necessary to control airspeeds during all spin or spiral dive recoveries.

CAUTION

Initiate recovery not later then 60 KIAS to avoid exceeding 108 KIAS limiting airspeed with tail weights installed.

Cockpit noise also varies during sustained spin oscillations. During steep phases of the spin, cockpit noise from outside airflow is loudest, while during flat phases, the cockpit is very quiet.

WARNING

The combination of varying cockpit noise levels, varying pitch attitudes, and varying rotation rates and airspeed indications can cause disorientation to those unfamiliar with spinning this aircraft. If this occurs, positive application of recovery controls should be initiated immediately to minimize any effects of disorientation.

Control forces during spins are light. There is a tendency for the ailerons to float into the direction of the spin, accompanied by 5 to 10 pounds of lateral force on the control stick. At the higher spin rates, the elevator and rudder forces at full prospin deflection drop to zero.

CONTROL EFFECTS

Flight Manual Recovery:

When opposite rudder is initiated at a slow point or flat phase of the spin, the rotation stops in 1/4 to 1/2 turn and the aircraft recovers. In the majority of cases, even at higher rotation rates, opposite rudder recovers the aircraft in 1/2 to 3/4 of a turn from the point of input. However, with cg's of 14 to 16 inches and at higher inertias, recovery can take up to 1 1/2 additional turns to recover once opposite rudder is applied. It is imperative that a slight pause occur between application of opposite rudder and forward stick or even greater delay in recovery can occur.

A recovery of 1 1/2 turns may take up to 5 seconds, which may seem excessively long to an inexperienced pilot. The flight manual procedure has a 100 percent success rate if given sufficient time to work.

Aileron Effects:

For the ASK-21, ailerons against the spin produce a noticeable bank angle away from the spin turn direction as well as a nose down pitch rate. This sometimes results in recovery as the yaw rate decreases through inertial coupling and the nose pitches down leaving the aircraft in a steep sideslip to terminate the spin. In other cases, the aircraft remains in the spin with a bank angle away from the spin direction. Therefore, ailerons against the spin are not a reliable contributor to spin recovery.

Ailerons with the spin increase rotation rate but this effect is masked by the oscillatory characteristics of the spin. In the majority of cases, ailerons into the spin achieve a slightly higher rotation rate and a more sustainable spin. The results of testing isolated aileron inputs indicate neutral aileron is the best position for recovery.

Elevator Effects:

In some case, application of forward stick with no rudder input will result in a continued spin. During either the incipient phase of the spin or at the start of a nose up oscillation, full forward stick can produce up to three more turns before recovery.

WARNING

During recovery from stalls in the presence of wing drop, or from departures and spins, application of forward stick prior to opposite rudder can delay recovery up to three additional turns.

Hands Off:

In the majority of cases, when the controls are released during a spin, the stick moves laterally in the direction of the spin. The stick usually reaches full aileron deflection and then starts forward toward neutral. The aircraft pitch attitude steepens and then the rudders return to neutral. At this point, the aircraft self-recovers in a steep attitude.

If the controls are released just after the pitch attitude has cycled nose low and the rotation rate is high, the stick moves abruptly into the direction of the spin and remains at full aft/full aileron deflection. Rudders also remain at full deflection, or nearly so, and the spin continues indefinitely until the pilot forces the controls to the recovery position. This is most prevalent in the 14- to 16-inch cg range with higher inertia loadings. Since airloads on the controls can occasionally cause them to "lock out" in a prospin position, releasing the controls is not a viable option for departure or spin recovery. The spin recovery procedure must be used to ensure successful recovery.

INVERTED SPINS

Flight testing has verified that the ASK-21 has an inverted spin mode. Testing has been conducted between 15.8 inches cg and the aft cg limit.

WARNING

Intentional inverted spins are prohibited.

Susceptibility:

For cg's between 15.8 and 17.0 inches, inverted spins can be achieved if ailerons are held opposite the yaw. Aft of 17.0 inches cg, sustained spins are possible without holding ailerons against the spin. Inverted spins become less likely to occur at cg's forward of 15.8 inches since control positions become more critical. Overall, the ASK-21 is extremely resistant to inverted spins since only sustained inverted stalls result in spins, regardless of cg. Although testing indicates increased resistance forward of 15.8 inches cg, this does not imply inverted spins at more forward cg's are impossible.

Characteristics:

The inverted departure and spin entry are essentially a mirror image of the upright case. The nose falls to approximately 60 degrees nose low and then hesitates. Cockpit g forces build to -2 g and the nose then oscillates back up to 40 degrees nose low. The spin develops in approximately 180 degrees of rotation and is oscillatory just as the upright spin. Altitude loss is 200 to 300 feet per turn and rotation rate is one turn every 3 to 3 1/2 seconds. At the cg's tested, the inverted spin oscillations occur every 3/4 to 1 turn. Once the spin is developed, g forces oscillate between -1 and -1.5 g. Airspeed oscillates near 40 KIAS and remains stalled throughout. Cockpit g forces are uncomfortable but other spin characteristics are very comparable to the upright case.

Inverted spin recovery is immediate (1/4 to 1/2 turn) when controls are neutralized. Altitude loss from initiating recovery to level flight is 400 to 500 feet. Since the spin includes a component of roll rate as well as yaw rate, the aircraft rolls to an upright attitude during recovery on its own, without further pilot input. Airspeeds are typically 90 to 100 KIAS maximum during inverted spin dive recoveries.

APPENDIX H

SPIN THEORY

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SPIN THEORY

PITCHING MOMENT BALANCE

In a fully developed spin, the contributors to the spin characteristics of the ASK-21 were the moments applied by aerodynamic effects (wing, tail, and control surfaces) and inertia (mass distribution). Figure H1 shows the balance of aerodynamic and inertia pitching moments in a spin. The inertia moment tended to pitch the nose up, as the aircraft attempted to align its inertial axes (i.e., wings and fuselage) perpendicular to the rotation axis. The aerodynamic moments tended to pitch the nose down, as the aircraft tried to align itself aerodynamically with the relative wind. Since these opposing aerodynamic and inertial moments never reached a balance, a constant pitch attitude was never achieved.

