

412TW-TP-14-18



DG-1000S STALL AND SPIN FLIGHT TEST AND EVALUATION

**Christopher J. Liebmann
Project Engineer**

**Timothy S. McDonald
Project Pilot**

JANUARY 2015

TEST PLAN

**4
1
2
T
W**

Approved for public release Distribution Statement A: distribution is unlimited.
412TW-PA-21400

**412TH TEST WING
EDWARDS AIR FORCE BASE, CALIFORNIA
AIR FORCE MATERIEL COMMAND
UNITED STATES AIR FORCE**

This test plan (412TW-TP-14-18, *DG-1000S Stall and Spin Flight Test and Evaluation*) was submitted under job order number (JON) MTDG1000 at Edwards AFB, California.

Prepared by:

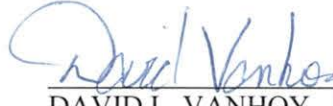
Submitted by:



CHRISTOPHER J. LIEBMANN

Project Engineer

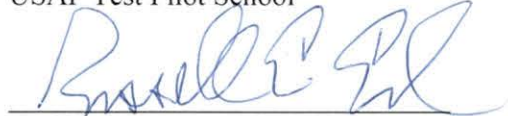
USAF Test Pilot School



DAVID L. VANHOY

Technical Director

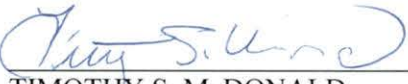
USAF Test Pilot School



RUSSELL E. ERB

Project Engineer

USAF Test Pilot School



TIMOTHY S. McDONALD

Project Pilot

USAF Test Pilot School

REPORT DOCUMENTATION PAGE				Form Approved OMB No. 0704-0188	
The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to the Department of Defense, Executive Service Directorate (0704-0188). Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ORGANIZATION.					
1. REPORT DATE (DD-MM-YYYY) 28-01-2015		2. REPORT TYPE Final Report		3. DATES COVERED (From - To) 15 Jan 2015 – 31 Mar 2015	
4. TITLE AND SUBTITLE DG-1000S Stall and Spin Flight Test and Evaluation Test Plan				5A. CONTRACT NUMBER	
				5B. GRANT NUMBER	
				5C. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) Christopher J. Liebmann, Project Engineer Russell E. Erb, Project Engineer Timothy S. McDonald, Project Pilot				5D. PROJECT NUMBER	
				5E. TASK NUMBER	
				5F. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) AND ADDRESS(ES) 412th Test Wing Edwards AFB CA 93524				8. PERFORMING ORGANIZATION REPORT NUMBER AFTC-TP-14-18	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) USAF TPS 220 South Wolfe Ave Edwards AFB, CA, 93524-6385				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release Distribution Statement A: distribution is unlimited. 412TW-PA-21400					
13. SUPPLEMENTARY NOTES SC: 012100 CA: 412th Test Wing, AFB CA Print this document in COLOR .					
14. ABSTRACT This test plan presents the ground and flight test plan for the DG-1000S stall and spin flight test and evaluation by the USAF Test Pilot School (TPS), 412th Test Wing, Edwards AFB, CA. The DG-1000S stall and spin flight test will evaluate the departure and spin susceptibility of the aircraft as a function of weight and C.G., definition of spin modes and mode characteristics as well as the control effects on those modes. The requesting agency is the USAF TPS, Edwards AFB, CA. The lead developmental test organization (LDT0) is the 412th Test Wing, Air Force Test Center, Edwards AFB. Testing will be conducted by the USAF TPS under job order number (JON) MTDG1000. At the conclusion of testing, the USAF TPS will provide a final technical report.					
15. SUBJECT TERMS gliders stalls departures sailplanes flight testing spin weight ballast spins spin modes					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report	18. NUMBER OF PAGES 83	19A. NAME OF RESPONSIBLE PERSON 412 TENG/EN (Technical Publications Office)
a. REPORT U	b. ABSTRACT U	c. THIS PAGE U			19B. TELEPHONE NUMBER (INCLUDE AREA CODE) 661-277-8615

This page was intentionally left blank.

When U.S. Government drawings, specifications, or any other data are used for any purpose other than a definitely related government procurement operation, the government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the government may have formulated, furnished or in any way supplied the said drawings, specifications, or any other data is not to be regarded by implication or otherwise, as in any manner licensing the holder or any other person or corporation or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

Do not return this copy; retain or destroy.

EXECUTIVE SUMMARY

This test plan presents the ground and flight test plan for the DG-1000S stall and spin flight test and evaluation by the USAF Test Pilot School (TPS), 412th Test Wing, Edwards AFB, CA. The DG-1000S stall and spin flight test will evaluate the departure and spin susceptibility of the aircraft as a function of weight and center of gravity (C.G.), determine the spin modes and mode characteristics, as well as determine the control effects on those modes.

The requesting agency is the USAF TPS, Edwards AFB, CA. The lead developmental test organization (LDTO) is the Air Force Test Center (AFTC). The Executing Test Organization (ETO) is the 412TW/USAF TPS under job order number (JON) MTDG1000. At the conclusion of testing, the USAF TPS will provide a final technical report. Testing will be conducted from 15 January through 31 March 2015. Testing consists of approximately 120 sorties encompassing approximately 40 flying hours. Testing will be accomplished using aircraft registration number N801DG. All testing will be performed at Mountain Valley airport, Tehachapi, CA and North Base, Edwards AFB, CA. The test pilots for this program will be TPS graduates; all personnel qualifications to be aircrew as a part of this program will be documented in the safety package.

Currently, the Glider Spin event at USAF TPS is only taught in the ASK-21 at Mountain Valley Airport, Tehachapi, CA. This particular ASK-21 has accumulated in excess of 8,100 flight hours, and the remaining service life is coming into question. The TPS/CT has identified a need to sustain/expand the capability of USAF TPS to conduct the Glider Spin event using another model of glider. While the DG-1000S was certified for spins under the Joint Aviation Regulations, a flight test evaluation is required by the USAF of any new glider used in the Glider Spin event. The curriculum development effort will determine whether existing courseware for the ASK-21 can be adapted.

This flight test program has one overall test objective: determine whether the DG-1000S can meet the USAF TPS spin test training and education requirements. This will be primarily accomplished by evaluating the stall, departure, spin, and recovery characteristics of the DG-1000S over its executable range of C.G. and pitch inertia.

The specific test objectives for the DG-1000S begin with a determination of mass properties and longitudinal moment arms to establish the validity of flight manual guidance. The stall characteristics will be evaluated. Spin susceptibility testing will determine the most forward C.G. and pitch inertia configuration at which the aircraft will enter and sustain spins. The upright spin and recovery characteristics will be evaluated using selected entry and recovery procedures, including use of selected control inputs during spins. Inverted spins will also be demonstrated at selected conditions.

A build-up approach to testing will be employed beginning with the C.G. configurations expected to be least spin susceptible and least dynamic. Additionally, configurations with smaller pitch inertias, as controlled with tail ballast and cockpit loading, will be tested before configurations with higher pitch inertias. All testing will be conducted in the Aerobatic category (18-m span with no water ballast) to allow for greater load-factor limits during dive pullout. The flight manual recovery was successfully used to achieve FAA certification, and will therefore be the first recovery attempted. Once confidence in the recoverability of a configuration is established, alternate recovery procedures such as the Rudder Only, NACA Modified, Neutral, and hands-off recoveries will be attempted. Effects of pro-spin and anti-spin lateral control stick inputs will additionally be investigated.

Evaluation criteria are chiefly focused on identifying educational value and possible issues for further development. The results from this flight test program will be used to provide recommendations regarding a re-development of the TPS Glider Spin event with the DG-1000S.

TABLE OF CONTENTS

	<u>Page No.</u>
EXECUTIVE SUMMARY	iii
TABLE OF CONTENTS.....	iv
1.0 INTRODUCTION	1
1.1 General	1
1.2 Background	1
1.3 Test Item Description	2
1.4 Overall Test Objective.....	4
1.5 Limitations.....	5
1.6 Test Resources.....	5
1.6.1 Modeling and Simulation.....	5
1.6.2 Test Facilities.....	6
1.6.3 Frequency Authorization	6
1.6.4 Support Aircraft	6
1.6.5 Support Vehicles.....	6
1.6.6 Test Range	6
1.6.7 Instrumentation	6
1.6.8 Test Support Facilities and Equipment	9
1.7 Safety Requirements.....	9
1.8 Security Requirements.....	9
1.9 Test Project Management	9
1.9.1 Key Personnel	9
1.9.2 Program Schedule	9
1.10 Test Environment	9
1.11 Environmental Impact Assessment	10
2.0 TEST AND EVALUATION	11
2.1 Specific Test Objectives (STOs)	11
2.2 Definitions and Test Methodology Applicable to STOs 2-8	11
2.2.1 Stall	12
2.2.2 Departure	12
2.2.3 Spin	12
2.2.4 Dive Pullout & Spiral Dive	13
2.2.5 Mass Property Effects on Spins	13
2.2.6 Extent of Spin Entry Determination.....	15
2.2.7 Extent of Spin Characteristic Evaluation	16
2.2.8 Extent of Spin Recovery Evaluation.....	16
2.2.9 Extent of Control Effects Evaluation	17
2.2.10 Repeatability	17
2.2.11 Progression of Testing	18
2.2.12 Build-Up Approach to Testing.....	20
2.3 MOPs by Specific Test Objective	21
3.0 TEST PROCEDURES	26
3.1 Test Readiness Review.....	26
3.2 Test Preparation.....	26

3.3 Test Execution	26
3.3.1 Spin Entry Procedures.....	26
3.3.2 Spin Recovery Procedures	30
3.3.3 Dive Pullout Procedures	31
3.4 Posttest Briefing	31
4.0 TEST REPORTING.....	32
5.0 LOGISTICS	33
5.1 Transportation	33
5.2 Support	33
5.3 Maintenance	33
5.4 Training	33
5.5 Administration Support	33
5.6 Test and Support Personnel	33
5.7 Schedule	33
REFERENCES	34
APPENDIX A – ENVIRONMENTAL CHECKLIST	A-1
APPENDIX B – DETAILED TEST ITEM DESCRIPTION	B-1
APPENDIX C – AEROTOW PROCEDURES	C-1
APPENDIX D – SPIN THEORY	D-1
APPENDIX E – TEST POINT MATRIX	E-1
APPENDIX F – ANALYSIS OF EXECUTABLE CONFIGURATIONS.....	F-1
APPENDIX G – LIST OF ABBREVIATIONS, ACRONYMS, AND SYMBOLS	G-1
APPENDIX H – DISTRIBUTION LIST.....	H-1

This page was intentionally left blank.

1.0 INTRODUCTION

1.1 General

This test plan presents the ground and flight test plan for the DG-1000S stall and spin flight test and evaluation by the USAF Test Pilot School (TPS), 412th Test Wing, Edwards AFB, CA. The DG-1000S stall and spin flight test will evaluate the departure and spin susceptibility of the aircraft as a function of weight and center of gravity (C.G.), determine the spin modes and mode characteristics, as well determine as the control effects on those modes.

The requesting agency is the USAF TPS, Edwards AFB, CA. The lead developmental test organization (LDTO) is the Air Force Test Center (AFTC). The Executing Test Organization (ETO) is the 412TW/USAF TPS under job order number (JON) MTDG1000. At the conclusion of testing, the USAF TPS will provide a final technical report.

Testing will be conducted from 15 January through 31 March 2015. Testing consists of approximately 120 sorties encompassing approximately 40 flying hours. Testing will be accomplished using aircraft registration number N801DG. All testing will be performed at Mountain Valley airport, Tehachapi, CA and North Base, Edwards AFB, CA. The test pilots for this program will be TPS graduates; all personnel qualifications to be aircrew as a part of this program will be documented in the safety package.

1.2 Background

The foundational principles of the USAF TPS curriculum are introduced in the classroom; subsequently, those principles are demonstrated in a relevant flight test environment. These flight test curriculum events occur in a variety of military and civil aircraft including gliders; the gliders particularly serve as an example of a classically-behaved wing-loaded aircraft free from the influence of power effects.

The TPS education division flying qualities (FQ) branch (TPS/EDF) has identified three major areas of focus in the FQ curriculum, one of which is envelope expansion testing and risk reduction. Stall, departure, and spin testing is a major topic included as a part of this area of focus. To demonstrate classical stall and spin characteristics, a flying curriculum event was created known as the “Glider Spin” event. The TPS/EDF master instructor has determined that the learning objectives in the Glider Spin event are expected to be a required part of the TPS curriculum for the foreseeable future. The learning objectives for the Glider Spin event are taken from the Glider Spin Mission Planning Guide (reference 1):

- Describe how the buildup approach is applied to stall/spin testing with regard to:
 - CG location,
 - Inertial effects, and
 - Aggravating inputs.
- Determine an aircraft’s departure susceptibility in accordance with MIL-F-83691B.
- Characterize a spin using the spin mode modifiers described in MIL-F-83691B.
- Evaluate the effectiveness and ease of execution of the spin recovery procedures that involve various combinations of rudder and stick inputs in a wing-loaded aircraft including:
 - Controls Neutral (Phase A/B/C stalls only)
 - Flight manual spin recovery procedure
 - Other procedures with different control inputs/phasing
- Demonstrate the effects of lateral stick inputs during a spin in a wing-loaded aircraft.
- Describe the relevant events that occurred in an aircraft after a highly dynamic test event.

Currently, the Glider Spin event is only taught in the ASK-21 glider at Mountain Valley Airport, Tehachapi, CA. The ASK-21 glider was approved for use in the USAF TPS curriculum as a result of the flight test documented in *AFFTC-TR-89-27 Schleicher ASK - 21 Glider (TG-9) Stall and Spin* (reference 2). This particular ASK-21 airframe (registration number N361KS) has accumulated in excess of 8,100 flight hours, and the remaining service life is coming into question. As a model, the ASK-21 is no longer produced for use with tail weights, which are required to achieve the cg locations required for spins. Thus, any other ASK-21 that could be acquired would not be new – more than likely, it would be of similar age and wear to N361KS. Dependence on this single asset can present significant scheduling challenges for the USAF TPS director of operations (DO). Additionally, flexibility is greatly limited in developing the EDF curriculum.

The TPS technical director (TPS/CT) has identified a need for curriculum development to sustain/expand the capability of USAF TPS to conduct the Glider Spin event using another model of glider. However, to ensure effective instruction, this curriculum development effort requires a flight test evaluation by the USAF of any new Glider Spin event aircraft. The curriculum development effort will determine whether existing courseware for the ASK-21 can be adapted, or whether a new approach is necessary. Additionally, inverted spins will be investigated for possible addition into the Glider Spin event.

A civil-owned Glaser-Dirks DG-1000S glider is currently used by USAF TPS for non-spin glider events. However, the DG-1000S is certified under the airworthiness requirements of Joint Aviation Regulation (JAR) Part 22 for spins in the Utility category, according to the flight manual (reference 3). All testing will be conducted in the Aerobatic category (18-m span with no water ballast) to allow for greater load-factor limits.

The testing proposed by this test plan is not an aircraft certification effort, nor is it a mishap investigation. Therefore, this testing is intentionally limited in scope. The limited scope does not capture all possible stall/spin entries and recovery procedures, student errors, and aircraft configurations. Specifically, entries involving steep banks (simulating thermalling, aerobatics, or traffic patterns) are beyond the scope of this program.

To date, the DG-1000S has not yet been evaluated for spin characteristics in flight test by the USAF. In 2011, the TG-16A was tested for use at the USAF Academy. The TG-16A is an aerobatic version of the DG-1001, which is a fixed-gear version of the DG-1000S. The DG-1001 and the DG-1000S share the same flight manual. No adverse characteristics were noted during stall or spin recoveries over a range of C.G. and pitch-axis moment of inertia (I_{yy}) conditions. This testing was documented in reference 4. Reference 3 currently provides a spin recovery procedure but no information on spin characteristics.

1.3 Test Item Description

The system under test will consist of the test aircraft with a crew of 1 or 2. The test aircraft will be a Glaser-Dirks DG-1000S glider, registration number N801DG. The aircraft is a two-place high-performance sailplane designed for training, cross-country flying, and aerobatic training. The best glide ratio of the DG-1000S ranges from 41.5-46.6, depending on speed and wingtip configuration. It features a mid-mounted wing, T-tail, tandem seating, conventional reversible flight controls, and airbrakes. The undercarriage consists of a high spring-mounted retractable main wheel with disc brake and a tail wheel. The wing is constructed from carbon-fiber reinforced plastic. The fuselage is mainly fiberglass, with steel as necessary for the landing gear.

Reference 3 was originally written in German. As a result of the translation and multiple revisions, there exists inconsistency or ambiguity in certain wordings. The test team has made its best effort to explain and resolve these inconsistencies as they became apparent including corresponding with the aircraft manufacturer directly.

The maximum speed is 146 KIAS. The team will use a maneuvering speed of 100 KIAS. See Appendix B: Detailed Test Item Description for a thorough explanation. At or below maneuvering speed in the aerobatic category with airbrakes retracted, the glider has load factor limits of +7.0/-5.0 g. In the aerobatic category, the maximum takeoff and landing weight is 1,389 lbs.

The test aircraft is available with two sets of wingtips which provide for different wingspans: an 18-meter wingspan or a 20-meter wingspan with winglets. Spins are approved with all spans. Additional maneuvers including half-rolls and inverted flight are only authorized with the 18-meter wingspan. See reference 3, section 2.6: “Approved manoeuvres” for full details.

The allowable C.G. range in flight is from 7.48 in. to 17.32 in. aft of the datum located at the wing leading edge at the root rib (1 in. C.G. travel = 2.65 % MAC). The C.G. is best controlled with the selection of crewmembers and ballast. There are provisions for ballast in the front and aft cockpits, as well as in the aircraft tail. Ballast bags (approximately 25 lbs each) may be placed under either seat. Trim weights are available in two sizes: 1.2 kg or 2.4 kg. Ballast boxes are installed in the front cockpit to hold up to 9.6 kg (21.1 lbs) of trim weights. A ballast box is installed in the tail of the aircraft which can hold up to 12 kg (26.5 lbs) of trim weights. The tail trim weights are secured by a rod with springs attached to a plastic cover which is then sealed with tape. Provisions exist for the use of water ballast, but the use of water ballast is prohibited by reference 3 during aerobatics. No water ballast will be used during this test program.

A three-view drawing of the aircraft is shown in figure 1: DG-1000S Three-View. A detailed description of the test aircraft is contained in Appendix B: Detailed Test Item Description. Thorough mass properties information will be obtained during ground testing.

The aircraft is considered representative of the configuration and mass properties that will be used in USAF TPS curriculum flights. However, some modifications have been made since production. In the judgment of the test team) the modification with the most potential to affect out-of-control characteristics is a Kevlar skid plate installed on the underside of the aircraft nose. This skid plate reduces damage to the aircraft, should an abrupt brake application cause the nose to contact the runway during landing rollout. Past high-AOA test experience with other USAF aircraft indicates that asymmetric vortex shedding from the nose may change the yawing moments on the aircraft. Given the large moment arm afforded by the aircraft nose, the spin characteristics of N801DG may be different from other DG-1000S aircraft. More information regarding this and other aircraft modifications may be found in Appendix B: Detailed Test Item Description.