The inertia moment magnitude was a function of rotation rate and mass distribution. A higher spin rate or greater mass distribution from the cg resulted in a greater nose up moment. For the ASK-21, loading heavyweight pilots and tail weights created a greater nose up inertial moment during a spin, than with lightweight pilots and no tail weights.

The aerodynamic moment was primarily a function of AOA and cg. A higher AOA or more forward cg created a greater nose down pitching moment. Therefore, in an ASK-21 upright spin, the pitching moment balance was derived from AOA, rotation rate, cg, and mass distribution.

ROTATION RATE OSCILLATION

Since cg and mass distribution were predetermined, the AOA and rotation rate were the only remaining variables to determine pitching moment balance. The rotation rate was primarily driven by the autorotative couple of the wings. Autorotation occurred due to the advancing wing operating at a lower AOA than the retreating wing (Figures H2 and H3).

The ASK-21 wings were tufted during these spin tests to document local flow characteristics of various wing sections. Upon spin entry, the attitude was steep enough that the outboard section of the advancing wing was not stalled, while the retreating wing was completely stalled. This created a strong autorotative couple which accelerated the rotation rate and increased the inertial pitching moment proportionately. At a threshold rotation rate, which varied as a function of configuration and mass distribution, the inertial pitching moment overpowered the aerodynamic moment and caused the nose to pitch up. The AOA, therefore, increased and the advancing wing also became completely stalled. This reduced the autorotative moment (Figure H4), which reduced the rotation rate and subsequently decreased the inertial pitching moment. The nose pitched down again causing the advancing wing outboard section to unstall.

This increased the autorotative couple, accelerated the spin again, and caused the cycle to repeat. The operating AOA of the various wing sections was mathematically computed and is shown in Figure H5.

Another contributor to the oscillating rotation rate during the spin was rudder effectiveness. At steeper attitudes (lower AOA), the airflow across the rudder had its greatest chord wise component velocity, thereby generating greater rudder effectiveness. As the nose pitched up during a spin oscillation, the relative wind component was more along the vertical axis (span) of the rudder, which reduced its effectiveness and caused a reduction in rotation rate.

A final contributor to the variation of rotation rate during the spin was the conservation of angular momentum of the rotating body. The yaw inertia of the ASK-21 was approximately 15 percent higher than the roll inertia. Therefore, conservation of momentum dictated a proportionately slower rate at flat attitudes, where the spin motion was primarily about the yaw axis, than at steep attitudes where the spin motion was primarily about the roll axis.

AILERON EFFECTS

During spins, ailerons remained effective in producing a bank angle change in the proper sense. By using ailerons to reorient the aircraft attitude on the spin axis, a component of the spin rate vector, $\overrightarrow{W}$, can be generated on the y body axis (lateral axis), creating a pitch rate, q (Figure H6).

Pitch rate caused the aircraft inertial moments to affect roll and yaw acceleration. This can be seen from

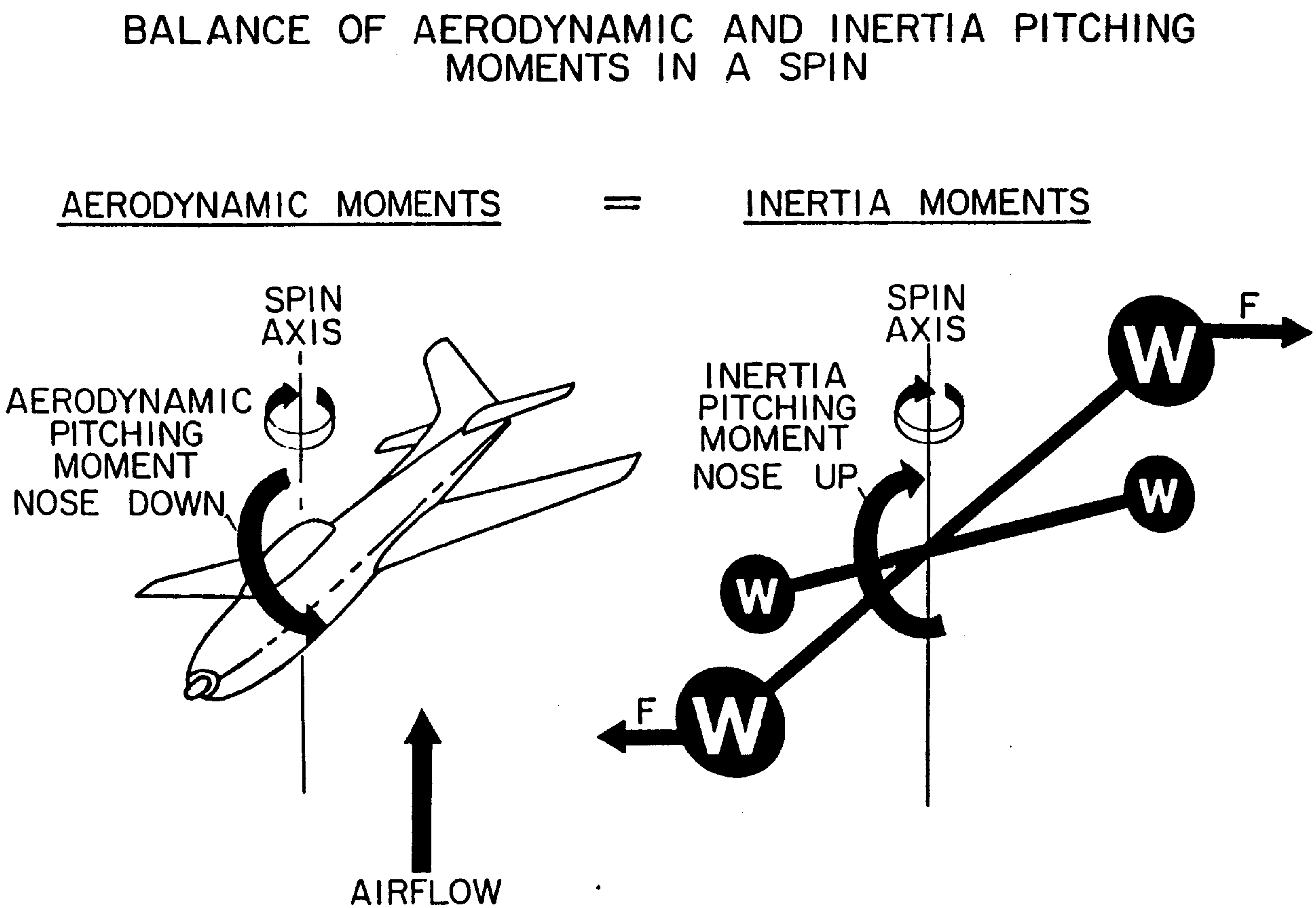
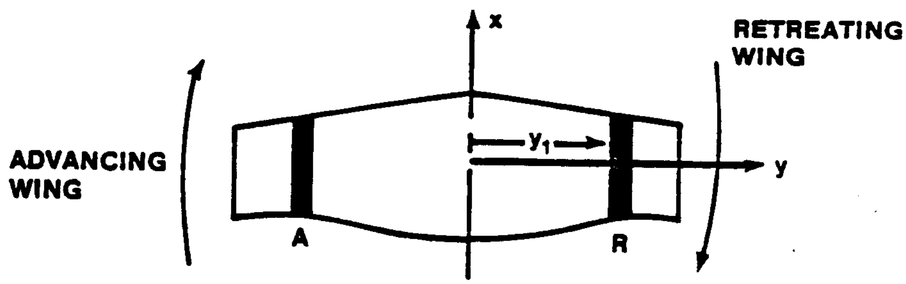


Figure H1 Pitching Moments in a Spin



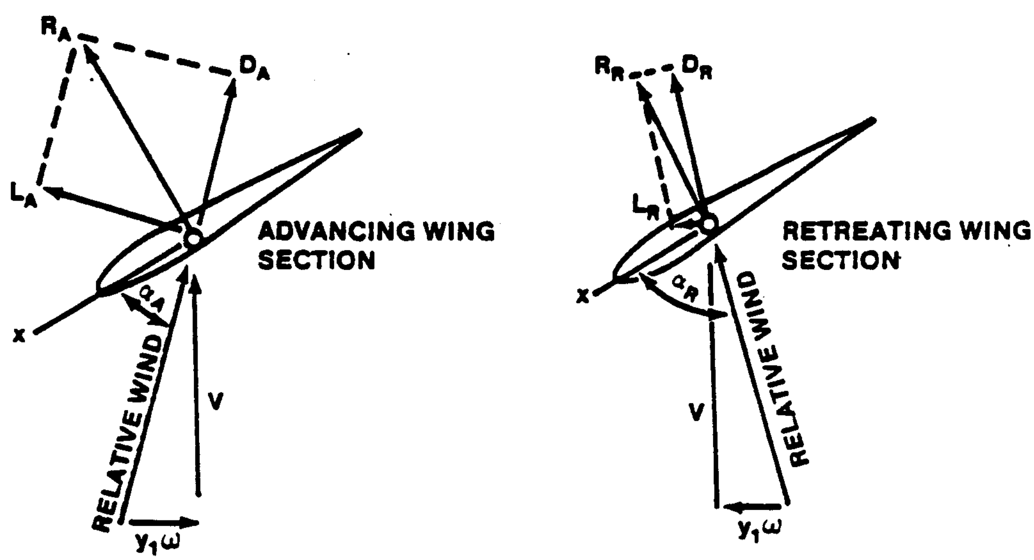
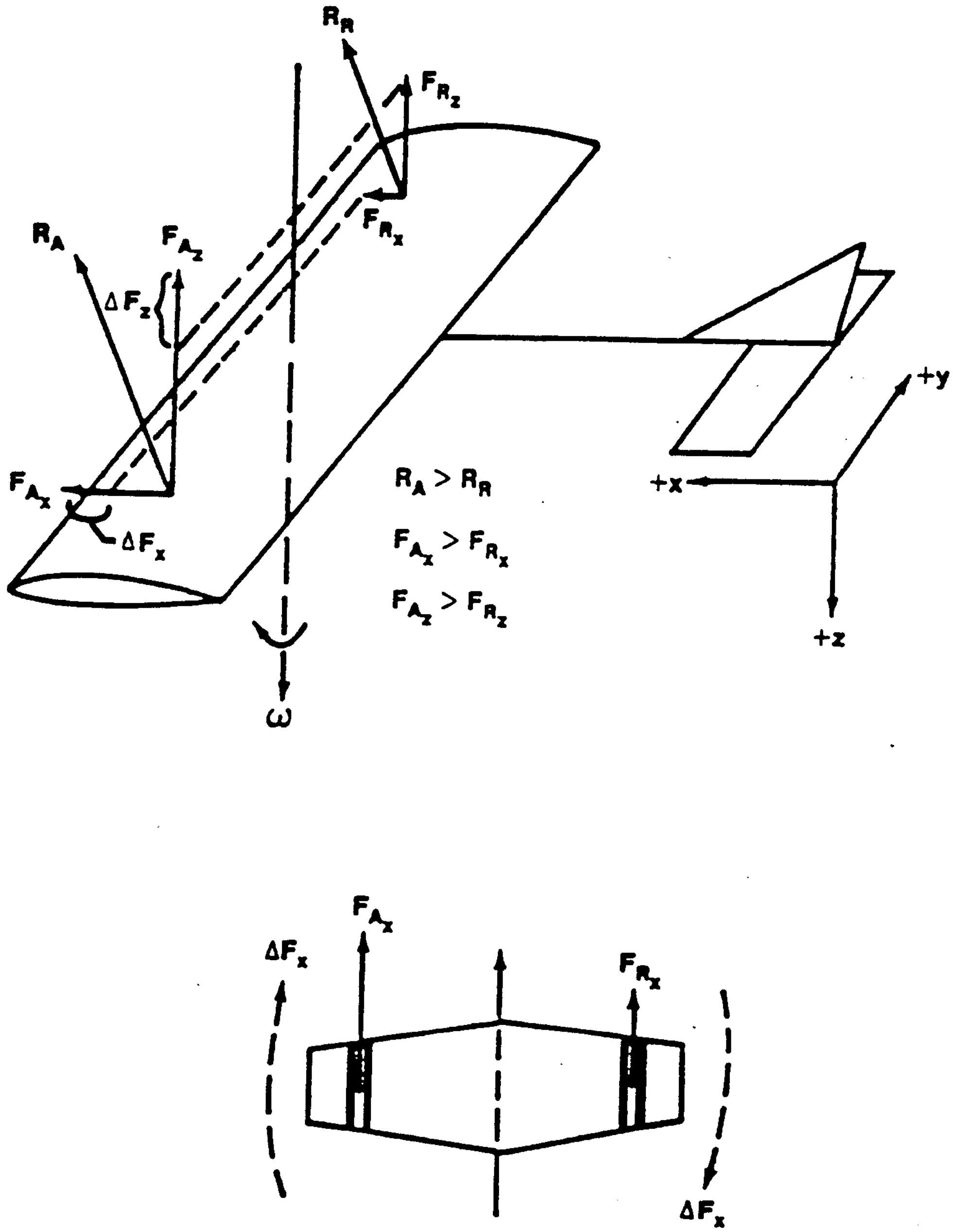