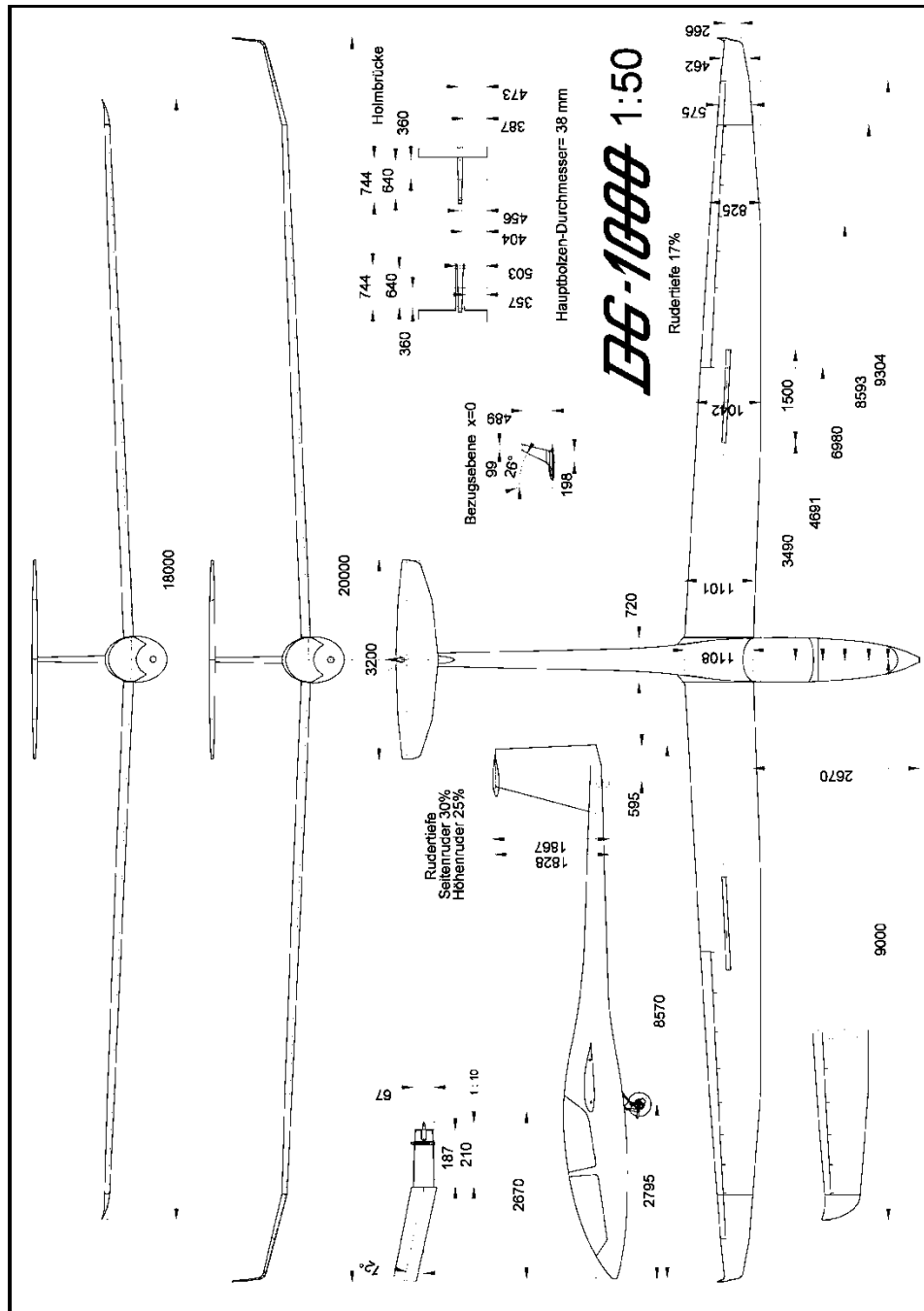


Figure 1: DG-1000S Three-View (Dimensions in mm).

1.4 Overall Test Objective

The primary purpose of this flight test program is to evaluate the DG-1000S glider for use in the USAF TPS Glider Spin event. This flight test program, therefore, will emphasize stalls, departures, spins, and spin recoveries. The effects of changing C.G. and pitch inertia on the stall and spin characteristics will be determined. In accordance with manufacturer specifications, the C.G. and gross weight will be varied by using different aircrew weights and by the use of ballast in the tail and cockpit. This aircraft is already certified for civil use in the United States. Since the aircraft is civil-owned, the requirements of

military specifications for flying qualities do not apply to procurement; however, they will be used as a guide for testing.

The results of this program will provide expected results for future safety planning and instructor pilots (IPs) guidance. Additionally, the final report will provide recommendations on a mission profile for the Glider Spin event using the DG-1000S. These recommendations may expand on the the current ASK-21 Glider Spin mission profile.

This flight test program has one overall test objective:

1. Determine whether the DG-1000S can meet the USAF TPS spin test training, education, and safety requirements.

This overall objective will be primarily accomplished by evaluating the stall, departure, spin, and recovery characteristics of the DG-1000S over its executable range of C.G. and pitch inertia. This flight test program will be further organized in a phases to address specific test objectives. These flight test program phases will be as follows:

1. Phase I: Departure and spin susceptibility evaluation.
2. Phase II: Spin modes and spin recovery characteristics determination.
3. Phase III: Determination of control effects on spin modes.
4. Phase IV: Inverted spin mode demonstration.

1.5 Limitations

As a result of the possibility that spin recovery could render the aircraft inverted, only the 18-meter wingspan configuration will be evaluated. This limitation will ensure that flight manual guidance (relevant to the 20-meter wingspan) is not violated with regard to inverted flight.

TPS glider spin sorties may be flown solo for TPS staff proficiency. Therefore, this program will include solo flights. However, to limit the size of the test point matrix, all configurations flown for this program will remain within the range of C.G. locations that can be achieved with two aircrew. Therefore, subsequent solo spin proficiency flights will likely be flown up to the two-pilot aft C.G. tested. Appendix F: Analysis of Executable Configurations discusses the theoretical and likely configurations that will be tested. By approving this test plan, TPS leadership is acknowledging this test limitation.

The test team for this program is necessarily small. Therefore, the aircraft C.G. and pitch inertia configurations tested will be limited by the weight of the test team members. Particularly, the minimum and maximum pitch inertia configurations attained during testing may be less than the theoretical minimum/maximum that would be achievable given extremely lightweight aircrew. Appendix F: Analysis of Executable Configurations contains a description of the process by which the minimum/maximum inertias configurations are found.

1.6 Test Resources

1.6.1 Modeling and Simulation

No modeling or simulation is planned for this test.

1.6.2 Test Facilities

Testing will be conducted in the open-air above Mountain Valley Airport, Tehachapi, CA or the northern end of Rogers Dry Lake, located near North Base, Edwards AFB, CA.

1.6.3 Frequency Authorization

A VHF radio in the aircraft may be used for test sorties to allow communication with ground personnel or other aircraft. VHF frequencies as authorized in the FAA Aeronautical Information Manual will be used to coordinate ground and airborne members of the test team.

1.6.4 Support Aircraft

The test aircraft is documented in section 1.3 Test Item Description. Additionally, a suitable tow aircraft, such as the Piper PA-25-235 Pawnee, will be required to provide Aero Tow of the glider from the surface to the release altitude. The tow aircraft will be equipped with a VHF radio. The DG-1000S maximum towing speed is 100 KIAS. If the glider fails to release, the tow aircraft has the ability to release the tow line. Standard procedures for glider tow will be followed. These procedures are documented in Appendix C: AeroTow Procedures.

1.6.5 Support Vehicles

There is no technical requirement for a chase aircraft or ground vehicles.

1.6.6 Test Range

No AFTC range resources will be used for this test if it is conducted at Mountain Valley Airport, Tehachapi, CA. The test will be conducted in public-use airspace.

For testing conducted at the northern end of Rogers Dry Lake, the airspace inside R-2515 will be used up to 12,000 ft above mean sea level (MSL).

1.6.7 Instrumentation

Instrumentation aboard the test aircraft will consist of calibrated airspeed indicators, altimeters, g-meters, and yaw strings. A small instrumentation unit will be mounted behind the rear cockpit which will measure body-axis parameters. Two cameras (one each in the front and aft cockpit) will be mounted in the cockpit to record relevant instrument indications as well as body-axis rates/angles. Ground-based video will also be used to supplement the cockpit recording as well as provide total aircraft view that is unavailable from the cockpit. The list of required parameters is shown in Table 1: Technically Required Parameters.

The rudder pedals will not be instrumented. Cockpit video will not directly show rudder pedal position, although the pilots legs will be in view, and the rudder pedal inputs may be approximated from that position. GPS time, IRIG, or time on the video is highly desired. Time synchronization must be possible to within 1 sec to allow audio, video and data to be roughly correlated.

An attitude heading reference system (AHRS) Nav-440 will provide all of the rates and angles. A master power switch for the AHRS with a power indicator will be installed in the front cockpit. The AHRS will feed data to a Tablet PC, which will record the parameters. “GoPro”-style cameras or the “wingman”-style camera will be used for video and audio recording. The cameras are battery powered

and have their own power switch. The AHRS, tablet, and cameras will be turned on prior to takeoff and turned off after landing. Crew will confirm that the instrumentation is on and functional prior to takeoff.

All modifications will be approved by the glider maintainer prior to installation with regard to the ability to de-modify the glider after testing is complete. No permanent modifications are permitted. Any holes in the aircraft must be repairable. The instrumentation will be treated like a T-2 modification for configuration control purposes. The T-2 documentation will be provided to the aircraft owner.

Testing will typically be flown Monday through Friday. For testing at North Base, the glider may be returned to Tehachapi for the weekends. When the glider is left unsecured (in Tehachapi) on weekends, the DAS will be removed to prevent damage. Ferry and DAS removal are expected to occur several times during testing. After initial installation, and upon reconnecting the DAS, technicians will perform a pre-flight functional check of the instrumentation system. Additionally, following initial installation, a check for electromagnetic interference will be performed and an instrumentation check flight will be conducted to confirm that the instrumentation system does not interfere with the aircrew in their duties.

Table 1: Technically Required Parameters

Parameter	Data Source	Primary Recording Method	Secondary Recording Method	Tertiary Recording Method	Safety of Test
Body-Axis Pitch Rate	AHRS: MEMS angular rate sensor	Tablet PC	Rear Cockpit Camera	Ground-Based Video	
Body-Axis Roll Rate	AHRS: MEMS angular rate sensor	Tablet PC	Rear Cockpit Camera	Ground-Based Video	
Body-Axis Yaw Rate	AHRS: MEMS angular rate sensor	Tablet PC	Rear Cockpit Camera	Ground-Based Video	
Body-Axis Pitch Angle	Derived from Pitch Rate	Tablet PC	Rear Cockpit Camera	Ground-Based Video	
Body-Axis Roll Angle	Derived from Roll Rate	Tablet PC	Rear Cockpit Camera	Ground-Based Video	
Heading Angle	Inertial Magnetometer	Tablet PC	Rear Cockpit Camera	Ground-Based Video	
Sideslip Angle	Yaw String	Rear Cockpit Camera	N/A	N/A	Yes
Altitude ¹	Cockpit Gauge	Front Cockpit Camera	N/A	N/A	Yes
Airspeed	Cockpit Gauge	Front Cockpit Camera	N/A	N/A	Yes
Normal Acceleration (Nz)	Cockpit Gauge (required) AHRS: Linear Acceleration Sensor (desired)	Cockpit Gauge: Front Cockpit Camera	AHRS: Tablet PC	N/A	Yes
Lateral Stick Position	Direct Measurement	Front Cockpit Camera	N/A	N/A	
Longitudinal Stick Position	Direct Measurement	Front Cockpit Camera	N/A	N/A	
Pilot's Leg Position	Direct Measurement	Front Cockpit Camera	N/A	N/A	
Aircrew Statements	Direct Measurement	Front Cockpit Camera	Rear Cockpit Camera	N/A	
Time	Manual Sync with USNO	Front Cockpit Camera	Rear Cockpit Camera	Ground-Based Video	

Notes:

MEMS = Micro-electromechanical Systems

USNO = United States Naval Observatory

¹The altimeter will be set to the local field elevation prior to takeoff.

1.6.8 Test Support Facilities and Equipment

Ground based video will be used to document spins.

1.7 Safety Requirements

A Safety Review Board will be convened IAW AFTCI 91-203 to assess the risk. The safety plan is documented in control number 2014048.

1.8 Security Requirements

This test is unclassified. Additionally, no proprietary information will be required or used. All source data are obtained from publically available sources. Therefore, all test planning, test execution, data acquisition, data processing, and data analysis will be accomplished at the unclassified level and is publically releasable.

1.9 Test Project Management

1.9.1 Key Personnel

Table 2: Key Personnel

Name	Title	Phone No.
Timothy McDonald	Project Pilot	661-277-6086
Christopher Liebmann	Project Engineer	661-277-9575
Russell Erb	Project Engineer	661-277-8829
Wah Wong	Technical Review Authority	661-277-4334
Paul Sorokowski	Technical Expert	661-277-6626
Roger Tanner	Operations Representative	661-277-0627
Gary Aldrich	TPS Chief Soaring Pilot	661-277-8881
Jane Barrett	Skylark North	661-822-5267

1.9.2 Program Schedule

Table 3: Program Schedule

Milestone	Month
Technical Review Board	Jan 2015
Safety Review Board	Jan 2015
Flight Test Readiness Review	Feb 2015
Beginning Flight Test Window	Feb 2015
End Flight Test Window	Mar 2015
Technical Report Complete	Apr 2015

1.10 Test Environment

This test will be conducted in open airspace above Mountain Valley airport, Tehachapi, CA or North Base, Edwards AFB, CA. Landings will be planned to paved surfaces, although the lakebed runways are

optional as a contingency. The advantage to executing at North Base is increased test efficiency (due to lower ground elevation), and the guarantee of sanitized airspace (thereby increasing test safety).

To ensure safety and to allow for quality ground-based video, the test will be performed in day visual meteorological conditions (VMC), free from precipitation (to avoid windscreen obscuration).

1.11 Environmental Impact Assessment

Based on Appendix A: Environmental Checklist, 412 Test Wing Environmental Office (412 CE/CEV), has certified this effort is covered under CATEX A2.3.33 and A2.3.11 and that 412 TW environmental planning is complete (AF Form 813, Control Number 14-0234). Significant impacts on the environment are not likely and no further environmental documentation is required.

2.0 TEST AND EVALUATION

In order for the spin and recovery characteristics of the DG-1000S to be evaluated, flight tests will be performed. Testing will consist of approximately 120 sorties encompassing approximately 40 flying hours. Testing will be accomplished using registration number N801DG. The USAF TPS staff (non-student) personnel will perform all testing at Mountain Valley airport, Tehachapi, CA or North Base, Edwards AFB, CA. The standard 412th Test Wing Rating Criteria will be used to determine the evaluations and ratings.

2.1 Specific Test Objectives (STOs)

Based on the overall test objective, the STOs are as follows:

1. Determine the DG-1000S mass properties (for the empty and loaded aircraft) and longitudinal moment arms relative to the aircraft's weight and balance datum at selected fuselage stations.
2. Evaluate the 1-g stall characteristics and departure susceptibility of the DG-1000S over the executable range of C.G. locations.
3. Determine the most forward C.G. location/pitch inertia configuration where the DG-1000S will reliably yield a developed spin.
4. Evaluate the spin characteristics and flight manual spin recovery over the executable range of C.G. locations where the DG-1000S will yield a developed spin ...
 - a. with minimum pitch inertia attainable by the test team and allowed by the flight manual for the C.G. location, and
 - b. with maximum pitch inertia attainable by the test team and allowed by the flight manual for the C.G. location.
5. Evaluate the upright spin characteristics when selected control inputs are applied with the down-selected aircraft C.G./pitch inertia configurations.
6. Evaluate the aircraft response to selected alternate upright spin recovery inputs with the down-selected aircraft C.G./pitch inertia configurations.
7. Evaluate the inverted spin characteristics and spin recovery of the DG-1000S at selected conditions within the range of down-selected aircraft C.G./pitch inertia configurations.
8. Qualitatively evaluate the DG-1000S flying/handling qualities during normal (non-stall/spin) operations.

2.2 Definitions and Test Methodology Applicable to STOs 2-8

For the purposes of the test, the definitions for specific terms are necessary. MIL-F-83691B (reference 5) is the primary source for these definitions, although they are amplified with respect to specific aspects of this test.

2.2.1 Stall

Stall is indicated when the pilot has a clear indication of at least one of the following:

- a. A definite g-break.
- b. A rapid, uncommanded angular motion.
- c. The pitch control aft stop has been reached and no other indication of stall has occurred. This may not be an aerodynamic stall, but represents the termination point for the stall attempt.
- d. Sustained intolerable buffet.

2.2.2 Departure

Departure from controlled flight is the event indicating loss of control which may develop into a spin. The departure may be characterized by divergent, large amplitude, uncommanded aircraft motions such as a nose-slice. The term departure is synonymous with a complete loss of control (as stated by MIL-S-83691A (USAF)). For the purposes of stall aggravation, departure is defined as any of the following occurring after the stall aggravation has ceased (controls have been neutralized):

- a. 90-degree uncommanded heading change with steady/increasing yaw rate
- b. 60-degree uncommanded bank-angle change with steady/increasing roll rate
- c. 30-degree uncommanded pitch change with steady/increasing pitch rate

Each of these criteria qualifies as large amplitude (the numerical values), divergent (the rates), and uncommanded (controls neutral). The amplitude criteria were chosen based on engineering judgment in the case of heading change and the definition of aerobatic flight from 14 CFR Part 91.307 in the case of pitch and roll changes (if starting from straight level flight). Additionally, these criteria can be easily determined qualitatively by aircrew in flight.

2.2.3 Spin

A spin is a post-departure motion characterized by a sustained yaw rotation at angles of attack (AOA) above stall. Cockpit airspeed indications are expected to be low (near zero) and possibly cyclic, depending on oscillations. Spins can be characterized by their spin mode (consisting of sense, attitude, body axis yaw rate, and oscillatory tendency). The stages of a spin are incipient, developed, fully developed, and recovery.

The incipient phase of a spin is the initial, transitory phase of the motion during which it is not possible to identify the spin mode. Therefore, spins which achieve at least one, but less than five turns, and self-recover in spite of maintaining pro-spin controls will be classified as incipient spins. This definition is consistent with that documented in reference 2, and will allow for a consistent comparison of test results.

A developed spin is the phase of the spin during which it is possible to identify the spin mode. A fully developed spin is attained when it is possible to identify the spin mode, the trajectory has become vertical, and no significant change is noted in the spin characteristics from turn to turn. In post-flight analysis, a spin turn will be counted from the heading at which a developed and fully developed spin is attained to the aircraft passing through that heading again. With trajectory maintained vertical, the AOA and pitch attitude are directly related.

Recovery is defined as the transition from out-of-control conditions to controlled flight. Recovery begins at the initiation of recovery control inputs and is complete when AOA returns to a state below stall

and no uncommanded angular motions remain. AOA will not be directly measured; however AOA returning below stall is often evident by a cease in aerodynamic buffet, the pitch attitude becoming vertical (aligned with the velocity vector), or an increase in airspeed. Procedures for recovery are documented in section 3.3.2: Spin Recovery Procedures. Recovery is typically followed by a dive pullout.

2.2.4 Dive Pullout & Spiral Dive

Dive pullout is defined as the transition from the termination of recovery to normal gliding flight. Procedures for dive pullout are documented in section 3.3.3: Dive Pullout Procedures. As a result of the high airspeed that may result from a dive pullout, followed by a potential “zoom climb”, the altitude at which the aircraft returns to normal gliding flight may not be the minimum altitude achieved during the dive pullout. For safety planning, the minimum altitude during any portion of the dive pullout is considered more critical.

Some maneuvers may result in a spiral dive. A spiral dive is defined as a rotational (dominated by roll/yaw) condition in which wind noise, normal load factor, and indicated airspeed rapidly increase (once the Pitot tube is oriented into the relative wind). The flight manual does not clearly distinguish between an incipient spin (a stalled condition) and a spiral dive (a non-stalled condition). Regarding these maneuvers, the flight manual states in section 4.5.8.1 Category U, Utility, Spins:

The nose down pitch and speed will be high so with [medium and forward] C.G. positions not more than 1 turn spins should be executed, to avoid high g-loads. [...] there is a tendency that the spin will turn into a spiral dive after 1 or 2 turns. On reaching this state you must recover immediately.

To comply with the flight manual, dive pullout will be initiated immediately upon recognition of a spiral dive. By definition, high normal forces (g-loads) are not likely during spins, given the velocity vector orientation. They are, however, likely during a spiral dive, as airspeed increases. Consequently, the translation of this statement from German to English is reasonably questionable for application to flight test. Given careful attention to the possibility of incipient spins recovering into spiral dives, the spirit of the “not more than 1 turn spins should be executed” statement may be preserved while more than 1 turn spins may be allowed to pass, so long as indications of a spiral dive are not apparent.

Airbrakes will not be planned to be extended during dive recoveries. When airbrakes are extended, the maximum load factor limits are reduced to +3.5/-0.0 g at all flight speeds. Increased g-available is preferred to control overspeed and dive recovery when compared to the drag increment from the airbrakes.

2.2.5 Mass Property Effects on Spins

As is documented in Appendix D: Spin Theory, spin entry, characteristics, and recovery are all affected by the applied aerodynamic and inertial moments on the aircraft.

The C.G. location changes the static margin and thus the magnitude of the aerodynamic pitching moment (more forward C.G. locations producing more nose-down pitching moments). Therefore, C.G. location is expected to be a primary factor in spin susceptibility. The flight manual states in section 4.5.8.1 Category U, Utility, Spins:

Prolonged spinning is satisfactorily accomplished with aft C.G. positions. If prolonged spinning is intended, ballast in the ballast box in the fin should be used to achieve an aft C.G. position [...].