Figure H2 Autorotative Couple of a Wing

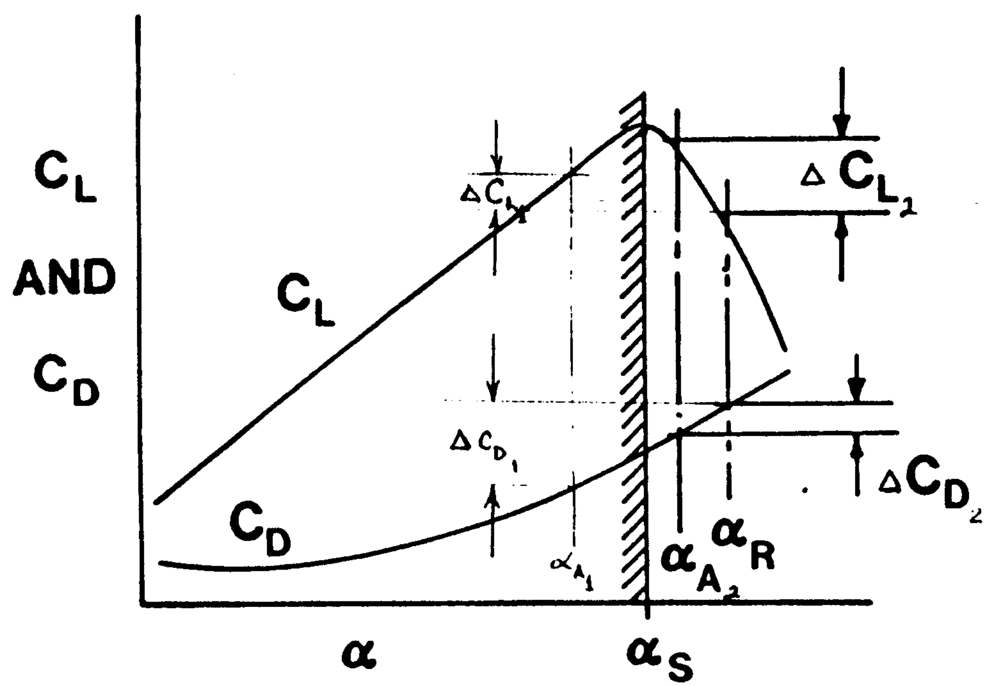


$F_{A_x} - F_{R_x} = \Delta F_X$ YAW SUSTAINING

SIMILARLY

$F_{A_z} - F_{R_z} = \Delta F_Z$ ROLL SUSTAINING

Figure H3 Autorotative Yawing Moments



- LIFT DEVELOPED BY THE RETREATING WING IS LESS THAN THAT DEVELOPED BY THE ADVANCING WING
- DRAG OF THIS RETREATING WING IS GREATER
- $\Delta C_{D_1} > \Delta C_{D_2}$ CAUSES SPIN TO

  SLOW AT HIGHER ANGLE OF ATTACK (FLAT PHASE) OF ASK-21 SPIN

THESE AERODYNAMIC EFFECTS PROLONG THE ROLLING MOMENTS (ΔC_L) AND YAWING MOMENTS (ΔC_D) RESPECTIVELY.

Figure H4 Autorotative Moment During a Spin

ASSUMPTIONS:

1. Vertical Flightpath ($\gamma = -90$ deg)
2. Constant Spin Rate (Ω)
3. Constant Pitch Angle (θ)
4. No Sideslip ($\beta = 0$)
5. Wings Level ($\phi = 0$)

Therefore:

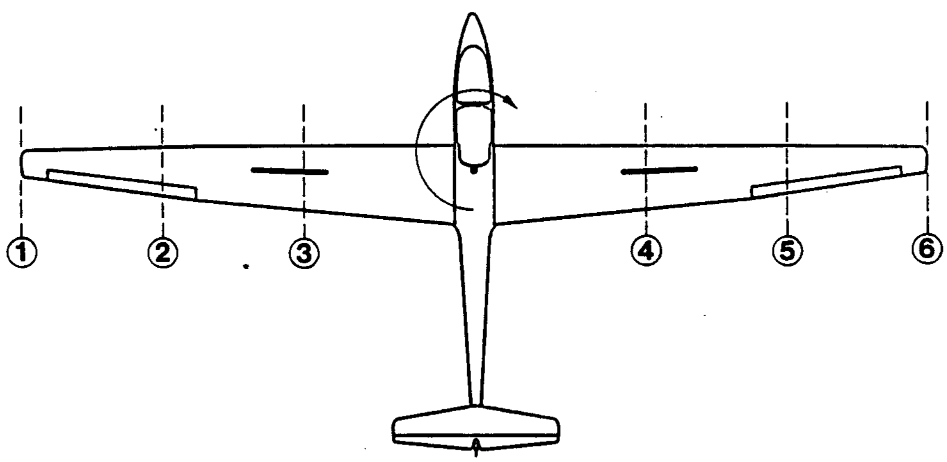
$\alpha_{cg} = \theta + 90$, $u = -\dot{h} \cos\alpha_{cg}$, $w = -\dot{h} \sin\alpha_{cg}$

$p = -\Omega \sin\theta$, $r = -\Omega \cos\theta$

LOCAL AOA EFFECTS:

$\Delta u = -r \cdot y$, $\Delta w = p \cdot y$

where y is the spanwise location (see diagram below)



Determine local AOA at the wingtips 1/3 and 2/3 semispan locations. The ASK-21 wingspan = 55.74 feet.

STATION ①: y = -27.87 ft	STATION ④: y = 9.29 ft
STATION ②: y = -18.58 ft	STATION ⑤: y = 18.58 ft
STATION ③: y = -9.29 ft	STATION ⑥: y = 27.87 ft

EXAMPLE I (STEEP PHASE OF SPIN):

$\theta = -60$ deg, $\Omega = 1$ turn/2.5 sec, $\dot{h} = -250$ ft/turn

$$\dot{h} = \frac{-250 \text{ ft}}{\text{turn}} \bullet \frac{1 \text{ turn}}{2.5 \text{ sec}} = -100 \text{ ft/sec}$$

Figure H5 Local Angles of Attack During a Spin

$\Omega = \dfrac{360 \text{ deg}}{2.5 \text{ sec}} \bullet \dfrac{2\pi \text{ rad}}{360 \text{ deg}} = 2.51 \text{ rad/sec}$

$p = -2.51 \sin(-60) = 2.17 \text{ rad/sec}$

$r = -2.51 \cos(-60) = 1.26 \text{ rad/sec}$

$\alpha_{cg} = -60 + 90 = 30 \text{ deg}$

$u = 100 \cos(30) = 86.60 \text{ ft/sec}$

$w = 100 \sin(30) = 50.00 \text{ ft/sec}$

LOCAL AOA CALCULATIONS:

① $\Delta u = -1.26 \cdot -27.87 = 35.12$ ft/sec, $\Delta w = 2.17 \cdot -27.87 = -60.48$ ft/sec

② $\Delta u = -1.26 \cdot -18.58 = 23.41$ ft/sec, $\Delta w = 2.17 \cdot -18.58 = -40.32$ ft/sec

③ $\Delta u = -1.26 \cdot -9.29 = 11.71$ ft/sec, $\Delta w = 2.17 \cdot -9.29 = -20.16$ ft/sec

④ $\Delta u = -1.26 \cdot 9.29 = -11.71$ ft/sec, $\Delta w = 2.17 \cdot 9.29 = 20.16$ ft/sec

⑤ $\Delta u = -1.26 \cdot 18.58 = -23.41$ ft/sec, $\Delta w = 2.17 \cdot 18.58 = 40.32$ ft/sec

⑥ $\Delta u = -1.26 \cdot 27.87 = -35.12$ ft/sec, $\Delta w = 2.17 \cdot 27.87 = 60.48$ ft/sec

$\alpha \text{ (local)} = \tan^{-1}\left(\dfrac{w + \Delta w}{u = \Delta u}\right)$

① $\alpha = \tan^{-1}\left(\dfrac{50.00 - 60.48}{86.60 + 35.12}\right) = -4.9 \text{ deg}$

② $\alpha = \tan^{-1}\left(\dfrac{50.00 - 40.32}{86.60 + 23.41}\right) = 5.0 \text{ deg}$

③ $\alpha = \tan^{-1}\left(\dfrac{50.00 - 20.16}{86.60 + 11.71}\right) = 16.9 \text{ deg}$

④ $\alpha = \tan^{-1}\left(\dfrac{50.00 + 20.16}{86.60 - 11.71}\right) = 43.1 \text{ deg}$

⑤ $\alpha = \tan^{-1}\left(\dfrac{50.00 + 40.32}{86.60 - 23.41}\right) = 55.0 \text{ deg}$

⑥ $\alpha = \tan^{-1}\left(\dfrac{50.00 + 60.48}{86.60 - 35.12}\right) = 65.0 \text{ deg}$

<u>EXAMPLE II (FLAT PHASE OF SPIN)</u>:

$\theta = -20$ deg, $\Omega = 1$ turn/3.0 sec, $\dot{h} = -200$ ft/turn

$\dot{h} = \dfrac{-200 \text{ ft}}{\text{turn}} \bullet \dfrac{1 \text{ turn}}{3.0 \text{ sec}} = -66.67 \text{ ft/sec}$

$\Omega = \dfrac{360 \text{ deg}}{3.0 \text{ sec}} \bullet \dfrac{2\pi \text{ rad}}{360 \text{ deg}} = 2.09 \text{ rad/sec}$

$p = -2.09 \sin(-20) = 0.71 \text{ rad/sec}$

$r = -2.09 \cos(-20) = -1.96 \text{ rad/sec}$

$\alpha_{cg} = -20 + 90 = 70 \text{ deg}$

$u = 66.67 \cos(70) = 22.80 \text{ ft/sec}$

$w = 66.67 \sin(70) = 62.65 \text{ ft/sec}$

Figure H5 Local Angles of Attack During a Spin (Continued)

LOCAL AOA CALCULATIONS:

① $\Delta u = -1.96 \cdot -27.87 = 54.63$ ft/sec, $\Delta w = 0.71 \cdot -27.87 = -19.79$ ft/sec
② $\Delta u = -1.96 \cdot -18.58 = 36.42$ ft/sec, $\Delta w = 0.71 \cdot -18.58 = -13.19$ ft/sec
③ $\Delta u = -1.96 \cdot -9.29 = 18.21$ ft/sec, $\Delta w = 0.71 \cdot -9.29 = -6.60$ ft/sec
④ $\Delta u = -1.96 \cdot 9.29 = -18.21$ ft/sec, $\Delta w = 0.71 \cdot 9.29 = 6.60$ ft/sec
⑤ $\Delta u = -1.96 \cdot 18.58 = -36.42$ ft/sec, $\Delta w = 0.71 \cdot 18.58 = 13.19$ ft/sec
⑥ $\Delta u = -1.96 \cdot 27.87 = -54.63$ ft/sec, $\Delta w = 0.71 \cdot 27.87 = 19.79$ ft/sec

$$\alpha\,(\text{local}) = \tan^{-1}\left(\frac{w + \Delta w}{u = \Delta u}\right)$$