*With **medium** and **forward** C.G. positions prolonged spinning is not possible. The DG-1000S will terminate the spin by itself after a certain number of turns dependent on the C.G. position. [...]*

Note the three C.G. regions indicated by the flight manual: “forward,” “medium,” and “aft”; these regions are not quantified. No quantifying values could be found in the flight manual. Therefore, given a C.G. range from 7.48 inches – 17.32 inches, the test team divided the C.G. regions into equal 3.28-inch sections, yielding the ranges shown in Table 4: C.G. Ranges. These ranges must be considered notional and not restrictions or limitations.

Table 4: C.G. Ranges

C.G. Region	Approximate C.G. Range (inches)
“Forward”	7.48 – 10.76
“Medium”	10.77 – 14.04
“Aft”	14.05 – 17.32

The flight manual statements, above, will be evaluated by flight test. To increase test efficiency, the departure/spin susceptibility determination will be started from a C.G. location which is slightly forward of where the DG-1000 is expected to spin. During testing of the DG-1001, the following results were reported in reference 4:

- During phase B stall testing, the aircraft was susceptible to spins at C.G. locations aft of 14.88 inches behind the datum to the aft limit.
- At approximately 10.5 inches behind the datum to the aft limit, phase C stall testing resulted in incipient spins.
- Sustained spins were only achieved during phase D stall testing and only approximately 12.75 inches behind the datum to the aft limit.

Therefore, Phase I (departure spin susceptibility) testing will begin at a C.G. location of 10.5 inches behind the datum for upright spins.

The C.G. locations for inverted spins will be based, in part, on the C.G. locations at which the glider spins upright. The primary reason for evaluating inverted spins in this program is to confirm satisfactory inverted spin characteristics across the range of C.G. locations identified during Phase I/II testing. There is no test requirement to determine the C.G. location at which inverted spins are possible (as in STO 3 for upright spins). While a range of C.G. locations will be tested inverted, a buildup starting from a forward C.G. location is not necessary. Notionally, the first configuration for inverted spins will be in the mid-range of the C.G. region that has been shown to achieve a developed spin upright.

Additionally, the test objectives refer to the “executable” C.G. range. This refers to a consideration of practicality: certain C.G. locations are unobtainable with two aircrew. The most aft C.G. location that is obtainable in the DG-1000S with two aircrew is forward of the aft limit. In the interest of flexibility, all C.G. locations allowed by the flight manual to be tested are listed in Appendix E: Test Point Matrix.

TPS glider spin sorties may be flown solo for TPS staff proficiency. Therefore, this program will include solo flights. However, to limit the size of the test point matrix, all configurations flown for this program will remain within the range of C.G. locations that can be achieved with two aircrew. Therefore, subsequent solo proficiency flights should only be flown up to the two-aircrew aft C.G. tested. Flying solo within the two-aircrew C.G. range will essentially change only the pitch inertia. As discussed in the

section 1.5: Limitations, the test team for this program is necessarily small. Therefore, the aircraft C.G. and pitch inertia configurations tested will be limited by the weight of the test team members. Particularly, the minimum and maximum pitch inertia configurations attained during testing may be less than the theoretical minimum/maximum that would be achievable given extremely lightweight aircrew. Appendix F: Analysis of Executable Configurations contains a description of the process by which the minimum/maximum inertias configurations are found.

Equally important, however, is the magnitude of the pitch inertia (I_{yy}). Changes in pitch inertia affect the inertial pitching moment that results from yaw-roll coupling. Loadings with greater pitch inertias generate greater inertial pitch-up moments, allowing spins to stabilize at a more forward C.G. despite the greater aerodynamic pitch down moments inherent to that C.G. location. By increasing the ballast in the cockpit and tail, C.G. location can be maintained relatively constant while pitch inertia is increased. The yaw rotations that result from an aircraft with greater pitch inertia are expected to result in flatter spins, and thus a higher sustained AOA.

In the JAR-22 Spin Compliance Report for the DG-1000 (reference 6), several critical cases were tested. The most extreme case was executed with the C.G. aft of the aft limit, the tail dolly attached, eight tail weights, and waterballast in the fin and wings. The pitch inertia values in that case greatly exceeded any pitch inertias that will be achieved during this test program. No safety or compliance discrepancies were reported.

A complicating factor in managing the C.G. locations and pitch inertia values on the DG-1000S is the quantized nature of the aircrew weights and the ballast that is available. Trim weights are either 1.2 or 2.4 kg. Both the tail and the nose ballast compartments are designed for specific configurations of weights and are space-limited. Ballast bags are approximately 25 lbs each. Therefore, only discrete C.G. location and inertial values are achievable for a given aircrew.

The test objectives require testing with minimum and maximum attainable pitch inertias. No intermediate steps of pitch inertia are required (at a given C.G. location) for two reasons. First, this test effort occurs within a smaller range of pitch inertia configurations than were tested during JAR 22 spin compliance tests. Additionally, the quantized nature of the weights makes intermediate buildups impractical.

2.2.6 Extent of Spin Entry Determination

The spin entry procedures used for this program are intended to accomplish two main goals: produce repeatable results and demonstrate common TPS student errors that may occur while executing flight test techniques. The flight test techniques which are expected to potentially produce spins are steady-heading sideslips and spin entries used to demonstrate a spin evaluation based on MIL-F-83691B. All of the TPS curriculum test maneuvers which are expected to potentially produce spins occur at one-g with airbrakes retracted.

During the ASK-21 spin investigation (reference 2), nine spin entry procedures were used. These entry procedures fulfilled three main categories: smooth AOA rate (one-g and accelerated), abrupt AOA rate (one-g and accelerated), and tactical. The categorization used in this report is useful in summarizing the spin entry procedures for the DG-1000S spin investigation.

The spin entry procedures are described in Table 11 Stall/Spin Entry Procedures. Entries 1 and 2 begin from wings-level coordinated flight with specified airspeed bleed rates; these entries are intended to be highly repeatable. Entry 3 is flown as a steady-heading sideslip which is allowed to stall. Entries 1 and

3 fall under the category “smooth AOA rate, one-g.” Entry 2 falls under the category “abrupt AOA rate, one-g.” All three entries are expected to produce the same spin mode(s).

All three entries will be flown upright to determine the most forward C.G. location at which the DG-1000S will reliably enter and sustain a spin. At C.G. locations aft of that, any one of the three entry procedures will be considered suitable provided that the entry procedures do not demonstrate the potential to produce different spin modes. The test team will select one suitable entry procedure to be used for the remainder of the program.

The inverted spin evaluation will be limited. Only Spin Entry Procedure 1 will be required for inverted spins.

Spins will be evaluated in both directions (left and right) until the test team is able to determine whether any difference exists in the direction of spin. If no difference is apparent in spin entry, spin characteristics, or spin recovery, then spins will only be required in one direction, although a variance between left/right entries is desired.

Accelerated stall/spin entries (load factor greater than 1-g) will not be attempted. Accelerated stall/spin entries are not required to satisfy any USAF TPS curriculum learning objectives at this time. Similarly, tactical stall/spin entries will not be attempted. The tactical entries listed in reference 2 replicated student errors during solo aerobatic flight and soaring. These appear to have been in response to a glider mishap that occurred at the USAF Air Force Academy and are not required to satisfy any USAF TPS learning objectives at this time.

2.2.7 Extent of Spin Characteristic Evaluation

Since one purpose of this test plan is to establish baseline data in the development of an effective DG-1000S curriculum spin event, spins will be allowed time to reveal their characteristics at points which are most relevant to USAF TPS curriculum execution. A post-test judgment as to when a developed and fully developed spin occurred will then be possible. For initial planning, the test team assumed that a spin will enter the developed phase after two turns. The current ASK-21 learning objectives require that students be able to identify the spin mode; therefore, the most critical spin characteristics data are associated with the developed phase.

During flight, spin characteristics will be evaluated until self-recovery occurs, the minimum altitude has been reached (see the safety plan), or five turns have passed from the initiation of pro-spin control inputs. At this point, recovery controls will be employed. In post-flight data analysis, spin characteristics will be evaluated based on the “typical” spin testing methodology which uses the establishment of a fully-developed spin as the point from which turns will be counted. This more extensive evaluation is necessary to ensure a safe and effective training environment for the future DG-1000S curriculum spin event.

2.2.8 Extent of Spin Recovery Evaluation

The spin recovery characteristics must be thoroughly investigated prior to use of the DG-1000S in the USAF TPS curriculum. To ensure a thorough evaluation of recovery characteristics, non-flight-manual recovery will be allowed two turns. This is consistent with similar glider spin testing documented in reference 2. The recovery procedures to be used are documented in section 3.3.2 Spin Recovery Procedures. Four procedures have historically been employed in spin recovery of aircraft. These are most properly named: Rudder Only, NACA Modified, Neutral, and “Hands-Off”. Each will be evaluated during the upright spin recoveries. All alternate spin recovery attempts will begin from a developed spin (for initial planning the test team assumed a spin will enter the developed phase after two turns).

If the alternate recovery procedures are unsatisfactory, that result will not necessarily be cause for concern, given that the flight manual recovery procedure is expected to work in all cases. Unsatisfactory recoveries may demonstrate important student learning points.

Only the flight manual recovery procedure from inverted spins will be investigated. If inverted spins are added to the TPS curriculum, they will likely be added as an instructor pilot (IP) demonstration. The purpose of this mission element would be to demonstrate the opposite-sign roll and yaw rates, as well as the disorienting nature of inverted spins. Alternate recovery characteristics will not be investigated for inverted spins.

To mitigate safety risk, the minimum altitude to initiate recovery will necessarily be higher until the spin recovery characteristics are known. Once the recovery characteristics are known, a lower recovery altitude may be specified. The flight manual states in section 4.5.8.1 Category U, Utility, Spins:

Height loss during recovery is approx. 100m (320 ft).

The safety plan thoroughly documents the minimum altitudes required for this test.

2.2.9 Extent of Control Effects Evaluation

The control effects to be evaluated are listed in Table E-1: Test Point Matrix; they are aileron affects and misapplied recovery controls. Only upright spins will be investigated with regard to control effects.

The aileron effects evaluation will include the entry, followed by one turn with ailerons-with-the-spin (a pro-spin input), then one turn with ailerons-opposite-the-spin (an anti-spin input). The purpose of the aileron effects demonstration is to show students how aileron inputs can vary the yaw rate. A spin is not required to be in the developed phase for the aileron effects demo. However, the rate should be stabilized sufficiently so that the aileron effects can be seen. Therefore, only one turn (the entry) is required before the aileron effects demo is attempted.

The misapplied recovery controls that will be investigated are incorrect order (stick before rudder) or poorly timed (stick forward too soon) flight manual recoveries. All misapplied recovery controls evaluations will begin from a developed spin (for initial planning, the test team assumes a spin will enter the developed phase after two turns). Specific procedures for misapplied controls are found in section 3.3.2 Spin Recovery Procedures.

This test plan does not purport to capture every possible student error. In the experience of the project pilot, the selected misapplied recoveries have been prevalent in the glider spin sorties flown in the ASK-21. If inverted spins are added to the TPS curriculum, they will likely be added as an IP demonstration. Therefore, misapplied controls will only be investigated with regard to upright spins.

If the aircraft has not recovered following a control effects evaluation, the flight manual recovery procedure will be used.

2.2.10 Repeatability

Variation in atmospheric dynamics and pilot-to-pilot differences may yield slight differences in test results. In the judgment of the test team, three repeats of each test point will be sufficient to establish the behavior of the test aircraft at a given C.G. position and pitch inertia configuration. A statistical analysis, such as discussion of confidence bounds, is not requested or desired by the customer. If, after three attempts, results are ambiguous, the test team may opt to perform additional repeats.

If entries to the left and to the right produce similar results during the departure susceptibility determination, three total entries are required, to include at least one entry in each direction.

2.2.11 Progression of Testing

From a test methodology standpoint, this program can be broken into four distinct phases, as mentioned in section 1.4: Overall Test Objective. The steps in this section and the decision trees in Appendix E are designed to produce the technical data to meet the test objectives. The decision trees may be modified based on lessons learned during testing. The constraints of the safety plan (documented separately) must be followed. Any deviations from the safety plan will require an amendment.

Phase I: Departure and spin susceptibility evaluation.

Figure E-1 depicts a decision tree applicable to Phase I. Generally, the test team expects the test to flow as follows:

1. Load the glider to achieve configuration 10-MIN from Table E-1.
2. Begin upright departure susceptibility tests (Phase A stalls) using entry procedure 1 (3 ea.), entry procedure 2 (3 ea.), then entry procedure 3 (3 ea) from Table 11.
3. Repeat step 2 for Phase B, C, and D stalls. Alternate left/right entries.
4. If a 2-turn spin was not maintained, repeat steps 2 and 3 in configuration 10-MAX.
5. If a 2-turn spin was still not maintained, move the C.G. location one inch aft, minimize the pitch inertia, and repeat steps 2, 3, and 4.

EXIT CRITERIA: Phase I will be complete once a configuration (as required by STO 3) is found in which a 2-turn spin can be maintained (with pro-spin inputs held).

NOTE: The test team is making no distinction between Phase D stalls and spin attempts. The rating of “extremely resistant to departure” may be established during Phase C stall testing.

Phase II: Spin modes and spin recovery characteristics determination.

Figure E-2 depicts a decision tree applicable to Phase II. Generally, the test team expects the test to flow as follows:

1. At the most forward C.G. location (XX-MIN) where the glider will sustain a 2-turn upright spin, attempt a Phase D spin attempt using upright entry procedure 1 (3 ea.) from Table 11.
2. If the spin entry procedure was not reliable in producing a spin, stop using that procedure.
3. If entries to the left & right are not equally reliable, document the difference.
4. If the characteristics during the spin or the recovery are unsatisfactory, stop investigating.
5. If the spin mode is different from the previously known modes, document the new mode.
6. If all the spin entry procedures (that are still in use) have not yet been attempted, attempt the next one (3 ea.).
7. If some entry procedures produce identical spin modes, choose one entry with which to finish the program. Past experience with glider spins tends to support the idea that only one upright mode exists. Therefore, only one entry procedure will likely remain.
8. Reconfigure the glider to the maximum pitch inertia (XX-MAX) and reattempt steps 1 through 6 (3 ea) with the remaining upright entry procedures.
9. Move the C.G. location one inch aft, minimize the pitch inertia, and repeat steps 1 through 7.

At this point, all the executable C.G. and pitch inertia configurations in which a 2-turn upright spin can be maintained (with satisfactory characteristics) will have been investigated.

A downselect will then appropriate. Some C.G./pitch inertia configurations may prove extremely difficult to achieve, and may be judged not applicable to USAF TPS curriculum. Additionally, some configurations may show themselves to be low value for an objectives-driven educational environment (e.g. inconsistent spin characteristics). The downselect will increase both safety (less exposure to hazards) and efficiency (less time spent pursuing inconsequential test points).

Based on this downselect, a more thorough investigation (5 spin turns) will be conducted for the remaining configurations. An added effect of delaying the more thorough investigation until all configurations have been tested through 2 turns is that test pilots will first be afforded a larger breadth of experience in DG-1000S spins.

EXIT CRITERIA: Phase II will be complete once the executable and “likely” C.G. and pitch inertia configurations during which a 5-turn upright spin can be maintained (with satisfactory characteristics) have been investigated.

Phase III: Determination of control effects on spin modes.

Figure E-3 depicts a decision tree applicable to Phase III. Generally, the test team expects the test to flow as follows:

1. Using only the executable and “likely” configurations determined in phase II, from a spin entry procedure in Table 11 (if more than one remains), enter a developed spin. Only one entry procedure will likely be used, given that only one upright spin mode is expected to exist.

2. Execute a control effects demo (3 ea) as found in section 2.2.9.

3. Document the spin characteristics and recovery characteristics as applicable.

4. Investigate the next control effect as found in section 2.2.9 (3 ea). Repeat step 2.

5. Once all control effects have been investigated, investigate an alternate spin recovery procedure listed in Table 12 (3 ea). Repeat step 3.

6. Once all control effects and alternate recoveries have been investigated at a given C.G. location with minimum pitch inertia, reconfigure the glider to the maximum pitch inertia (XX-MAX) and repeat steps 1 through 5.

7. Once all control effects and alternate recoveries have been investigated at both pitch inertia configurations, move the C.G. aft to the next location of interest (as determined during downselect), minimize the pitch inertia, and repeat steps 1 through 5.

EXIT CRITERIA: Phase III will be complete once all the planned control effects and alternate recoveries are evaluated at all the configurations of interest, as determined during the downselect. The characteristics of each spin and recovery will be documented.

Phase IV: Inverted spin mode demonstration.

The methodology used in Phase IV will be similar to that used in Phase II. The test points will be a subset of the configurations shown in Table E-1. The configurations to be flown for inverted spins will be over the narrowed range of C.G. locations that remain after the downselect. The most forward and most

aft C.G. locations at which favorable upright spin results exist will determine the configurations. Both minimum and maximum pitch inertia configurations will be flown at these locations.

Three inverted spins will be flown in each configuration of interest. Only one entry procedure is planned and only the flight manual recovery procedure will be used.

EXIT CRITERIA: Phase IV will be complete once the selected configurations from Table E-1 have been evaluated for inverted spins.

2.2.12 Build-Up Approach to Testing

Testing will follow a build-up approach. This section is intended as a general overview for the reader. Additionally, the methodology section of Tables 6, 7, and 8 and the decision trees in Appendix E describe the build-up in more detail.

The Phases discussed in section 2.2.11 will be accomplished in order. The required progression of testing will be:

1. Mass properties, moment arm, and control rigging determination.
2. Flight manual recoveries (3 each) after 2 turns.
Downselect for “likely” spin configurations (C.G./pitch inertia) at USAF TPS
3. Flight manual recoveries (3 each) after 5 turns.
4. Control effects investigation (3 each).
5. Alternate recoveries (3 each) investigation.
6. Inverted spins with flight manual recoveries (3 each) at selected configurations.

The above progression accomplishes several things simultaneously. As a result of FAA certification, the flight manual recovery procedure is expected to be effective in all allowable C.G. and pitch inertia configurations; it will, therefore, provide a foundation on which to build. A limited investigation (2 spin turns) will be conducted for these configurations. The 2-turn investigation allows a relatively efficient general survey of the spin envelope. Following the 2-turn investigation, a more extensive 5-turn spin investigation will occur to ensure that no “cliffs” or high-value learning points exist beyond the first 2 turns.

Following the 5-turn spin investigation, an investigation of the control effects during the spin and alternate recovery procedures will be appropriate. This evaluation will occur near the end of testing, and thus, at a high level of test team experience with DG-1000S spins, which will be appropriate given the possibly aggravating nature of these control inputs.

The final portion of testing will be a limited demonstration of inverted spins. The configurations at which inverted spins are evaluated will be determined during the downselect, once the spin-likely configurations are known. Inverted spins are expected to be the most disorienting to aircrew, and will therefore be executed last, to ensure maximum aircrew experience.

2.3 MOPs by Specific Test Objective

Table 5: STO 1: Determine Mass Properties and Moment Arms

MOP Name	Pitch Moment of Inertia	Longitudinal Moment Arm
Description	The integral quantity describing the inertial distribution of a body along a designated axis. This quantity is required for the empty aircraft and the loaded aircraft. Symbolized by I_{yy} .	The distance between the center of mass of a body and a designated datum along the longitudinal axis. Symbolized by x
Test Methodology	For the empty aircraft, as documented thoroughly in reference 7: 1) Allocate the total aircraft weight to six separate groups: a. wing group b. horizontal tail group c. vertical tail group d. fuselage group e. additional items This allocation primarily involves distributing the subsystems throughout the aircraft without identifying the actual location of each wire, cable, line, or component. This is done on an "historical" or "accepted design practice" basis. 2) Calculate the moment of inertia of each group about its own centroid and then transfer these inertias to a set of remote axes. 3) Locate the aircraft center of gravity, sum the inertias, and translate them back to the aircraft center of gravity to obtain the desired moments of inertia. For the loaded aircraft, add the empty aircraft inertia to each added mass multiplied by the square of the distance from the C.G. for that mass.	Measure the distance from the datum to the center of mass of the following point masses: • Front pilot • Front cockpit ballast bag • Front cockpit ballast box • Rear pilot • Rear cockpit ballast bag • Instrumentation package • Tail weights
Data Requirements	Empty aircraft: weights and x-distance from the aircraft C.G. to the centroid of each group indicated in 1) a.-e., above. Loaded aircraft: Weights of each point mass and the x-distances from the aircraft C.G. of each item indicated in the longitudinal moment arm MOP	This is a direct measurement.
Success Criteria	Values of each principle moment of inertia are determined once for the empty condition and once for each loaded configuration.	Values of each longitudinal moment arm are determined once.
Evaluation Criteria	N/A	N/A
Expected Results	The principle moments of inertia are expected to be consistent with that of a wing-loaded aircraft ($I_{zz} > I_{xx} > I_{yy}$) and should be comparable in magnitude to that of other gliders.	The distances are expected to compare closely to those indicated in the flight manual.
Final Data Products	A table of numerical values indicating the weights, distances, and resulting principle moments of inertia, as well as the total aircraft moment of inertia. Additionally, a tool will be developed to help aircrew determine the correct amount of weights necessary to achieve a desired C.G. location.	A table of measured values compared to the values indicated by the flight manual, with differences shown, in percent.