① $\alpha = \tan^{-1}\left(\frac{62.65 - 19.79}{22.80 + 54.63}\right) = 29.0$ deg

② $\alpha = \tan^{-1}\left(\frac{62.65 - 13.19}{22.80 + 36.42}\right) = 39.9$ deg

③ $\alpha = \tan^{-1}\left(\frac{62.65 - 6.60}{22.80 + 18.21}\right) = 53.8$ deg

④ $\alpha = \tan^{-1}\left(\frac{62.65 + 6.60}{22.80 - 18.21}\right) = 86.2$ deg

⑤ $\alpha = \tan^{-1}\left(\frac{62.65 + 13.19}{22.80 - 36.42}\right) = 100.2$ deg

⑥ $\alpha = \tan^{-1}\left(\frac{62.65 + 19.79}{22.80 - 54.63}\right) = 111.6$ deg

Figure H5 Local Angles of Attack During a Spin (Concluded)

- THE SPIN AXIS CAN BE ORIENTED TO PRODUCE A PITCHING MOMENT
- ASSUME AN UPRIGHT, RIGHT SPIN

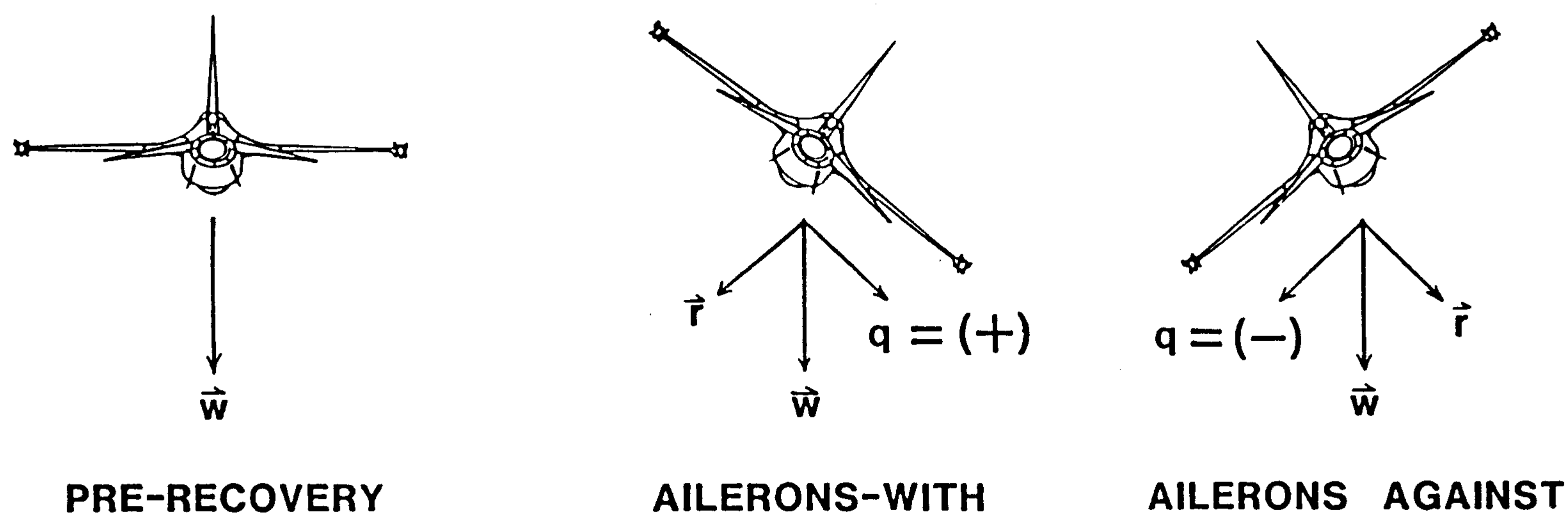


Figure H6 Aileron Effects During a Spin

the inertia terms of the yaw acceleration equation of motion (Figure H7).

For the ASK-21, $I_{zz} > I_{xx} > I_{yy}$. Therefore, ailerons against the spin produced antispin yaw acceleration. Conversely, ailerons with the spin produced prospin yaw acceleration.

AILERON EFFECTS

REPOSITION AIRCRAFT ATTITUDE SPIN AXIS (INERTIAL EFFECTS)

$$\dot{p} = \ldots + \frac{I_y - I_z}{I_x} qr$$

$$\dot{r} = \ldots + \frac{I_x - I_y}{I_z} pq$$

→ PREDOMINANT TERM IN RECOVERY

NOTE:

1. SIGN OF $(I_x - I_y)$ → FUNCTION OF AIRCRAFT LOADING
   - (+) → WING LOADED
   - (−) → FUSELAGE LOADED

2. SIGN OF $|pq|$ AND $|I_x - I_y|$ DETERMINES SIGN OF YAW ACCELERATION ($\dot{r}$)

Figure H7 Equations of Motion

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APPENDIX I

MANUFACTURER'S TEST DATA

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MANUFACTURER'S TEST DATA

The following flight test reports document testing done by the Schleicher Aircraft Company. The first two pages are a letter written to USAFA from the Alexander Schleicher Aircraft Company on 20 December 1988 outlining the flight test reports. Schleicher determined the forward cg boundary for spins to be 0.4 meters or 15.75 inches. The AFFTC test team found this cg boundary to be 12.5 inches for incipient spins and 13.5 inches for sustained spins. Particularly for low inertia configurations, the forward cg boundary for sustained spins was 15.0 inches. Therefore, Schleicher's cg of 15.75 inches was not far off for low inertia configurations.

Schleicher was also unable to achieve inverted spins. The AFFTC test team achieved inverted spins at cg's aft of 15.8 inches.

Please find enclosed our comments and copies (as well as translations) of the ASK 21 spin test reports which we could find here.

The ASK 21 does not spin - or does only just spin - when two persons are on board. For that reason the glider could not be used for spin training. As this, however, is mandatory for training sailplanes in Australia and Switzerland, the Technical Note No.4 (copy enclosed) was issued to handle the spin weights at the tail. Australia eventually has not adopted the ASK 21 as a basic trainer; they want a trainer which spins at nearly all c.g. positions.