Table 6: STO 3: Determine the C.G. Location to Enter/Maintain a Spin

MOP Name	x_{cg} Location
Description	The smallest distance between the designated datum along the longitudinal axis and the C.G. for which a 2-turn spin can be maintained.
Test Methodology	Starting from the C.G. location slightly forward of where spins are expected to occur (the most aft C.G. in the “Forward” range shown by Table 4, attempt Phase A, B, C, and D stalls by varying the following: - Spin entry procedure (see Table 11) - Direction of aggravation (left vs. right) - Pitch inertia (first minimum, then maximum allowed by the flight manual for that C.G. location) - C.G. location Details of the test flow are shown in Figure E-1: Phase I Departure and Spin Susceptibility Decision Tree. The value of X_{cg} at the location in which a developed spin is maintained will be compared to the flight manual description of the region in which prolonged spinning is possible.
Data Requirements	This is a direct measurement.
Success Criteria	The value of the X_{cg} at the location in which a developed spin is maintained is determined three times.
Evaluation Criteria	N/A
Expected Test Results	The region of spin susceptibility is expected to be approximately as specified in the flight manual.
Final Data Products	A table of spin entry procedures, associated C.G. location, and the results of the spin entry procedure will be documented in a table.

Table 7: STO 4-7: Evaluate the Developed Spin Characteristics.

MOP Name	Sense	Attitude		Rate		Oscillations	Altitude Loss in the Spin
Description	The sign of AOA (derived from pitch attitude). Positive or negative AOA indicates an upright or inverted spin, respectively.	The magnitude of the average AOA (α_{avg}), further classified as follows:		The body-axis yaw rate (R), further classified as follows:		The qualitative magnitude of three-axis oscillations, rated by pilot comments as: • “smooth” • “mildly oscillatory”, • “highly oscillatory”, or • “violently oscillatory”.	The altitude lost (in feet) from the initiation of pro-spin inputs to the first initiation of recovery inputs. Additionally altitude loss per turn in the spin will aid in development of the DG-1000S curriculum spin event.
		extremely steep:	stall $\alpha_{avg} < \alpha_{avg} < 35$ deg	slow	$R \leq 60$ deg/sec		
		steep:	$35 \text{ deg} \leq \alpha_{avg} < 70$ deg	fast	$60 \text{ deg/sec} < R \leq 120$ deg/sec		
		flat:	$\alpha_{avg} \geq 70$ deg	extremely rapid	$R \geq 120$ deg/sec		
Test Methodology	Starting at the most forward x_{cg} location which yields a developed spin, enter developed left and right spins. Observe the spin characteristics until the minimum altitude is reached or five turns in the spin have occurred, and then recover. Vary the following: a. Spin entry procedure (see Table 11) b. Direction of aggravation (left vs. right) c. Pitch inertia (first minimum, then maximum allowed by the flight manual for that C.G. location) d. C.G. location Details of the test flow are shown in Figure E-2.						
Data Requirements	Crew comments, or video review.	Crew comments, instrumented pitch attitude, or video review.		Crew comments, instrumented aircraft rates, or video review.		Crew comments or video review.	Indicated altitude readings or instrumented aircraft altitude.
Success Criteria	The developed spin characteristics are recorded three times at each x_{cg} location between the most forward location yielding a developed spin and the most aft attainable x_{cg} location (with two crew aboard) for both minimum and maximum pitch inertias allowed by the flight manuals.						
Evaluation Criteria	The developed spin characteristics will be considered satisfactory if they do not hinder the ability of the pilot to apply recovery control inputs, cause unreasonable pilot disorientation (as determined by pilot comments), or are otherwise judged a barrier to USAF TPS student learning. The justification for this evaluation will be substantiated with reference to the MOPs identified above.						See Table 8: STO 2, & 4-7 Evaluate the Spin Recovery Characteristics
Expected Test Results	The developed spin characteristics are expected to be satisfactory. Inverted spins are expected to be more disorienting than upright spins with similar dynamics, but still satisfactory.						
Final Data Products	Tables of the spin characteristics and the recovery characteristics will document each attempt, summarized in prose. Time histories and video will also be included.						

Table 8: STO 2 & 4-7: Evaluate the Spin Recovery Characteristics.

MOP Name	Altitude Loss in Recovery	Altitude Loss in Dive Pullout	Spin Turns in Recovery	Recoverability
Description	The altitude lost (in feet) during the recovery, as defined above.	The altitude difference (in feet) from the beginning of the dive pullout, as defined above, to the lowest altitude encountered during the dive pullout.	The number (or fraction) of turns of continued spinning during the recovery.	The qualitative assessment of ease by which the aircraft is recoverable from a spin.
Test Methodology	For every maneuver at a given x_{cg} location and ballast configuration which yields a developed spin, apply control inputs known to be used in spin recovery (as specified in section 3.3.2: Spin Recovery Procedures). For the first recovery attempt, apply the recovery procedure specified by the flight manual to confirm its effectiveness. Repeat the test by re-establishing a developed spin and applying one of the recovery procedures specified in section 3.3.2 Spin Recovery Procedures (besides the flight manual recovery procedure). If the aircraft does not recover after two turns, return to full aft-stick, neutralize rudder/aileron inputs, then initiate the recovery procedure specified by the flight manual. Repeat with each recovery procedure specified in table 11: Stall/Spin Recovery Procedures.			
Data Requirements	Altitudes will be measured based on indicated altitude, or from instrumented altitude indications.		Crew comments or video review.	Crew comments.
Success Criteria	The spin recovery procedures are evaluated three times for each recovery procedure listed in section 3.3.2 Spin Recovery Procedures at each X_{cg} and ballast location for which a developed spin occurs.			
Evaluation Criteria	The combined altitude lost in the spin, recovery, and dive pullout will be considered satisfactory if, from a 5,000 ft aerotow, the aircraft has sufficient altitude to execute that maneuver two times before reaching the mandatory IP recovery altitude (from the ASK-21 Glider Spin Training safety package).		The spin turns in recovery shall be considered satisfactory if the aircraft is recoverable in two turns from the point where rudder opposite the spin is initiated.	The recoverability will be considered satisfactory if pilot comments include no mention of unacceptably objectionable qualities or potential educational ineffectiveness that cannot be overcome with current resources.
Expected Results	The altitude lost per turn in the spin is expected to be satisfactory and similar to that of the TG-16A (up to ≈ 550 ft/turn upright or ≈ 900 ft/turn inverted). Altitude lost in the recovery and dive pullout is expected to be approximately in accordance with the flight manual (< 320 ft.)		The spin turns in recovery and recoverability are expected to be satisfactory for the flight manual recovery and similar to that of other gliders (< 1 turn). Some alternate recovery procedures may not recover the aircraft from developed spins.	
Final Data Products	Tables of the spin characteristics and the recovery characteristics will document each attempt, summarized in prose. Time histories and video will also be included.			

Table 9: STO 8: Evaluate the flying/handling qualities during normal (non-stall/spin) operations.

MOP Name	Pilot Comments
Description	The qualitative assessment regarding changes in aircraft characteristics during normal operations as a result of C.G. or pitch inertia configuration changes.
Test Methodology	Pilots will note any changes in aircraft characteristics (due to C.G. location or pitch inertia configurations) that differ from the “nominal” configurations that are typically flown during normal glider operations. No specific maneuvers will be flown to accomplish this test. Special attention should be paid to pitch sensitivity on takeoff, aerotow, and landing. Takeoff, aerotow, and landing are all required phases of flight.
Data Requirements	Crew comments or video review.
Success Criteria	This test objective will be accomplished if pilots note any changes in aircraft characteristics.
Evaluation Criteria	The flying/handling qualities will be considered satisfactory as long as no characteristics are noted which hinder the ability of the pilot to fly normal maneuvers or are otherwise judged a barrier to USAF TPS student learning.
Expected Test Results	With more aft C.G. locations, the aircraft is expected to be more pitch sensitive, but still controllable.
Final Data Products	Pilot comments will be captured by the instrumentation.

3.0 TEST PROCEDURES

3.1 Test Readiness Review

Prior to the start of testing, a test readiness review will be conducted among participating USAF TPS and contractor personnel. The following topics will be addressed in the briefing:

- | | |
|--|---|
| 1. System under test status | 8. Go/No-go criteria |
| 2. Instrumentation status | 9. Real-time data requirements |
| 3. Aircraft configuration | 10. Quick-look data requirements |
| 4. Test objective and procedure review | 11. Final data requirements to include
format, algorithms, and data
definitions |
| 5. Test coordination | |
| 6. Safety | |
| 7. Success criteria | |

3.2 Test Preparation

A weight & balance measurement will be performed prior to testing. Additionally, a control (elevator/ailerons/rudder) rigging check will be completed prior to test in accordance with the manufacturer maintenance manual tolerances. The maximum and neutral control deflections and angles will be documented in the final report.

3.3 Test Execution

Test execution will follow the procedures outlined in the test plan. The USAF TPS staff will be responsible for producing test cards that meet the requirements of this test plan and USAF TPS OI 11-3 (reference 8).

3.3.1 Spin Entry Procedures

The control applications for Phase A, B, C, and D stalls are shown in Table 10: Control Applications for Phase A through D Stalls/Spin Attempts. To determine what the pro-spin inputs are for the test aircraft, the flight manual is used. Per the flight manual, the spin entry procedure for the DG-1000S is as follows from section 4.5.8.1 Category U, Utility, Spins:

Inducing the spin: *Gradually bring the sailplane into a stall. When buffeting starts, pull the stick back completely and kick in full rudder in the direction of spin.*

The above procedure, which appears to apply only to upright spin entries, is non-specific with regard to the rate of airspeed decay or the pitch attitude to be used and may produce inconsistent results. Spin entry procedures require additional clarification. Because the DG-1000S is heavily wing loaded ($I_{xx} > I_{yy}$), dynamic rolling maneuvers are expected to be ineffective in producing departures or spins. Three upright spin entry procedures, based on common techniques, are shown in Table 11: Stall/Spin Entry Procedures. All follow the general guidance offered by the flight manual, but differ in the rates of airspeed decay and the use of lateral-directional control inputs. Spin entry procedures that prove ineffective in causing a spin where others reliably succeed (for that C.G./pitch inertia configuration) need not be attempted on subsequent test points.

The inverted spin entry procedures are shown as well; these are based on common techniques and an understanding of the factors necessary to cause a spin. No guidance exists in the flight manual regarding inverted spins; however, the maneuver is not prohibited in any documentation.

Table 10: Control Applications for Phase A through D Stalls/Spin Attempts.

Stall Testing Phase	Control Application	Entry Conditions	If Aircraft Departs ¹ During that Stall Testing Phase:
A Stalls	Pitch control applied to achieve the specified airspeed rate. Roll, yaw, and decoupled 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 no other indication of stall has occurred, or d) sustained intolerable buffet.	One-g stall with smooth airspeed rate (1 kt/sec) One-g stall with abrupt AOA rate (5 kt/sec)	“Extremely Susceptible to Departure”
B Stalls with Aggravated Control Inputs	Pitch control applied to achieve the specified airspeed rate. Roll, yaw, and decoupled control inputs as normally required for the maneuver task. When conditions a, b, c, or d from above have been attained, controls briefly misapplied intentionally, then neutralized. 1 second of pro-spin inputs will be used for this test.	One-g stall with smooth airspeed rate (1 kt/sec) One-g stall with abrupt AOA rate (5 kt/sec)	“Susceptible to Departure”
C Stalls with Aggravated and Sustained Control Inputs	Pitch control applied to achieve the specified airspeed rate. Roll, yaw, and decoupled control inputs as normally required for the maneuver task. When conditions a, b, c, or d from above have been attained, controls are misapplied intentionally or in response to unscheduled air vehicle motions, and held for 3 seconds, then neutralized.	One-g stall with smooth airspeed rate (1 kt/sec) One-g stall with abrupt AOA rate (5 kt/sec)	“Resistant to Departure”
D Spin Attempts	Pitch control applied to achieve the specified airspeed rate. Slight bank angles may be used to influence the direction of spin entry. Roll, yaw, and decoupled control inputs as normally required for the maneuver task. When conditions a, b, c, or d from above have been attained, controls are applied in the most critical manner to attain each possible mode of post-stall motion, and held for two or five turns.²	One-g stall with smooth airspeed rate (1 kt/sec) One-g stall with abrupt AOA rate (5 kt/sec)	“Extremely Resistant to Departure”

Note:

¹See section 2.2.2 Departure for a program-specific definition of “departure.”

²If a spiral dive is encountered, the Phase D spin attempt will be discontinued and recovery/dive pullout will be initiated.

Table 11: Stall/Spin Entry Procedures.^{1,2}

Entry Procedure	Initial Airspeed Rate of Decay	Initial Bank Condition / Coordination	Control Input Procedure ³
	Initial Pitch Condition		
1	Smooth: 1 kt/sec	Wings Level / Coordinated	- Trim for level flight at approximately 55 KIAS. - Establish and maintain pitch attitude until buffeting starts. - Smoothly apply simultaneous full-aft (forward) stick and full rudder in the desired direction of spin.
	≈5 deg above horizon		
2	Abrupt: 5 kt/sec	Wings Level / Coordinated	
	≈10 deg above horizon		
3	Smooth: 1 kt/sec	Steady-Heading Sideslip [full rudder in the desired direction of spin, bank as required to maintain heading]	- Trim for level flight at approximately 55 KIAS. - Establish a steady-heading sideslip. - Establish the pitch condition to assure airspeed decay. - Maintain the airspeed decay rate and sideslip until departure occurs. - At departure, smoothly apply full aft stick, and confirm full rudder input while neutralizing lateral stick.
	≈5 deg above horizon		

Notes:

1. All stall/spin entries will be with landing gear up, airbrakes retracted and the window closed.
2. Only one-g spin entries will be investigated (-1g for inverted spin entries).
3. Pitch inputs in parenthesis, (), denote procedures for inverted spin entries. For inverted entries, prior to step 1, a half-roll will be used to establish the aircraft in inverted flight.

Table 12: Spin Recovery Procedures.

Flight Manual ¹	Rudder Only ²	NACA Modified ³	Neutral ⁴	Hands-Off ⁴
0. Stick – Full aft 1. Ailerons – Neutral 2. Rudder – Full opposite direction of spin ***Pause ½ turn*** 3. Stick – Ease forward (aft) ***Once rotation stops:*** 4. All Controls – Neutral	0. Stick – Full aft 1. Ailerons – Neutral 2. Rudder – Full opposite direction of spin ***Once rotation stops:*** 3. Rudder – Neutral 4. Stick – Ease forward to neutral	0. Stick – Full aft 1. Ailerons – Neutral 2. Rudder – Full opposite direction of spin 3. Stick – Neutral ***Once rotation stops:*** 4. Rudder – Neutral	1. All Controls – Centered	1. All Controls – Release from pro-spin inputs

Notes:

¹ Reference 3

² Reference 9 and Appendix D.

³ Reference 10

⁴ Reference 11

Stick positions in parenthesis, (), denote procedures for inverted spin recoveries. See Reference 12.

If any alternate recovery procedures do not recover the aircraft from a spin after two turns from the initiation of the procedure, the flight manual recovery procedure will be used. If a spiral dive occurs, dive pullout will be initiated immediately.

3.3.2 Spin Recovery Procedures

Per the flight manual section 3.5, Spin Recovery, the spin recovery procedure for the DG-1000S is as follows (originally written in German):

Apply full rudder opposite to the direction of spin, pause. Then ease stick forward until the rotation ceases, centralize the controls and carefully pull out of the dive. The ailerons should be kept neutral during recovery.

The flight manual section 4.5.8.1, Category U, Utility, Spins lists a nearly identical spin recovery procedure, with one important exception: the word “*pause*” is omitted. This appears to be erroneous. Pausing to wait for recovery is an important step in classical spin recovery (refer to the NACA Standard Recovery discussed in Appendix D). The amount of pause was not specified, so the test team selected a pause of ½ turn, which follows the NACA Standard Recovery procedure. Despite this omission, section 4.5.8.1, Category U, Utility, Spins adds additional important notes:

It is not necessary to extend the dive brakes during spin recovery. The DG-1000S displays a large nose down pitch attitude after leaving the spin. So you have to flare out correspondingly.

Furthermore, the NACA Standard recovery procedure requires that the stick start full aft. This is the logical stick position (given that a stall will likely include full-aft stick). Since this is an implied step, it was added as “step zero” to the recovery procedure.

This procedure is most appropriate for recovery from upright spins; no procedure was found with regard to recovery from inverted spins (logically, longitudinal stick inputs should be reversed to recover from inverted spins). The above procedure has been converted into discrete chronological steps, shown in Table 12: Spin Recovery Procedures. Four other procedures have historically been employed in spin recovery of aircraft. These are most properly named: Rudder Only, NACA Modified, Neutral, and “Hands-Off”. For historical record, a brief discussion of the origin for the names of these recovery procedures is contained in Appendix D: Spin Theory. The inverted spin recovery procedure is also shown in Table 12: Spin Recovery Procedures, and is based on common techniques and an understanding of the effect of each control.

The misapplied recovery controls that will be investigated are incorrect order (stick before rudder) or poorly timed (stick forward too soon) flight manual recoveries. These recoveries are modifications of the flight manual recovery and are enumerated in Table 13: Misapplied Recovery Procedures.

If any non-flight manual recovery procedures (alternate or misapplied recovery controls) fail to recover the aircraft to controlled flight after two turns from their initiation, the flight manual recovery procedure will be used.

Table 13: Misapplied Recovery Controls Procedures.

Poorly Timed ¹	Incorrect Order ²
0. Stick – Full aft	0. Stick – Full aft
1. Ailerons – Neutral	1. Ailerons – Neutral
2. Rudder – Full opposite direction of spin	2. Stick – Ease forward
Pause ¼ turn	***Pause 1 second***
3. Stick – Ease forward (aft)	3. Rudder – Full opposite direction of spin
Once rotation stops:	***Once rotation stops:***
4. All Controls – Neutral	4. All Controls – Neutral

Notes:

¹ The critical case is attempting to apply forward stick too soon, rather than too late.

² The 1-second pause accounts for an IP issuing directive corrections to the student.

3.3.3 Dive Pullout Procedures

If recovery is successful, all spin recovery procedures will be followed immediately by a dive pullout. Additionally, dive pullout will be initiated immediately upon recognition of a spiral dive. With regard to spin recovery, the flight manual states (section 3.5, Spin Recovery and section 4.5.8.1. Category U, Utility: Spins):

[...] the max. speed is 200 km/h (108 kts.).

The context of this statement is somewhat ambiguous, but, in the judgment of the test team, appears to be a limitation based on airbrake extension, not a demonstrated result. (This judgment was made based on wording in section 3.7: Recovery from intentional cloud flying.)

Section 2.2: Airspeed states the never exceed airspeed as 146 KIAS and maneuvering speed as 100 KIAS. From section 3.6 Spiral dive recovery, the flight manual procedure is:

Apply rudder and aileron in opposite direction and carefully pull out of the dive.

The dive pullout must be aggressive enough to avoid over-speeding the aircraft (nominally, 4 g's, but in no case to exceed the load factor limits of the airframe), but not so abruptly initiated as to induce an accelerated stall. The test team will plan all dive pullouts to leave airbrakes retracted (to allow use of the increased load factor limits). Both the never exceed speed and the maneuvering speed guidance will be treated as limits. While pilots will plan to avoid exceeding 108 kts, no special post-flight action will be required if it is exceeded.