The Swiss have adopted the TN and are happy with it.

The German Aero Club - together with the LBA - decided that spins must not be performed with any training twoseaters. It is sufficient and more important to demonstrate to the student flyer how to recover from wing dropping and/or incipient spin as quickly as possible.

USAF wanted the ASK 21 for spin training and therefore accepted the tail weights. Capt.Valdez reported once flat spins and Schleicher tried to explain the situation and recommended more forward c.g. positions if heavy pilots sit in the front seat requiring heavy tail weights. There was no answer if the recommendation worked and what the new limits are. Please report on this now.

As Annex (1) you find a copy of the LFSM Airworthiness Requirements For Sailplanes And Powered Sailplanes. The relevant requirements are marked.

As Annex (2) you get a partial copy and translation of the Schleicher test reports in 1979 and 1980.

As Annex (3) you get a partial copy and translation of the test reports of Feb.23, 1982, and May 18, 1983, about spin tests with the tail weights.

As Annex (4) you get a partial copy and translation of the test report done by R.Matthes who made the aerobatic test flights for our ASK 21.

As Annex (5) you get a partial copy and translation of the test report done by G.Stich, DFVLR (German NASA), who also made aerobatic test flights for the ASK 21.

We hope that these reports help you to correlate your test results with those given by us.

You received already (by fax and letter) the calculation of the impact strength and of the necessary deceleration of the ASK 21 which was necessary to break the tail off.

If you think that one of our designers or any other competent person whom we would have to find in the U.S., could be helpful for your investigations, please let us know.

In any case please keep and store the wreck so that we can look at it whenever we are in the U.S. anyway and possibly find an occasion to visit you.

In the meantime we contacted the LBA and asked them to be prepared with any ASK 21 accident reports if FAA Brussels asks them on your behalf for details. We are also interested to learn what they recorded.

Thank you very much for your kind cooperation.

Yours sincerely,

*ALEXANDER SCHLEICHER
GmbH & Co.*

Roland Waibel

Encl.s

cc: EASTERN SAILPLANE

ANNEX (2)

(Enclosure to our letter dated Dec.20, 1988)

TRANSLATION BY A.SCHLEICHER

Report on test flights carried out with the glider
ASK 21, 21001, D-1521

Take off airfield: Poppenhausen - Huhnrain.

2041
C.G. positions
The c.g. range from r = 0,234 m to r = 0,480 m was covered by flight tests.
This results in an approved c.g. range of: 0,234 m to 0,480 m - (0,01 * 1,121) = 0,469 m.

SPINS

2501, 2513, 2515
Spin tests were performed covering the entire c.g. range as given in the enclosed diagram "Knüppelwege über CA" (= stick displacement versus CL). It was demonstrated that the sailplane does not spin at forward c.g. positions, but does develop a spiral dive.
Only for c.g. positions greater than r = 0,4 m constant spins are possible.
The sailplane spins in an oscillating mode one turn steep, one turn more flat and then steeper again. There is about 1/2 turn after recovery initiated according to the standard method.

Normal control measures for spins:
Elevator fully pulled, rudder fully deflected, aileron in neutral position. Aileron applied against the direction of rotation of the spin results in a sliplike and unpleasant recovery from spin. Aileron applied in the direction of the rotation of the spin makes no measurable change in spin characteristics.
It seems to be so that even more aft c.g. positions than demonstrated here can be safely controlled.

2517
It is no problem to round out from a recovery without major structural loads.

2521
Tendency to spiral dive
Under the condition that the spiral dive is recognized as such in good time and is not misinterpreted as a spin, the recovery from the spiral dive is not an extraordinary effort. There are no control difficulties for recovery.

ALEXANDER SCHLEICHER
GmbH & Co.

ANNEX (3)

(Enclosure to our letter dated Dec.20, 1988)

TRANSLATION BY A.SCHLEICHER

ASK 21, 21095, HB-1630
<u>Test flights report dated February 19, 1982</u>

Test pilots:	Edgar Kremer	(88,2 kg including chute)
	Martin Heide	(79,5 kg including chute)

Spin tests with lead disks at the tail (spin ballast).
Left and right turn spins were performaed.

1. Flight (14:26- 14:40) with 6 disks; r = 0,38 m:
The pilot tried to enter into a spin by using the following procedures :
- rudder into intended spin direction at a developed stall
- rudder into intended spin direction at a developed stall and in addition opposite aileron
- dynamic pullup and stall, rudder into intended spin direction
- stalled attitude in a turn and full rudder applied into intended direction of the spin.

No wing dropping for turning into a spin could be achieved.

2. Flight (14:47- 15:00) with 8 disks; r = 0,397 m:
(Full) rudder deflection applied in a stalled attitude succeeded now in a spin. After one very steep first spin turn a flatter phase followed (about 1/2 to 3/4 turn); then stationary spins follow with a great pitch down angle (4 spin turns were done). Recovery was possible by applying opposite rudder alone - also from the flatter phase noticeable additional turns could not be found. With elevator neutral and opposite rudder a nearly instant stop of the turn is achieved.

3. Flight (15:08 - 15:22) with 10 disks; r = 0,414 m:
No differences for entry of spins. The spin starts very steep and gets flatter after one turn. After about 1/2 flat turn the pitch gets steeper again. The sailplane then does not continue a steep and stationary spin (as before above), but oscillates with a steep and flat phase, as it began after spin entry. It could not be noticed that the flat phases get more or even flatter.
Four to five turns were done for the tests.
Also for this test recovery was possible with opposite rudder alone (with the stick held still full back). The behaviour is the same as for the second flight.

Poppenhausen, 23.02.82

(M.Heide) (R.Kaiser)

ASK 21, s/n 21164, HB-1700

Flight report May 18, 1983

Pilot: Martin Heide; Gp = 81 kp including chute

Aerotow altitude: 2500 m

The sailplane was balanced by the use of tail weights to an in flight c.g. of r = 0,48 m. This is the same position as the rearmost one used for the longitudinal stability tests.

Spins

The spin test covered the c.g. range up to 0,48 m. In front of an in flight c.g. position of 0,4 m spins are impossible. After an entry the sailplane performs a spiral dive.