3.4 Posttest Briefing

After each mission, the flight will be debriefed. Lessons learned will be applied to subsequent test missions.

4.0 TEST REPORTING

A technical report (TR) will be available to key personnel within 60 days from the completion of testing.

5.0 LOGISTICS

5.1 Transportation

If testing is conducted at a location other than Mountain Valley airport, Tehachapi, CA, the glider and tow aircraft will be transported by aero-tow. This will minimize maintenance actions in disassembly and re-assembly of the glider. Most likely, this location would be North Base at Edwards AFB, CA.

5.2 Support

Fuel for the tow aircraft is available at Edwards South Base. The test aircraft and tow aircraft will be stored in a hangar at North Base.

5.3 Maintenance

All maintenance except flight-test-specific modifications will be handled in accordance with existing FAA regulations. Temporary installation of the flight-test-specific instrumentation will be performed by USAF TPS technical support personnel and will be inspected by an FAA-certified maintainer familiar with the test aircraft.

5.4 Training

The test team training requirements including recency of experience and practice bailout procedures are documented in the safety plan. Highly experienced Glider Spin instructor test pilots and engineers accustomed to the aircraft spin environment via first-hand experience are desired.

Tow pilots will be familiar with the local area around which testing will be conducted. If testing is conducted inside R-2515, the tow pilots will receive a local area orientation brief from a qualified aircrew.

5.5 Administration Support

Flights will be tracked and billed according to existing contractual agreements between USAF TPS and the Skylark North glider operator.

5.6 Test and Support Personnel

A videographer will be required to coordinate ground-based video recording.

5.7 Schedule

USAF TPS personnel will coordinate directly with the Skylark North glider operator with regard to scheduling of testing at Edwards AFB.

6.0 REFERENCES

1. USAF TPS Staff. *FQ 9751 Glider Spin Mission Planning Guide Class 14B*. USAF Test Pilot School. Edwards AFB, CA. January 2015.
2. Janzen, D. Precourt, C. *AFFTC-TR-89-27 Schleicher ASK - 21 Glider (TG-9) Stall and Spin Evaluation*. Air Force Flight Test Center. Edwards AFB, CA, 1989.
3. DG Flugzeugbau GmbH. *Flight Manual for the Sailplane DG-1000S*. German Data Sheet No. LBA 413, EASA.A.072. Otto-Lillienthal-Weg 2. Bruchsal, Germany. Originally issued March 2002. Includes revisions 1 through 12, June 2012.
4. AFFTC-TR-11-66 *United States Air Force Academy TG-16A Training Glider Qualification Test and Evaluation*, 28 September 2011.
5. Department of Defense. *MIL-F-83691B Military Specification, Flight Test Demonstration Requirements for Departure Resistance and Post-Departure Characteristics of Piloted Airplanes*, March 1991.
6. Lehner, S. *JAR-22.221 Proof of Compliance report for DG-1000*. Flugzeugbau GmbH. December 2001.
7. Lanham, Olarles, *ASD-TR-79-5004 Inertia Calculation Procedure for Preliminary Design*, Aeronautical Systems Division. Wright-Patterson AFB, OH. April 1979.
8. USAF TPS/DO. *USAF TPS OI 11-3 Flight Operations*. USAF Test Pilot School. Edwards AFB, CA. April 2009.
9. McAvoy, W. H. *NACA-TN-555 Piloting Technique for Recovery from Spins*. National Advisory Committee for Aeronautics. Langley Memorial Aeronautical Laboratory. 1936.
10. Zimmerman, C. H. *NACA Report 557 Preliminary Tests in the N.A.C.A. Free-Spinning Wind Tunnel*. National Advisory Committee for Aeronautics. Langley Memorial Aeronautical Laboratory. 1936.
11. Neilhouse, et. al. *NASA-TR-R-57 Status of Spin Research for Recent Airplane Designs*. National Aeronautics and Space Administration. Langley Research Center. 1960.
12. Scher, S. H. *NACA-TN-3531 Pilot's Loss of Orientation in Inverted Spins*. National Advisory Committee for Aeronautics. Langley Aeronautical Laboratory. October 1955.
13. Airman Testing Standards Branch. *FAA-8083-13A Glider Flying Handbook*. U.S. Department of Transportation. Federal Aviation Administration. 2013.
14. DG Flugzeugbau GmbH. *Maintenance Manual for the Glider DG-1000S*. German Data Sheet No. LBA 413, EASA.A.072. Otto-Lillienthal-Weg 2. Bruchsal, Germany. Originally issued March 2002. Includes revisions 1 through 14, June 2012.
15. DG Flugzeugbau GmbH. *Scale Drawing of the DG-1000S*. <http://www.dg-flugzeugbau.de/Data/3s-dg-1000.pdf>. Retrieved 20 Oct 2014.

This page was intentionally left blank.

APPENDIX A – ENVIRONMENTAL CHECKLIST

APPENDIX A – ENVIRONMENTAL CHECKLIST FOR 412 TW DEVELOPMENT, OPERATIONAL, OR FOLLOW-ON TEST & EVALUATION ACTIVITIES

Project Title: DG-1000S Stall and Spin Evaluation Name of Proponent/Point of Contact: Christopher Liebmann Organization/Office Symbol: USAF TPS/EDF				Date: 20 Jan 2014 Phone Number: 661-277-9575
Purpose: To identify activities requiring impact analysis as directed by AFI 32-7061, The Environmental Impact Analysis Process (EIAP) and compliance with other environmental legislation requirements. Responses to the below questions will facilitate a more thorough assessment and evaluation of potential environmental concerns as a result of the proposed project. Procedure: Please provide a brief description for any questions for which a "yes" answer is given. Please note turn-around time for document completion takes 5-14 days. If you have questions, call 412 TW/CEVN's J-TECH contractor, CH2M HILL at (661) 277-6233 (Alison Sims), (661) 277- 7058 (Michael Hanna), or 412 TW/CEV Customer Service Desk at (661) 277-1401 for consultation and resolution. Attach the completed checklist to the C&RE request as well as to 412TW.EMEAP@edwards.af.mil with a cc to brenda.simoni@edwards.af.mil , Thomas.Mull@edwards.af.mil , and samuel.cox@edwards.af.mil .				
The factors below indicate potential environmental concerns. Answers should take into account all aspects of the action.				
	Yes	No	Don't Know	Would the proposed project:
1		X		Involve a new program, expanded program, unique test requirements, or use new or unproven technology?
2		X		Involve a project that is non-DoD sponsored?
3		X		Involve a request to establish or modify special use airspace, or alter existing air traffic patterns?
4a	X			Require: flight below 3000 feet AGL outside of FAA-approved low level areas/routes or MOAs; supersonic flight outside FAA-approved supersonic operating areas? Minimum altitude may be as low as 1,500 AGL before pre-landing checks begin. Gliders generate little noise.
4b		X		Require flight outside restricted area R-2515 but within R-2508?
4c	X			Require flight outside R-2508? Airspace above Mountain Valley Airport, Tehachapi, CA may be used for testing.
5		X		Deliberately jettison/drop/employ any object from the aircraft?
6		X		Result in a major increase in ground noise levels above existing levels at the proposed ground facility location, or underlying the proposed flight operations?
7		X		Result in a change, or generate new air emissions that might require a new or modified air quality permit?
8		X		Vent any gas, liquid, or objectionable odor into the air, such as exhaust from AGE, GSE, APU, or HVAC systems?
9		X		Involve: a paint spray booth; abrasive blasting, blast booth; scrubbers-baghouse, filter, rotocloner cyclone, chrome; or cooling towers, chillers, boilers?
10		X		Bring on base, or require 412th Test Wing to receive and operate new AGE, GSE, or portable electric generators that are ≥ 50 BHP?
11		X		Involve installation, repair, or closure of runways, taxiways, ramps, parking lots, roads, curbs, gutters, landscaping, utility lines, drainage, or facilities?
12		X		Involve reflective surfaces (such as solar /photovoltaic panels) that could cause reflections, or a new source of light and glare?
13		X		Involve the use of lasers or other RFR emitters?
14		X		Involve the use, storage or disposal of explosives, highly flammable or radioactive materials, or other hazardous materials or hazardous waste?
15		X		Expose Base employees or residents, or off base personnel to potential health hazards that are not part of normal test operations such as a new type of fuel, laser, explosive device, or insulating material?
16		X		Involve any ground activity (ground testing, ground disturbance, equipment/target set-up, etc)
17		X		Involve a change in use of a structure or other facility?
18		X		Involve installation, construction, modification, repair, demolition, or moving (temporary or permanent) of a structure or trailer, or other interior/exterior equipment (including antennas, tanks (above or below ground), oil water separators, hazardous waste storage equipment, test stands, airfield operational equipment, etc.)?
19		X		Involve trenching, excavating, grading, removal of vegetation, or any potential activity off improved roads?
20		X		Involve any activity on a lakebed, clay pan, drainage, pond, marsh or wetland? (Excluding routine flight/maintenance operations on runways.)
21		X		Involve removal or disturbance of birds during roosting or nesting?
22		X		Increase groundwater withdrawal, or include groundwater recharge?
23		X		Involve discharge of water to the ground surface?
24		X		Involve and-seal/re-seal cleaning process, vapor/degreaser, wash rack, bulk fuel storage tank, loading rack, fuel fill stand or solvent recycle/recovery?
25		X		Involve installation of septic tanks or leach fields?
26		X		Involve the use of substantial amounts of water, fuel or energy.
27		X		Produce large quantities of solid waste (from construction, demolition, remodeling or reconfiguration of buildings or facilities, runways or roads, disposal of equipment, or facility operations), liquid waste or waste water?
28		X		Be located on land controlled by a private party, or another public agency, and involve a real estate permit, lease agreement, or other real estate transaction?

APPENDIX B – DETAILED TEST ITEM DESCRIPTION

APPENDIX B – DETAILED TEST ITEM DESCRIPTION

The system under test will consist of the test aircraft with a crew of 1 or 2. The test aircraft will be a Glaser-Dirks DG-1000S glider, registration number N801DG. The aircraft is a two-place high performance sailplane designed for training, cross-country flying, and aerobatic training. It features a mid-mounted wing, T-tail, tandem seating, conventional reversible flight controls, and airbrakes. The undercarriage consists of a high spring mounted retractable main wheel with disc brake and a tail wheel. The wing is constructed from carbon-fiber reinforced plastic. The fuselage is mainly fiberglass, with steel as necessary for the landing gear.

The best glide ratio of the DG-1000S ranges from 41.5-46.6, depending on speed and wingtip configuration. At or below maneuvering speed (100 KIAS) in the aerobatic category, the glider has load factor limits of +7.0/-5.0 g. In the aerobatic category, the maximum takeoff and landing weight is 1,389 lbs.

The test aircraft is available with two sets of wingtips which provide for different wingspans: an 18-meter wingspan or a 20-meter wingspan with winglets. Spins are approved with all spans. Additional maneuvers including half-rolls and inverted flight are only authorized with the 18-meter wingspan.

The allowable C.G. range in flight is from 7.48 in. to 17.32 in. aft of the datum located at the wing leading edge at the root rib (1 in. C.G. travel = 2.65 % MAC). The C.G. is best controlled with the selection of crewmembers and ballast. There are provisions for ballast in the front and aft cockpits, as well as in the aircraft tail. Trim weights are available in two sizes: 1.2 kg or 2.4 kg. Ballast boxes are installed in the cockpit to hold up to four 9.6 kg (21.1 lbs) of trim weights. A ballast-box is installed in the tail of the aircraft which can hold up to 12 kg (26.5 lbs) of trim weights. The tail trim weights are secured by a rod with springs attached to a plastic cover which is then sealed with tape. Provisions exist for the use of water ballast, but the use of water ballast is prohibited by reference 3 during aerobatics. No water ballast will be used during this test program.

Table B-1: DG-1000S Relevant Values shows a summary of relevant values. Table B-2: N801DG Most Recent Weight and Balance Calculation shows the results of a weighing of N801DG in English engineering units.

A three-view drawing of the aircraft is shown in figure B-1: DG-1000S Three-View (from reference 15). Thorough mass properties information will be obtained prior to testing. Figures B-2 through B-5 show the provisions for ballast, the factory-installed flight instruments, and the yaw strings for each cockpit in the test aircraft.

The aircraft is considered representative of the configuration and mass properties that will be used in USAF TPS curriculum flights. However, some modifications have been made since production. In the judgment of the test team) the modification with the most potential to affect out-of-control characteristics is a Kevlar skid plate installed on the underside of the aircraft nose. This skid plate reduces damage to the aircraft, should an abrupt brake application cause the nose to contact the runway during landing rollout. Past high-AOA test experience with other USAF aircraft indicates that asymmetric vortex shedding from the nose may change the yawing moments on the aircraft. Given the large moment arm afforded by the aircraft nose, the spin characteristics of N801DG may be different from other DG-1000S aircraft. Figure B-7 shows the skid plate. Additional modifications to N801DG include the following:

- The Plexiglas surrounding the front window has developed cracks in it. An aluminum reinforcement bracket was fashioned. These are not expected to influence aircraft flight characteristics. See Figure B-8.

- Solar panels were installed on the top of the fuselage aft of the rear cockpit to recharge the aircraft battery. See Figure B-9.
- Occasionally consumable products such as turbulators on controls surfaces (see Figure B-10), tape on control surfaces (see Figure B-11), and tape on the wing-attach points (see Figure B-12) will require replacement. The state of these products may affect airflow over and around the glider, and thus, flight characteristics.

When the landing gear is retracted, the landing gear doors are held closed by bungee cords. The elasticity of these bungee cords may allow the landing gear doors to flap during spins. This flapping is audible from the cockpit, and may be disconcerting to aircrew. The technical consequence of this flapping in high-AOA flight is expected to be small, given that the landing gear doors are nearly co-located with the aircraft C.G. Over time, as the bungees age, their elasticity may vary, thus providing a possible source of inconsistent results.

The aircraft was certified under Joint Aviation Regulations (JAR) Part 22, change 5 through type certificate 413, issued on March 12, 2002. The following features are installed:

- Automatic hook ups for all controls
- Large 2-piece canopy for very good in-flight vision.
- Sealed airbrake and landing gear boxes
- Controls in each cockpit.
- All controls are operated with the left hand, which enables the right hand to remain on the control stick.

Table B-1: DG-1000S Relevant Values (reference 3 unless otherwise noted).

	Quantity	Flight Manual Section	Value
Speeds	Maneuvering speed (kts)	2.2: Airspeed	100 ¹
	Maneuvering speed (kts)	4.5.8: Aerobatics	97 ¹
	Maximum speed (kts)	2.2: Airspeed	146 ²
	Maximum towing speed (kts)	2.11 Aerotow, wing, and autotow launching	100
Weights	Maximum takeoff weight, aerobatic category (lbs)	2.4: Mass (weight)	1,389
	Trim ballast fin (lbs)	2.4: Mass (weight)	26.5
	Front seat minimum weight (lbs)	6.8.7.b) Trim possibility for heavy pilots	154.3 ³
	Front seat maximum weight (lbs)	2.4: Mass (weight)	231 or 242 ⁴
	Rear seat maximum weight (lbs)	2.4: Mass (weight)	242 or 198 ⁴
	Cockpit maximum weight (lbs)	2.4: Mass (weight)	463
	Maximum weight of non-lifting parts (lbs)	2.4: Mass (weight)	1,034
Dimensions	Span (m)	1.4 Descriptive data	18.000
	Wing area (m ²)	N/A ⁵	16.715
	Root chord (m)	N/A ⁵	1.108
	Tip chord (m)	N/A ⁵	0.511
	Aspect ratio	N/A ⁵	19.384
	Taper ratio	N/A ⁵	0.461
	Mean aerodynamic chord (m)	N/A ⁵	0.958
	Fuselage height (m)	1.4 Descriptive data	1.0
	Fuselage width (m)	1.4 Descriptive data	0.730
	Length (m)	1.4 Descriptive data	8.570
	Span of the horizontal tailplane (m)	1.4 Descriptive data	3.200
	Center of gravity limits (in.)	2.5 Centre of gravity	7.48-17.32
Misc	Maximum load factor, aerobatic category (g)	2.7 Manoeuvring load factors	+7.0/-5.0
	Maximum load factor with airbrakes extended (g)	2.7 Manoeuvring load factors	+3.5/-0.0
	Maximum wing loading (lb _f /ft ²)	1.4 Descriptive data	9.20

Notes:

¹ Reference 3 cites 185 km/hr for maneuvering speed but two different values in English units. The 97-kt value in section 4.5.8 appears to be erroneous and a result of incorrect unit conversion. 185 km/hr converts to 100 kts.

² Per reference 3, at maximum speed, only 1/3 of the maximum control movements are allowed.

³ Per reference 3, section 7.15.1, “the front cockpit ballast boxes can accommodate 2 ballast weights of min 2.4 kg (5.3 lbs.) each. Each weight compensates a pilot mass of 3.2 kg (7 lbs.). So a max. of 12.8 kg (28 lbs.) missing pilot mass can be compensated.”

Per section 6.8.7.b, with regard to ballast in the tail fin, “one trim weight of 1.2 kg raises the min. load in the front seat by 3.5 kg (7.7 lbs.). One trim weight of 2.4 kg raises the min. load in the front seat by 7 kg (15.4 lbs.).”

⁴ The guidance from reference 3 is confusing in this regard. Email correspondence with Wilhelm Dirks yielded the following clarifications:

1. The maximum loads are:

- 105 kg (231 lbs) front seat
- 110 kg (242 lbs) rear seat
- 210 kg (463 lbs) both seats combined

2. When flown with two pilots, using the front and rear seat limits (1.a. and 1.b., above), it would be possible to exceed the maximum load of both seats combined [210 kg (463 lbs)]. Therefore, pilots must verify that the total load does not exceed the 210 kg (463 lbs) limit.

3. When flown with two pilots, the maximum load in the front seat may be increased to 110 kg (242 lbs), but, in that case, the maximum load in the rear seat is decreased to 90 kg (198 lbs). In this case, the highest possible combined load is 200 kg (440 lbs), which is below the maximum combined limit [210 kg (463 lbs)].

⁵ Value provided by Wilhelm Dirks from the proof of compliance for the type DG-1000 submitted to EASA and LBA written by DG Flugzeugbau GmbH. No issue date exists.

Table B-2: N801DG Most Recent Weight and Balance Calculation

Aircraft Registration: N801DG, Serial no 10-123S80 *****			
Item	Weight in lbs	Arm	Moment
Nose Wheel	834	7.9375	4,117.875
Tail Wheel	106.7	205.125	21,886.8375
Empty Weight (as weighed)***	940.7		26,004.7125
Empty Weight CG (inches)		27.644	
Notes: * W&B calculated for 18 Meter wing configuration Weighted with Landing Gear Down. ** Refer to TCDS No. G15CE and Manufacture Flight Manual Weight and Balance calculated by: Patti D. Browne _____ A&P 3063573, Date: January 10, 2015			

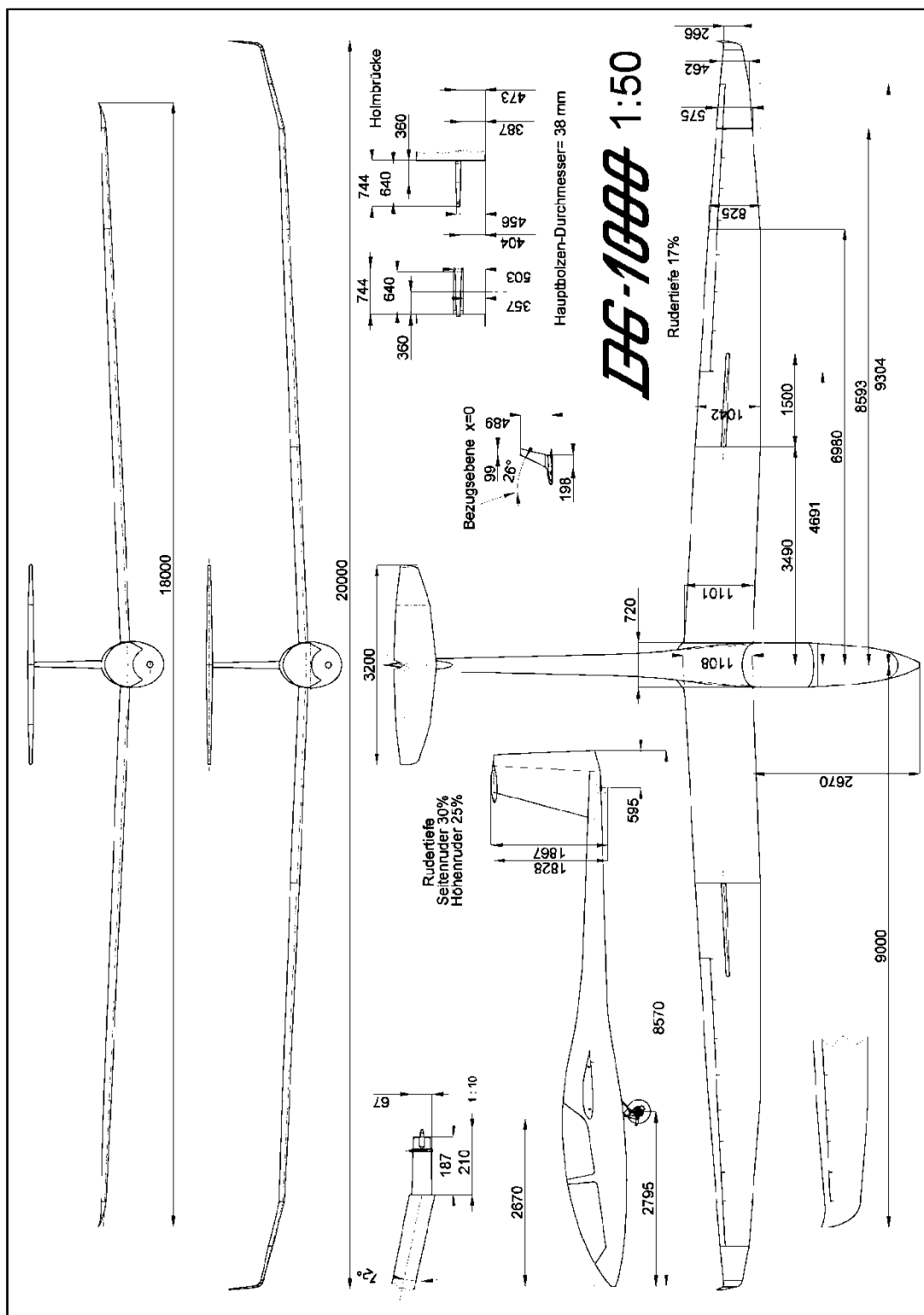


Figure B-1: DG-1000S Three-View (Dimensions in mm).

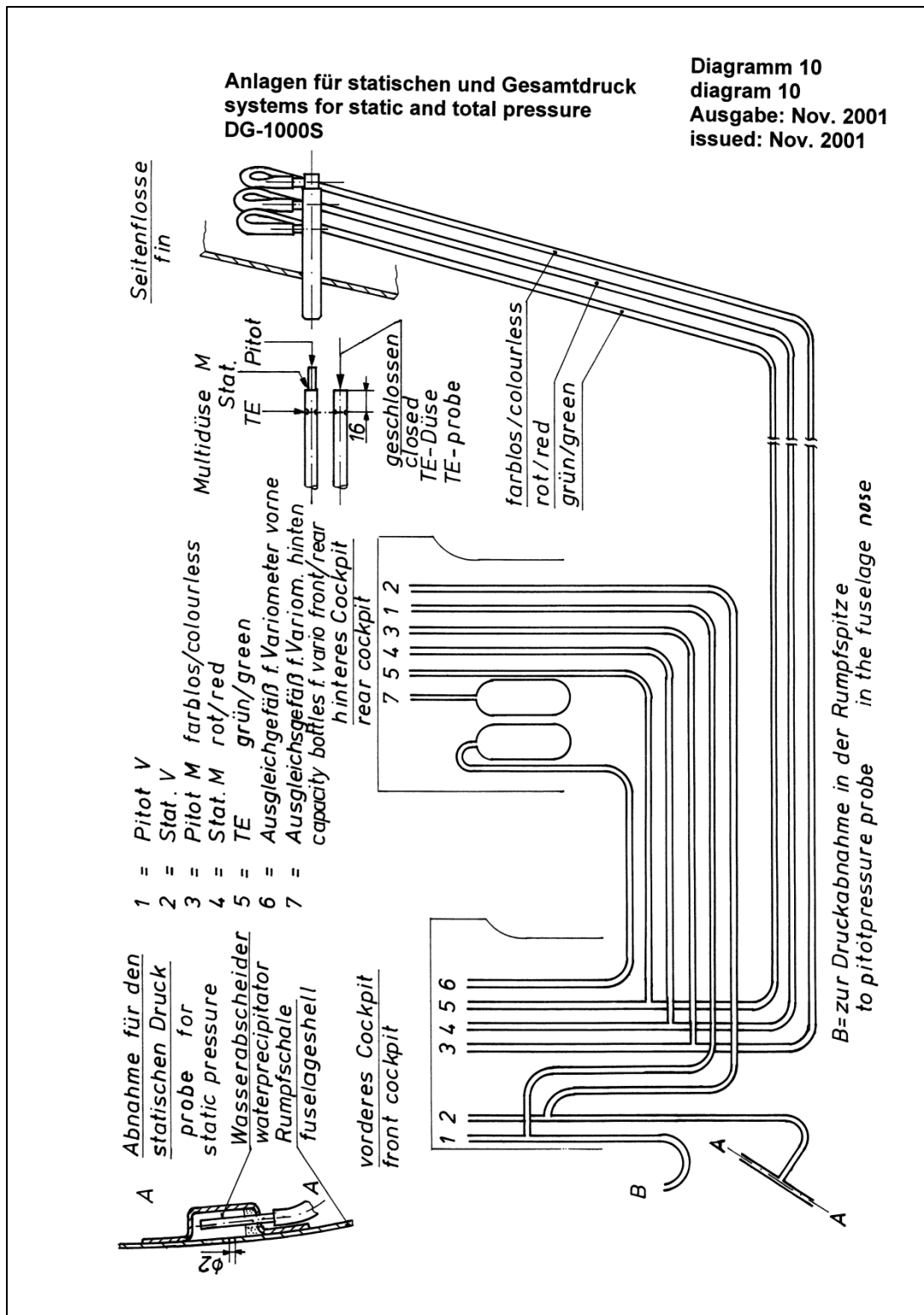


Figure B-2: DG-1000S Systems for Static and Total Pressure (reference 14).



Figure B-3: DG-1000S N801DG Front Cockpit Ballast Boxes.



Figure B-4: DG-1000S N801DG Tail Ballast Boxes.



Figure B-5: DG-1000S N801DG Production Instruments.



Figure B-6: DG-1000S N801DG Yaw Strings.



Figure B-7: DG-1000S N801DG Skid Plate.



Figure B-8 DG-1000S N801DG Window Reinforcement Bracket.



Figure B-9 DG-1000S N801DG Solar Panels.

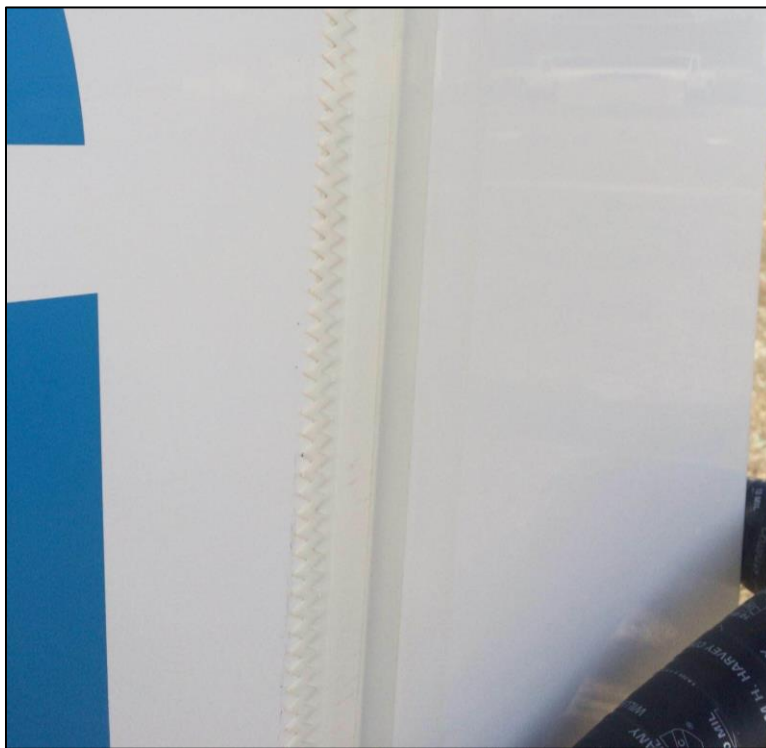


Figure B-10 DG-1000S N801DG Rudder Turbulator.



Figure B-11 DG-1000S N801DG Aileron Taped Seam.

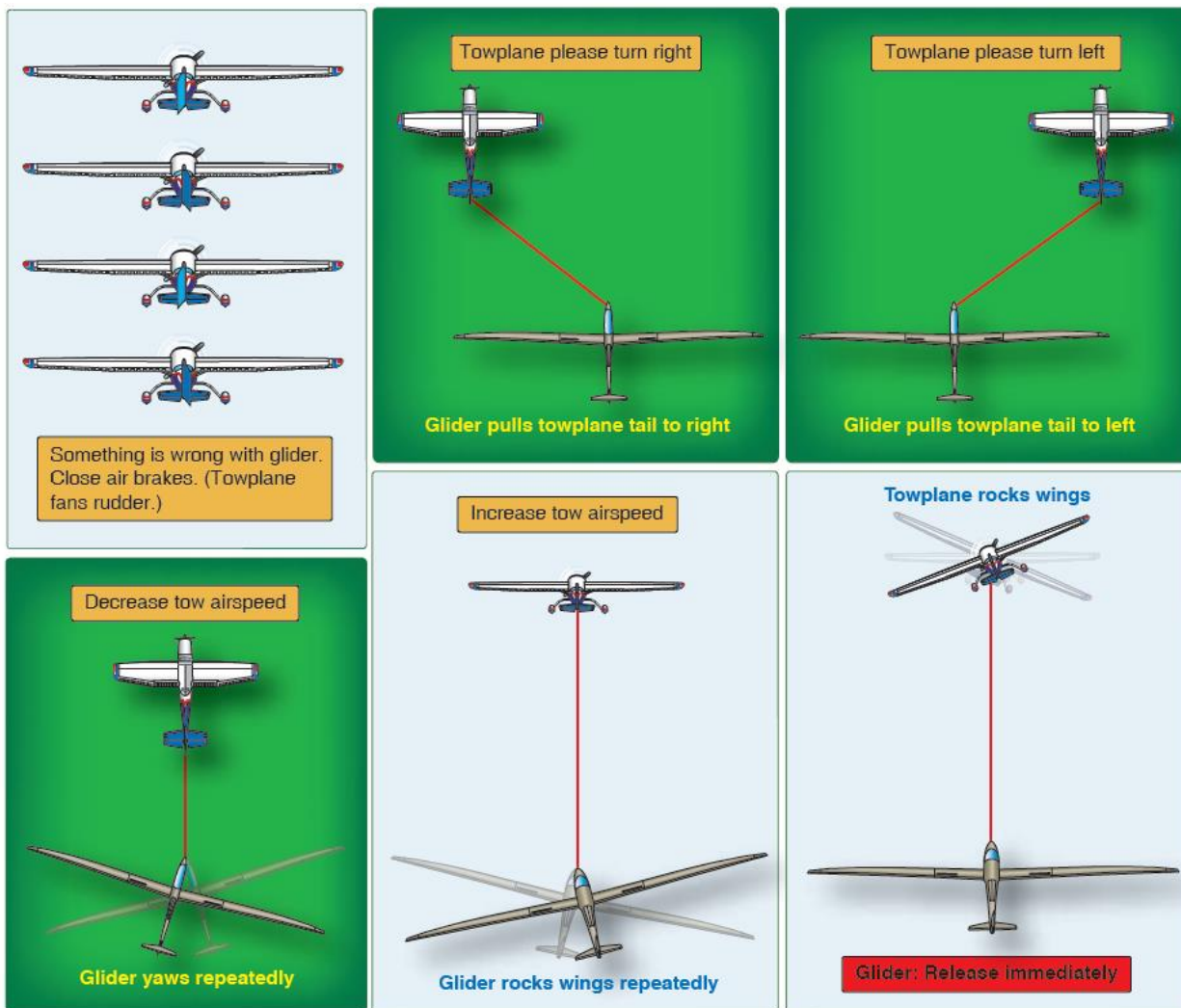


Figure B-12 DG-1000S N801DG Wing Attach Point Taped Seam

APPENDIX C – AEROTOW PROCEDURES

APPENDIX C – AEROTOW PROCEDURES

AeroTow operations will be conducted in accordance with standard procedures for glider tow operations. These procedures are thoroughly documented in FAA-8083-13A, Glider Flying Handbook (reference 12). Standard procedures allowing communication between the tow pilot and glider are shown below:



APPENDIX D – SPIN THEORY

APPENDIX D – SPIN THEORY

The following appendix is adapted for the DG-1000S and is partially excerpted from reference 2. This section serves as a useful reference for key concepts relating to spinning aircraft, as well as a historical record of the naming of spin recovery procedures.

EQUATIONS OF MOTION

The derivation of the equations of motion for spinning flight requires several basic assumptions regarding aircraft motion such as:

1. An inertial reference frame is used.
2. The aircraft can be treated as a rigid body in translation and rotation.
3. The mass of the aircraft remains constant during the maneuver.
4. A flat, non-rotating Earth is a suitable inertial reference frame.
5. Aircraft motion will be described using a body-fixed reference frame.
6. The atmosphere is at rest relative to the inertial reference frame.
7. Thrust effects are negligible for a glider.
8. The aircraft has symmetry about the XZ plane. Therefore, $I_{yz} = I_{xy} = 0$.

At this point, the rotational equations of motion are may be expressed as:

$$\left[\frac{d\vec{H}}{dt} \right]_{Inertial} = \sum (\vec{M}_{aero})$$

$$\dot{P}I_{xx} + QR(I_{zz} - I_{yy}) - (\dot{R} + PQ)I_{xz} = L_{aero}$$

$$\dot{Q}I_{yy} - PR(I_{zz} - I_{xx}) + (P^2 - R^2)I_{xz} = M_{aero}$$

$$\dot{R}I_{zz} + PQ(I_{yy} - I_{xx}) + (QR - \dot{P})I_{zx} = N_{aero}$$

Solving for the aircraft response in angular acceleration:

$$\dot{P} = \frac{I_{yy} - I_{zz}}{I_{xx}} QR + \frac{I_{xz}}{I_{xx}} (\dot{R} + PQ) + \frac{L_{aero}}{I_{xx}}$$

$$\dot{Q} = \frac{I_{zz} - I_{xx}}{I_{yy}} PR - \frac{I_{xz}}{I_{yy}} (P^2 - R^2) + \frac{M_{aero}}{I_{yy}}$$

$$\dot{R} = \frac{I_{xx} - I_{yy}}{I_{zz}} PQ + \frac{I_{xz}}{I_{zz}} (\dot{P} - QR) + \frac{N_{aero}}{I_{zz}}$$

The DG-1000S is nearly symmetric about the XZ plane. Therefore, it is appropriate to additionally assume:

9. Because the aircraft body axis system is chosen somewhat arbitrarily based on aircraft geometry, the aircraft body axis system is chosen to coincide with the aircraft inertial axis. $I_{xz}=0$.

The rotational equations of motion reduce to:

$$\dot{P} = \frac{I_{yy} - I_{zz}}{I_{xx}} QR + \frac{L_{aero}}{I_{xx}}$$

$$\dot{Q} = \frac{I_{zz} - I_{xx}}{I_{yy}} PR + \frac{M_{aero}}{I_{yy}}$$

$$\dot{R} = \frac{I_{xx} - I_{yy}}{I_{zz}} PQ + \frac{N_{aero}}{I_{zz}}$$

At this point, recall that I_{zz} is the largest inertia term. Also recall that the definition of a wing-loaded aircraft requires that $I_{xx} > I_{yy}$. Therefore, the sign of the inertial terms is as shown:

$$\begin{aligned} \dot{P} &= \frac{I_{yy} - \overset{(-)}{I_{zz}}}{I_{xx}} QR + \frac{L_{aero}}{I_{xx}} \\ \dot{Q} &= \frac{I_{zz} - \overset{(+)}{I_{xx}}}{I_{yy}} PR + \frac{M_{aero}}{I_{yy}} \\ \dot{R} &= \frac{I_{xx} - \overset{(+)}{I_{yy}}}{I_{zz}} PQ + \frac{N_{aero}}{I_{zz}} \end{aligned}$$

From this result, note the effect of pitch rate (Q), yaw rate (R), and roll rate (P) on the aircraft response. For instance, the product of P and R couple to produce pitch acceleration. This is conversationally referred to as “yaw-roll coupling” or “inertial coupling”. Loadings with greater pitch inertias (I_{yy}) generate greater inertial pitch up moments, allowing spins to stabilize at a more forward C.G. despite the greater aerodynamic pitch down moments inherent to that C.G. location.

PITCHING MOMENT BALANCE

In a fully developed spin, the contributors to the spin characteristics of a wing-loaded aircraft are the moments applied by aerodynamic effects (wing, tail, and control surfaces) and inertia (mass distribution). Figure D-1 shows the balance of aerodynamic and inertia pitching moments in a spin.

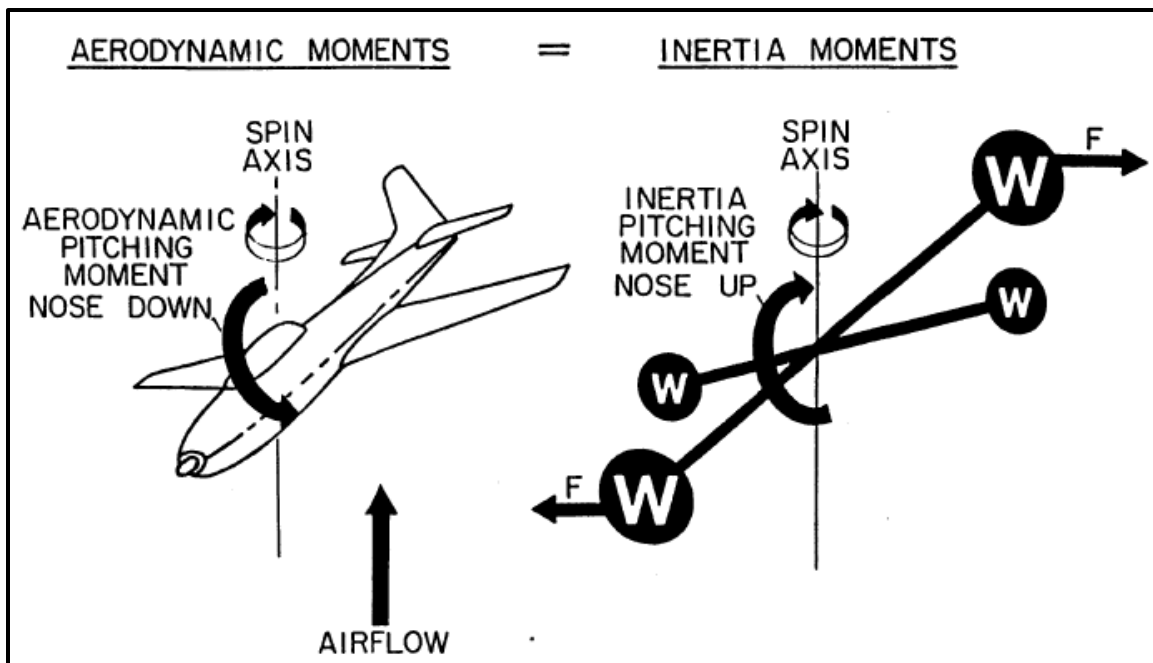


Figure D-1: Balance of Aerodynamic and Inertial Pitching Moments in a Spin.

Inertia moments tend to pitch the nose up, as the aircraft attempts to align its inertial x and y axes (i.e., wings and fuselage) perpendicular to the spin axis. The aerodynamic moments tend to pitch the nose down, as the aircraft aligns itself aerodynamically with the relative wind. Pitch attitude will vary until the moments reach equilibrium; depending on the dynamics of the aircraft, this may not occur before recovery controls are used.

The inertia moment magnitude is a function of rotation rate and mass distribution. A higher spin rate or greater mass distribution from the cg results in a greater nose up moment. For the DG-1000S, loading heavyweight pilots and tail weights are expected to create a greater nose up inertial moment during a spin than with lightweight pilots and no tail weights. The aerodynamic moment is primarily a function of AOA and C.G. location. For a statically stable aircraft, a higher AOA or more forward C.G. tends to create a greater nose down pitching moment. In an upright spin, the pitching moment balance is derived from AOA, rotation rate, C.G. location, and mass distribution.