For aft c.g.positions up to the maximum of 0,48 m the following characteristics are found:
After spin entry the sailplane performs an oscillating spin sequence, beginning with one steep turn, followed by a flatter turn, then again a steeper turn and so on.

Control setting normal for spins :
Elevator control full back, rudder fully deflected, aileron in neutral position. Aileron applied against the direction of rotation of the spin (opposite aileron) results in a sideslip-like and unpleasant termination of the spin. Aileron applied into the direction of rotation of the spin makes no noticeable change to the spin characteristics.
Full rudder deflection opposite to the spin direction terminates the spin without remarkable additional turn.
Additional turn after recovery initiated by use of the standard method is about 1/2 turn.
Up to six spin turns were performed for the tests.

Airbrake Actuation

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M.Heide R.Kaiser

ANNEX (4)

(Enclosure to our letter dated Dec.20, 1988)

TRANSLATION BY A.SCHLEICHER

VI.3 Spin tests (category N) and introduction in special flight attitudes as per § 81 (3) of the German Luft Pers.V.

Report by Rudi Matthes:
On one of the test flights one spin turn for each direction was performed. However, the tests were not further extended, as I assumed that all spin tests according to category N had already been demonstrated. At 70 km/h IAS - entry from level flight - the ASK 21 spins steeply and accurate. The sailplane terminates the one turn without noticeable additional turn after the rudder had been set to neutral position.
The test flight was a solo flight with the following data: m = 469 kg; c.g. position r = 0,426 m behind datum.
(Permissible aftmost c.g. is: r = 0,480 m).

For values r ≤ 0,426 the ASK 21 obviously does not spin. This was verified on Feb.18, 1980, in a flight test with a series production sailplane (D-6537, s/n 21005). The c.g. position was 0,405 m.

Following a spin entry with rudder and elevator as well as a spin entry with rudder, elevator and opposite aileron, the wing dropping is to the usual direction. The sailplane fulfills up to 1/2 turn (x-axis) with the airflow attached and tries self-recovery. The loss of altitude is about 180 m. The proneness to spin seems to begin at c.g. positions as of r = 0,40 m behind datum.

Left and right spins can be entered at normal c.g. by applying really full rudder. The ASK 21 spins steeply and accurate. The spin is instantly terminated when the pilots starts to set the rudder to neutral; this is due to the T-tail effect as the rudder is fully exposed to the airflow.

ANNEX (5)

(Enclosure to our letter dated Dec.19, 1988)

TRANSLATION BY A.SCHLEICHER

Dipl.Ing.Stich. Braunschweig, 21.03.1980

Aerobatics flight testing with the glider ASK 21, OO-ZLN, carried out at Braunschweig on March 20, 1980

With five aero tows to FL 80, two test pilots with a co-pilot in the second seat could terminate the aerobatics flight testing. The in flight c.g. was in the forward to middle range. The Pitot probe was made longer by 7 cm (by an insert).

Spins: For middle to forward c.g. positions spins are not possible.

Inverted flight: -
-
-
-

Inverted spins could not be achieved neither by static nor by dynamic entry. There is a strong wing dropping tendency, but by one half positive loop level flight can be regained at 130 to 150 km/h without major loss in altitude.

LIST OF ABBREVIATIONS AND SYMBOLS

Abbreviation or Symbol	Definition	Unit
A/C	aircraft	---
AFB	Air Force Base	---
AFFTC	Air Force Flight Test Center	---
AGL	above ground level	---
AOA	angle(s) of attack	deg
CFIG	Certified Flight Instructor - Glider	---
cg, CG	center of gravity	pct MAC
cos	cosine	---
DL	datum line	---
deg	degree(s)	---
FAA	Federal Aviation Administration	---
FAR	Federal Aviation Regulation	---
FWD	forward	---
g	acceleration due to gravity	32.2 fps^2
h	vertical velocity	ft/sec
in, IN	inches	---
I_{xx}	rolling moment of inertia	$lb\text{-}in^2$
I_{yy}	pitching moment of inertia	$lb\text{-}in^2$
I_{yy_c}	cockpit weights I_{yy} translated to in-flight cg	---
I_{yy_f}	front seat pilot I_{yy} translated to in-flight cg	---
I_{yy_o}	empty aircrart I_{yy} translated to in-flight cg	---

LIST OF ABBREVIATIONS AND SYMBOLS (Continued)

Abbreviation or Symbol	Definition	Unit
I_{yy_r}	rear seat pilot I_{yy} translated to in-flight cg	---
I_{yy_t}	tail weights I_{yy} translated to in-flight cg	---
I_{zz}	yawing moment of inertia	lb-in^2
JAR	Joint Aviation Regulations	---
KIAS	knots indicated airspeed	---
lb, LB	pound(s)	---
MIL-STD	military standard	---
msl	mean sea level	---
N/A	not applicable	---
No	number	---
PIC	pilot in command	---
PSG	poststall gyration	---
p	body axis roll rate	deg/sec
r	body axis yaw rate	deg/sec
rad	radians	---
S/N	serial number	---
SPORT	space positioning optical radar tracking	---
sin	sine	---
$\tan^{-1}$	arctangent	---
U.S.	United States	---
USAF	United States Air Force	---
USAFA	United States Air Force Academy	---

LIST OF ABBREVIATIONS AND SYMBOLS (Concluded)

Abbreviation or Symbol	Definition	Unit
USAFTPS	United States Air Force Test Pilot School	---
u	body axis forward velocity	ft/sec
VHF	very high frequency	---
W_c	weight of the cockpit weights	lb
W_f	front seat pilot weight	lb
W_r	rear seat pilot weight	lb
W_t	weight of the tail weights	lb
Wts	weights	lb
w	body axis vertical velocity	ft/sec
y	spanwise location	ft
/	per	---
@	at	---
>	greater than	---
Δ	delta	---
α	angle of attack	deg
π	PI	3.1416
γ	flightpath angle	deg
Ω	angular velocity	deg/sec
θ	pitch angle	deg
β	sideslip angle	deg
ϕ	bank angle	deg
α_{cg}	angle of attack at the cg	deg

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