ROTATION RATE OSCILLATION

Since C.G. and mass distribution will be determined prior to flight test, the AOA and rotation rate will be the only remaining variables required to determine pitching moment balance. The rotation rate is primarily driven by the autorotative couple of the wings. Autorotation occurs as a result of the advancing wing operating at a lower AOA than the retreating wing (Figure D-2). The advancing wing may or may not be completely stalled, but the resulting lift and drag forces are still higher and lower, respectively, relative to the retreating wing. This phenomenon is thoroughly documented in reference 2.

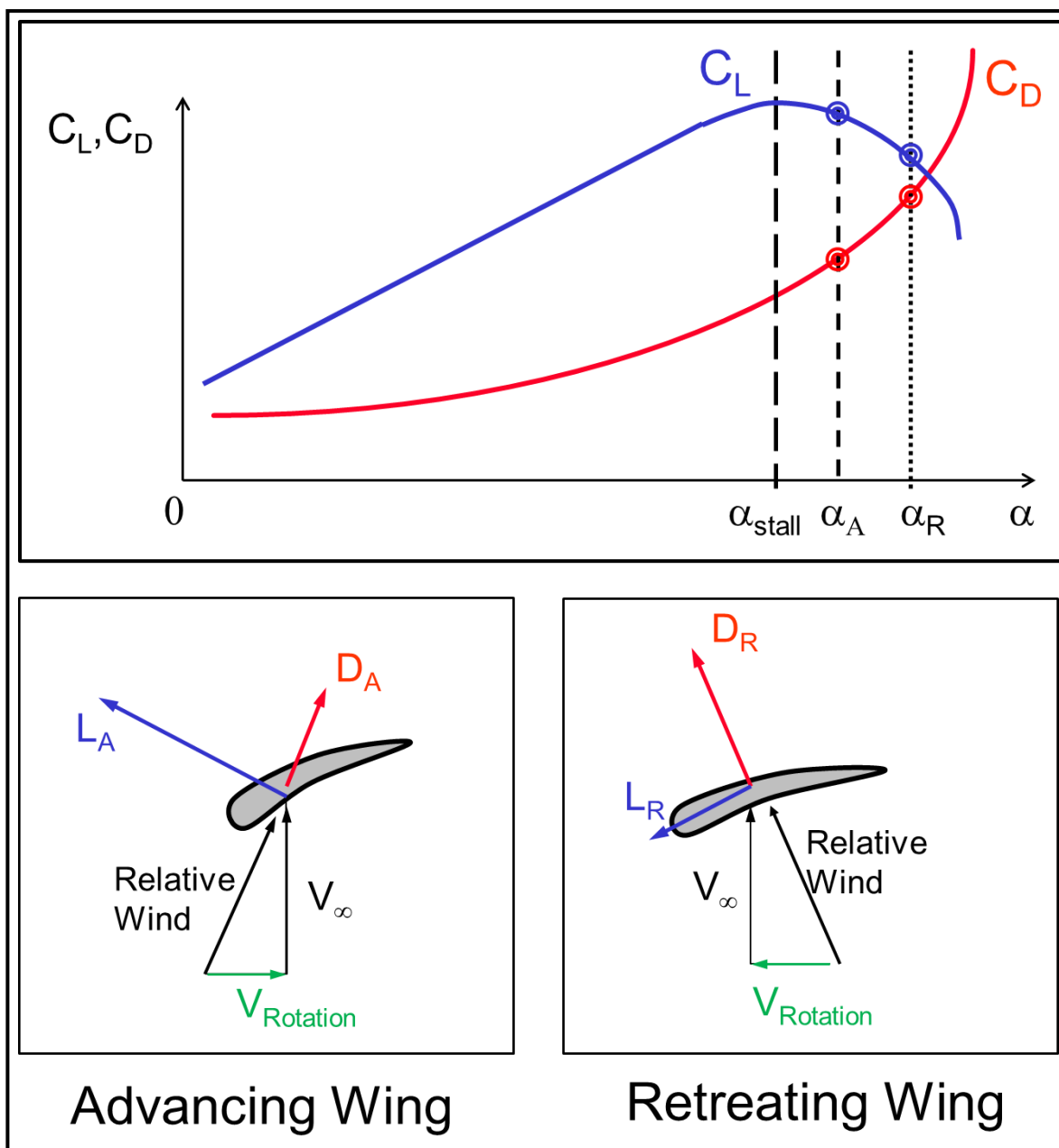


Figure D-2: Lift and Drag Vectors Forming an Autorotative Couple in a Spin.

This autorotative couple accelerates the rotation rate and increases the inertial pitching moment proportionately. At a threshold rotation rate, which varies as a function of configuration and mass distribution, the inertial pitching moment can overpower the aerodynamic moment and cause the nose to pitch up. The AOA, therefore, increases and the advancing wing also becomes completely stalled. This reduces the autorotative moment, which reduces the rotation rate and subsequently decreases the inertial pitching moment. The nose pitches down again causing the advancing wing outboard section to un-stall. This increases the autorotative couple, accelerating the spin again, and causing the cycle to repeat.

Another contributor to the oscillating rotation rate during spins is rudder effectiveness. At steeper attitudes (lower AOA), the airflow across the rudder has its greatest chord wise component velocity, thereby generating greater rudder effectiveness. As the nose pitches up during a spin oscillation, the

relative wind component is 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 spins is the conservation of angular momentum of the rotating body. For a wing-loaded aircraft, the yaw inertia (I_{zz}) is expected to be greater than the roll inertia (I_{xx}). Therefore, conservation of momentum dictates a proportionately slower rate at flat attitudes, where the spin motion is primarily about the yaw axis, than at steep attitudes where the spin motion is primarily about the roll axis.

AILERON EFFECTS

During spins, ailerons are expected to remain somewhat effective in producing bank angle changes in the proper sense. By using ailerons to reorient the aircraft attitude on the spin axis, a component of the spin rate vector (ω) can be generated on the body axis (lateral axis), creating a pitch rate (Q) (Figure D-3). Additionally, the outside wing panel may not be stalled once a spin is established. The ailerons may be capable of producing significant rolling and yawing moments, which will influence spin behavior (and recovery). No differentiation can readily be made between aerodynamic and inertial effects, so the sum total is the only effect that can be observed.

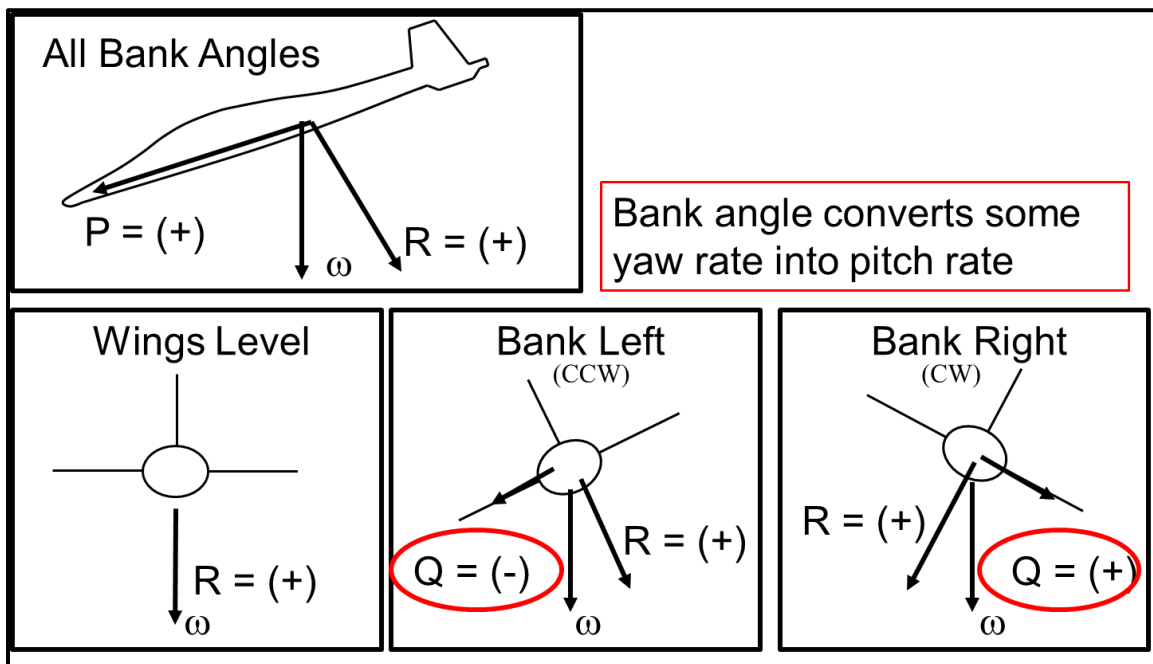


Figure D-3: Effect of Bank Angle Changes on an Upright, Right Spin.

Pitch rate causes the aircraft inertial moments to affect roll and yaw acceleration. This is shown from the inertia terms of the yaw acceleration equation of motion. For the DG-1000S, $I_{zz} > I_{xx} > I_{yy}$. Therefore, ailerons against the spin produce antispin yaw acceleration. Conversely, ailerons with the spin produce prospin yaw acceleration.

RECOVERY PROCEDURE ORIGINS

For many years, USAF TPS executed alternate spin recovery procedures referred to as NASA Standard, NASA Modified, and NASA Neutral. The first time the NASA Standard and NASA Modified

recoveries were named appears to have been in the first USAF TPS Flying Qualities Text (AFFTC-TN-59-12). In that document, those recoveries were referred to as NACA Standard and NACA Modified. The NASA Neutral recovery seems to have materialized in the USAF TPS FQ text between the 1977 and the 1982 versions. It appears as though USAF TPS may have taken liberties in creating those names. However, the details are more nuanced.

With regard to the “NASA Standard” recovery, NASA-TN-D-6575 (from 1971) states:

"This technique was proved in full-scale spin tests conducted on several airplanes by the NACA in 1935 [NACA-TN-555], and the results from these tests led to the so-called NACA recommended spin-recovery technique: Briskly move the rudder to full against the spin; after the lapse of appreciable time (approximately one-half turn), briskly move the elevator to approximately full down, and hold these controls until the recovery is complete."

To dig deeper, NACA-TN-555 states:

The recommended operation of the controls for recovery from a spin, which presupposes that the ailerons are held in neutral throughout the recovery, is as follows:

- 1. Briskly move the rudder to a position full against the spin.*
- 2. After the lapse of appreciable time, say after at least one-half additional turn has been made, briskly move the elevator to approximately the full down position.*
- 3. Hold these positions of the controls until recovery is effected.*

There are a number of reasons why the rudder movement should precede the elevator movement. The effect of the reversed rudder is to check the rate of rotation and cause the nose of the airplane to go down. The blanketing of the rudder by the elevator is generally less, and hence the effectiveness of the rudder greater, when the elevator is up. While the rate of rotation is being checked by the rudder, the elevator becomes increasingly effective in assisting recovery. An opposite sequence of operation, that is, one in which the elevator movement precedes the rudder movement, is decidedly objectionable because the usual effect of putting the stick forward while the rudder is held with the spin is an increase in the rate of rotation.

Slow and cautious movement of the controls during recovery is to be avoided. In certain cases it has been found that, with a slow and cautious reversal of the rudder and elevator, spinning will continue indefinitely; whereas brisk operation of these controls would have effected recovery.

One step implicit in the enumerated recovery procedure that is not mentioned is the initial longitudinal stick position. The text below the recovery procedure in NACA-TN-555 points out that the longitudinal stick should be held full-aft to maximize rudder effectiveness.

These documents (NACA-TN-555 and NASA-TN-D-6575) are regarded as some of the landmark works on the subject. Therefore, based on these, the term “NASA Standard” is most correctly “NACA Recommended”, although “NACA Standard” is acceptable.

A review of TPS FQ publications (including the FQ texts published in 1986, 1982, 1977, 1974, 1968, and 1959) revealed a consistent discrepancy: while the TPS documents referred to the “NASA/NACA Standard” recovery, the procedure listed under that title does not fully coincide with the procedure in NACA-TN-555. The procedure in the TPS FQ publications omits the step: “briskly move the elevator to

approximately the full down position”. Instead, the FQ publications direct the stick be held full aft until the spin stops. As an example, see the words from the 1959 FQ Text (AFFTC-TN-59-12):

The NACA Standard recovery starts with the rudder in the direction of the spin, stick full back and ailerons neutral (if ailerons were held during the spin, neutralize them before starting the recovery). Full opposite rudder is applied and the stick held full back until the rotation stops when the rudder is neutralized and the stick eased forward to approximately the neutral position.

Given this divergence, the recovery procedure in the TPS FQ texts cannot genuinely be called “NASA/NACA Standard”. Therefore, the term “Rudder Only” is proposed as a substitute.

With regard to the “NASA Modified” recovery, that term seems to have come from NACA Report 557 (from 1936) concerning spin testing in a free-spinning wind tunnel. The recovery mechanization of the model used in that test program caused all recovery controls to actuate at once, rather than pausing between rudder and elevator inputs. That appears to have been a byproduct of the mechanization at the time, and doesn't appear to have been an intentional deviation from the NACA-TN-555 technique. Similar to the “Standard” recovery, the term “NASA Modified” is most appropriate.

The term “NASA Neutral” seems to have materialized in the USAF TPS FQ text between the 1977 and the 1982 versions. Neutralizing controls is, of course, not a new technique. Research found the technique first formally documented in NASA-TR-R-57 (from 1960), although researching such a simple technique is rather difficult. Use of the term “Neutral” seems most appropriate without attaching an organizational name.

The 1968 TPS FQ Text (FTC-TIH-68-1002) calls out a “Hands Off Recovery” as well. However, it first instructs the student to move all controls to neutral before releasing them. This procedural step does not seem to follow the intent of a "hands off" concept, but the original authors were unavailable for comment.

As an item of historical interest, a hybrid recovery technique may have first been partially employed in what has become known as Parke's Dive - the first documented spin recovery. The article documenting the recovery, as found in the Aug 31, 1912 edition of Flight magazine, states:

"His right hand he had already removed from the control wheel in order to steady himself by grasping the body strut forming an upright between the windows of the enclosed body.[...] It was his recognition, through this forcible effect, of the predominating influence of the spiral motion, as distinct from the dive, that caused him to ease off the rudder and finally push it hard over to the right (i.e., to turn machine outwards from the circle), as a last resource, when about 50 feet from the ground. Instantly, but without any jerkiness, the machine straightened and flattened out-came at once under control and, without sinking appreciably, flew off in perfect attitude."

APPENDIX E – TEST POINT MATRIX

APPENDIX E – TEST POINT MATRIX

The test point matrix is as follows and will be downselected as test results become known. All possible test points are shown:

Table E-1: Test Point Matrix.

Configuration Number ¹	C.G. Location			Pitch Inertia ⁴	Spin Entry Procedure ⁵	Spin Recovery Procedure ⁶	Control Effects ^{7,8}
	C.G. Range ²	Aft of Datum ³ (inches/mm)	Percent MAC				
FWD-MIN	“Forward”	7.5 / 190.5	19.89%	Minimum	1U, 2U, 3U, 1I	FM, R-O, MOD, NEUT, H-O	AA, AW, IO, PT
FWD-MAX		7.5 / 190.5	19.89%	Maximum	1U, 2U, 3U, 1I		
8-MIN		8.5 / 215.9	22.54%	Minimum	1U, 2U, 3U, 1I		
8-MAX		8.5 / 215.9	22.54%	Maximum	1U, 2U, 3U, 1I		
9-MIN		9.5 / 241.3	25.19%	Minimum	1U, 2U, 3U, 1I		
9-MAX		9.5 / 241.3	25.19%	Maximum	1U, 2U, 3U, 1I		
10-MIN	“Medium”	10.5 / 266.7	27.84%	Minimum	1U, 2U, 3U, 1I		
10-MAX		10.5 / 266.7	27.84%	Maximum	1U, 2U, 3U, 1I		
11-MIN		11.5 / 292.1	30.49%	Minimum	1U, 2U, 3U, 1I		
11-MAX		11.5 / 292.1	30.49%	Maximum	1U, 2U, 3U, 1I		
12-MIN		12.5 / 317.5	33.14%	Minimum	1U, 2U, 3U, 1I		
12-MAX		12.5 / 317.5	33.14%	Maximum	1U, 2U, 3U, 1I		
13-MIN	“Aft”	13.5 / 342.9	35.79%	Minimum	1U, 2U, 3U, 1I		
13-MAX		13.5 / 342.9	35.79%	Maximum	1U, 2U, 3U, 1I		
14-MIN		14.5 / 368.3	38.44%	Minimum	1U, 2U, 3U, 1I		
14-MAX		14.5 / 368.3	38.44%	Maximum	1U, 2U, 3U, 1I		
15-MIN		15.5 / 393.7	41.10%	Minimum	1U, 2U, 3U, 1I		
15-MAX		15.5 / 393.7	41.10%	Maximum	1U, 2U, 3U, 1I		
16-MIN		16.5 / 419.1	43.75%	Minimum	1U, 2U, 3U, 1I		
16-MAX		16.5 / 419.1	43.75%	Maximum	1U, 2U, 3U, 1I		
AFT-MIN	“Aft”	17.32 / 440.0	45.92%	Minimum	1U, 2U, 3U, 1I		
AFT-MAX		17.32 / 440.0	45.92%	Maximum	1U, 2U, 3U, 1I		

Notes:

¹ Configurations will be attempted starting with configuration 10-MIN, building up in C.G. location, pitch inertia, and with upright entries before inverted entries.

² The C.G. ranges shown are derived from Table 4: C.G. Ranges.

³ The C.G. data band is +/- 0.5 inch from the specified value, not to exceed the C.G. limits of the test aircraft.

⁴ The number of nose and tail weights will be varied to the maximum or minimum attainable with the test team and allowed by the flight manual weight & C.G. limits while achieving the given C.G location. This will directly affect the pitch inertia (I_{yy}) of the configuration.

⁵ The spin entry procedures are numerically identified in Table 11: Stall/Spin Entry Procedures with aggravation in accordance with Table 10: Control Applications for Phase A through D Stalls/Spin Attempts. At least 2 entries will be attempted in each direction (left vs. right). Spin entries may be attempted in either direction first.

U = upright entry,

I = inverted entry.

⁶ The spin recovery procedures are identified in Table 11: Spin Recovery Procedures. The flight manual recovery must be successfully completed for a given configuration before any other recoveries will be attempted.

FM = Flight manual recovery,

R-O = Rudder-only recovery,

H-O = Hands-off recovery.

MOD = NACA modified recovery,

NEUT = Neutral recovery,

Recovery from inverted spins will only be attempted using the flight manual recovery procedure.

⁷ The control effects investigation will include applying pro-spin and anti-spin lateral stick inputs, misapplied inputs, and poorly timed inputs

AA = Ailerons against (stick away from) the direction of spin,

IO = Incorrect order (forward stick before opposite rudder),

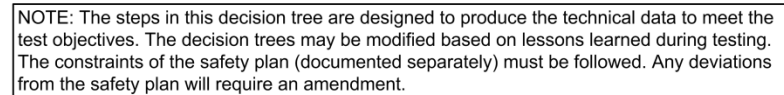
AW = Ailerons with (stick towards) the direction of spin,

PT = Poorly timed (too early).

⁸ No control effects will be investigated during inverted spins.

STO 2. Evaluate the 1-g stall characteristics and departure susceptibility of the DG-1000S over the executable range of C.G. locations.

STO 3. Determine the most forward C.G. location/pitch inertia configuration where the DG-1000S will reliably yield a developed spin.



E-3

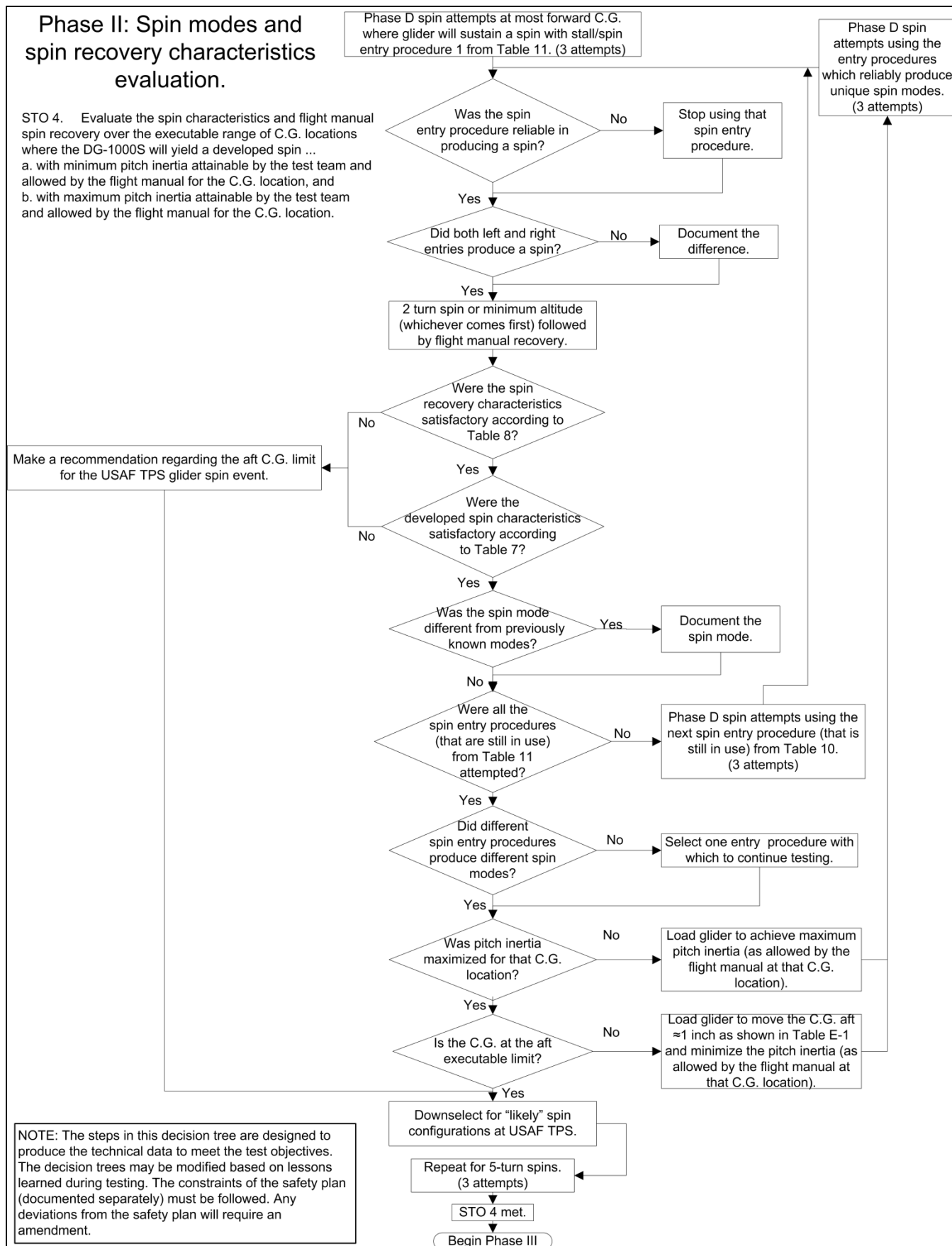


Figure E-2: Phase II Spin Modes and Spin Recovery Characteristics Determination Decision Tree.

Phase III: Determination of control effects on spin modes.

STO 5: Evaluate the upright spin characteristics when selected control inputs are applied with the down-selected aircraft C.G./pitch inertia configurations.
STO 6: Evaluate the aircraft response to selected alternate upright spin recovery inputs with the down-selected aircraft C.G./pitch inertia configurations.

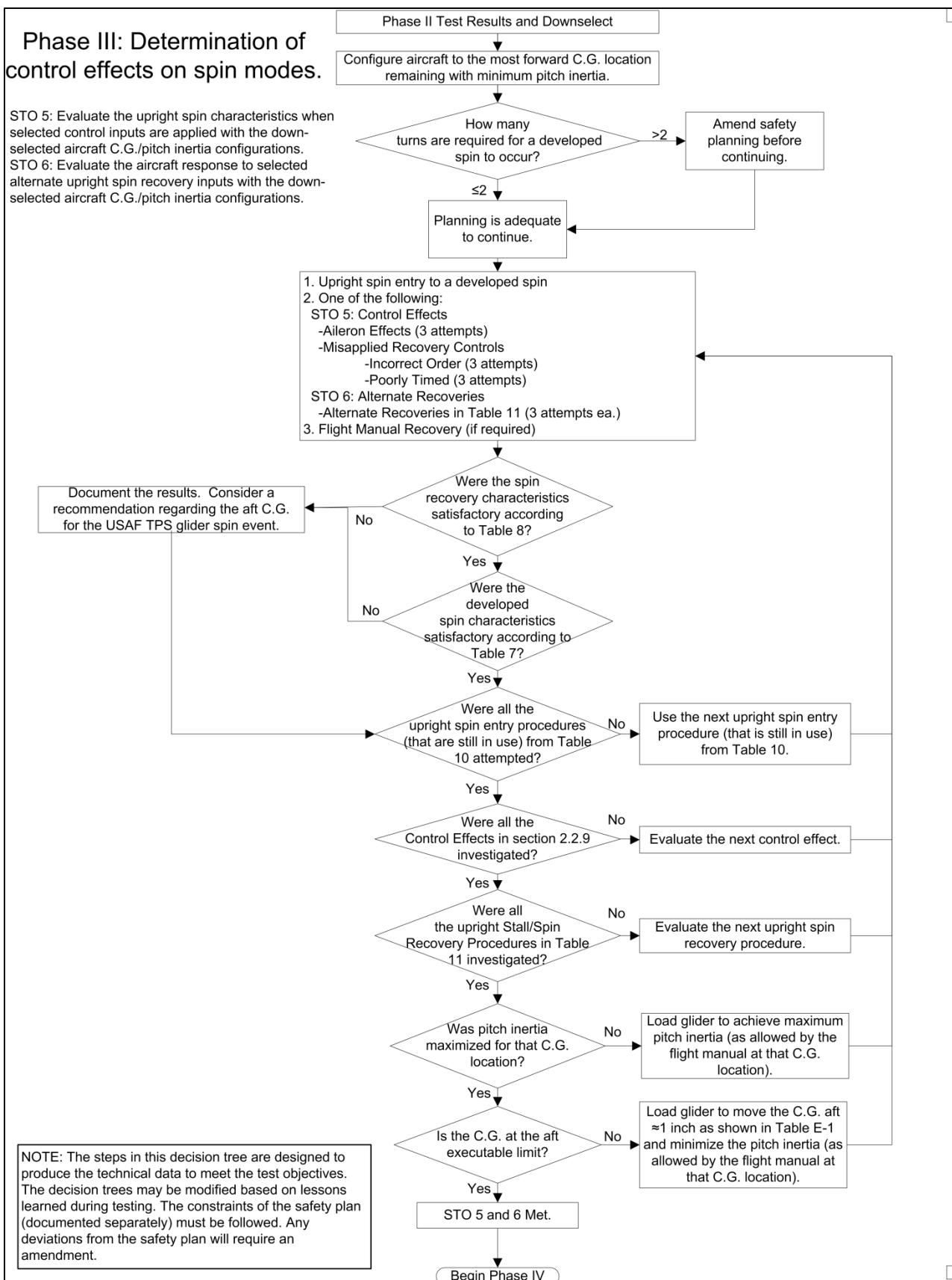


Figure E-3: Phase III Control Effects and Alternate Recoveries Evaluation Decision Tree.

APPENDIX F – ANALYSIS OF EXECUTABLE CONFIGURATIONS

APPENDIX F – ANALYSIS OF EXECUTABLE CONFIGURATIONS

The C.G. and pitch inertia configurations achievable by the test team are central to the test program. To determine the “minimum achievable pitch inertia configuration allowed by the flight manual”, three analyses were conducted:

- Idealized Aircrew Weights
- With Quantized Available Pilot (FCP) and Idealized Second Crew (RCP)
- With Quantized Available Pilot (RCP) and Idealized Second Crew (FCP)
- With Quantized Available Pilot (FCP solo)

The pitch inertia of the empty test aircraft is estimated to be 5.73×10^6 lbs-in² using the method outlined in reference 7. These values are preliminary and will be analyzed further. The empty aircraft has a C.G. location of 27.65 in. (702 mm) at a weight of 940.7 lbs. The instrumentation weights are estimated as 10 lbs in the baggage area and 2 lbs in the rear instrument panel.

A spreadsheet was designed with a Solver function that determined the loading configuration required to maximize or minimize the pitch inertia condition for the Configuration Number as specified in Table E-1 (e.g. 10-MAX represents the maximum pitch inertia conditions for a C.G. range of 10.00 in. to 10.99 in.) by varying a combination of some of the following point masses:

- aircrew in each cockpit,
- ballast bags under the front cockpit,
- trim weights in the front cockpit ballast box,
- trim weights in the tail fin.

The Solver function considered all the relevant flight manual limits; those limits are:

- front cockpit minimum
- front cockpit maximum weight,
- rear cockpit maximum weight,
- total cockpit weight, and
- gross weight in the aerobatic category.

By plotting the results of the Solver function in several cases, envelopes showing C.G. location at various whole aircraft pitch inertias were constructed in Figure F-1: DG-1000S Notional Aircraft Configurations. The envelopes illustrated in figure F-1 are not final values and must be considered notional. However, the lessons learned from these plots may be useful to the test team during planning.

IDEALIZED AIRCREW WEIGHTS

Set Up

Using idealized aircrew weights in both cockpits, theoretical configurations can be found that explore the edges of the pitch inertia vs. C.G. envelope defined by flight manual limits and the chosen Configuration Number.

A spreadsheet was designed with a Solver function that determined the loading configuration required to maximize or minimize the pitch inertia condition for the Configuration Number by varying a combination of the following:

- aircrew in each cockpit (minimum 110lbs including parachute),
- trim weights in the front cockpit ballast box,
- trim weights in the tail fin.

While the aircrew weights were taken as pure variables, the trim weights remain quantized increments. Large trim weights are 5.3 lbs/weight and small trim weights are 2.6 lbs/weight. The front cockpit ballast box only accommodates large weights, and can house up to 4 total weights. The tail fin accommodates up to 4 large weights and 2 small weights.

The 110-lbs minimum aircrew weight was specified to consider second aircrew members of low but realistic weights (a parachute would not fit a 46-lb aircrew). With a 14-lb parachute, this analysis accounts for pilots weighing at least 96 lbs.

Analysis

The minimum and maximum pitch inertia configurations were limited by various factors as the target C.G. range (Configuration Number) was changed.

- At all but the most aft C.G. conditions with maximum pitch inertia, the rear seat pilot was set to maximum weight (242.5 lbs).
- Until less aircrew weight was required to drive the C.G. aft, the maximum pitch inertia condition required that the gross weight was set to maximum weight (1388.9 lbs).
- To achieve the most forward C.G. conditions, the front cockpit ballast box was filled (with the tail fin ballast box empty).
- To achieve the most aft C.G. conditions, the tail fin ballast box was only filled (with the front cockpit ballast box empty) to achieve the maximum pitch inertia. Aft C.G. conditions with minimized pitch inertia were achieved with the tail fin ballast box empty.

QUANTIZED AVAILABLE PILOT AND IDEALIZED SECOND CREW

Currently, two pilots have been identified for this program: one weighing 190 lbs and one weighing 205 lbs. In this case, the pilot weight is fixed to 190lbs. The case of the 205-lb pilot was not as relevant. With two ballast bags (50 lbs), the 205-lb pilot would exceed the maximum seat weight, and thus be limited to 1 ballast bag (thereby decreasing the total pitch inertia as compared to a 190-lb pilot). The roster for the second crew member is more variable; it was varied from the flight manual limit down to 110 lbs.

Set Up

A similar set up was used to analyze the possible configurations with a few changes. The Solver function was modified to determine the loading configuration required to maximize or minimize the pitch inertia condition for the Configuration Number by varying the following:

- aircrew in one cockpit (minimum 110 lbs),
- ballast bags under the front cockpit (up to 2 bags),
- trim weights in the front cockpit ballast box,
- trim weights in the tail fin.

Cases were evaluated with the pilot and idealized second crew member in either cockpit. With the quantized available pilot in the front cockpit, the use of ballast bags allowed for some variation in the

total front cockpit weight. Each ballast bag weighs approximately 25 lbs. Given the limits of the pouch in which the bags are secured, no more than 2 bags are planned. The pouch currently exists under the front seat of the glider; moving the pouch to the rear cockpit is non-trivial and is not planned. With the idealized second crew in the front cockpit, ballast bags were unnecessary.

Results

With an available pilot and an idealized second crew, the minimum and maximum pitch inertia achieved with 2 idealized crew are still nearly achievable in the forward C.G. configurations. If an available pilot and an idealized second crew are used, certain aft C.G. configurations could not be reached. The most aft C.G. condition that could be achieved in this case was 13.03 in. (minimum I_{yy}) and 13.00 in. (maximum I_{yy}). The C.G. and pitch inertia envelope delineated by an available pilot and an idealized second crew are most useful.

QUANTIZED AVAILABLE SOLO PILOT

For the case of a quantized available solo pilot, the pilot weight is fixed to 190lbs. The second seat was set to remain empty.

Set Up

With a fixed crew weight, the Solver function was modified to determine the loading configuration required to maximize or minimize the pitch inertia condition for the Configuration Number by varying the following:

- ballast bags under the front cockpit (up to 2 bags),
- trim weights in the front cockpit ballast box,
- trim weights in the tail fin.

Results

With an available pilot, the aft C.G. configurations could be reached that were unattainable with two crew. These may be achievable during IP proficiency sorties, but do not represent conditions which should be considered executable during the TPS Glider Spin curriculum event. The forward range of C.G. conditions achieved by a solo pilot overlapped with the more useful envelope delineated by a quantized pilot and idealized second crew.

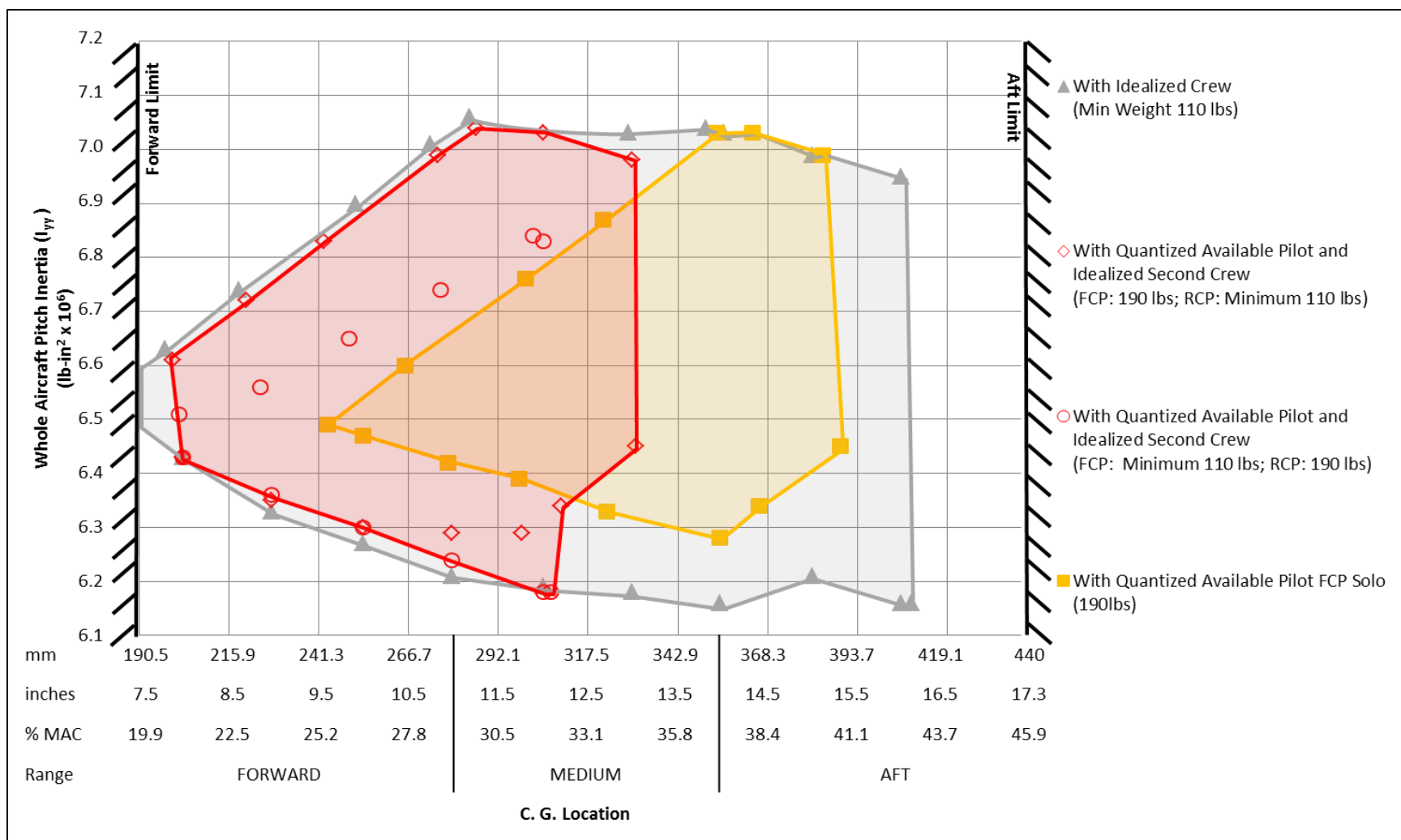


Figure F-1: DG-1000S Notional Aircraft Configurations.

APPENDIX G – LIST OF ABBREVIATIONS, ACRONYMS, AND SYMBOLS

APPENDIX G – LIST OF ABBREVIATIONS, ACRONYMS, AND SYMBOLS

<u>Abbreviation</u>	<u>Definition</u>	<u>Units</u>
AFB	Air Force Base	---
AGL	above ground level	---
AHRS	attitude heading reference system	---
AOA	angle of attack	deg
α	angle of attack	deg
CA	California	---
C.G.	center of gravity	---
cm	centimeters	cm
CT	technical director	---
deg	degrees	deg
DO	director of operations	---
DoD	Department of Defense	---
EDF	education division, flying qualities branch	---
FAA	Federal Aviation Administration	---
EIAP	environmental impact analysis process	---
ft	feet	---
g	normal load factor	g
hr	hour	hr
I	inertia	---
in.	inches	in.
IP	instructor pilot	---
JAR	joint aviation regulations	---
JON	job order number	---
KIAS	knots indicated airspeed	kt
kg	kilograms	kg
km	kilometer	km
kts.	knots	kt
m	meters	m
MAX	maximum	---
MIN	minimum	---
MSL	mean sea level	---
lbs	pounds	lbs

LDTO	lead developmental test organization	---
NACA	National Advisory Committee for Aeronautics	---
NASA	National Air and Space Administration	---
OI	operating instruction	---
N/A	not applicable	---
P	body-axis roll rate	deg/sec
PC	personal computer	---
Q	body-axis pitch rate	deg/sec
R	body-axis yaw rate	deg/sec
sec	second	sec
STO	specific test objective	---
TPA	traffic pattern altitude	---
TPS	Test Pilot School	---
TR	technical report	---
USAF	United States Air Force	---
USNO	United States Naval Observatory	---
VMC	visual meteorological conditions	---
ω	spin rate vector	deg/sec
x	longitudinal distance	---
xx	principle condition about the x-axis	---
yy	principle condition about the y-axis	---
zz	principle condition about the z-axis	---

APPENDIX H – DISTRIBUTION LIST

APPENDIX H – DISTRIBUTION LIST

<u>Onsite Distribution</u>	<u>Number of Copies</u>		
	<u>Email</u>	<u>CD</u>	<u>Paper</u>
Edwards AFB Technical Research Library ATTN: Mr. Darrell Shiplett 307 E Popson Ave, Bldg 1400 Edwards AFB CA 93524-6630	0	2	2
773TS/ENF ATTN: Ms. Katherine Wood 307 E Popson Ave, Bldg 1400 Edwards AFB CA 93524-6841	1	0	0
USAF TPS/CS ATTN: Dr. M. Christopher Cotting 220 S Wolfe Ave Edwards AFB CA 93524-6150	1	0	0
<u>Offsite Distribution</u>			
Skylark North ATTN: Ms. Jane Barrett 16334 Harris Rd. Tehachapi, CA 93561	0	2	0
Defense Technical Information Center ATTN: DTIC-O 8725 John J. Kingman Rd, Ste 0944 Fort Belvoir VA 22060-6218	1	0	0
TOTALS	3	4	2