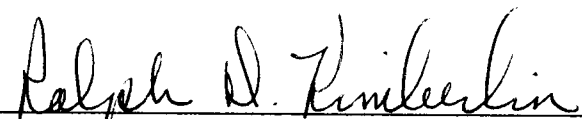
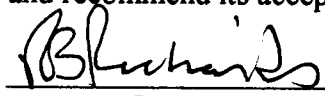


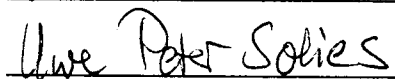
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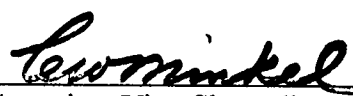

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**THE T-45 HIGH ANGLE OF ATTACK
EVALUATION:
The Testing of an Advanced Trainer Aircraft**

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Joseph Maximillian Rogers
December, 1994

DEDICATION

I would like to dedicate this thesis to all the future Naval Aviators of the land. May the T-45 Test Team have done you justice in providing a safe and effective training aircraft for your future endeavors as one of America's finest. God Bless.

ACKNOWLEDGMENTS

I would like to take this opportunity to acknowledge the unending support of my wife Amy, who's patience and dedication to our family have allowed me the time to complete this rigorous and demanding project. Additionally, I would like to thank the entire T-45 staff at SATD, NAWCAD Patuxent River Maryland for their selfless effort and dedication to getting the best product to the fleet as we possibly could. In particular, I would like to thank Mr. Pat Perusse for his technical expertise and companionship throughout the rigors of this high pressure test, and for its ultimate success. I would like to thank my major professor Dr. Ralph Kimberlin, for his guidance and patience. Last but certainly not least, I would also like to thank the other committee members, Dr. Solies, Dr. Collins, and Dr. Richards for their comments and assistance over the term of this thesis.

ABSTRACT

Thesis statement: The objective of this thesis is to document the testing of the T-45 for its viability as an Out of Control Flight (OCF) and Spin trainer in the High Angle of Attack (HAOA) regime for the US Navy Advanced Jet Training syllabus.

In October 1993, following the completion of the primary contractor's High Angle of Attack (HAOA) demonstration program, a Navy HAOA evaluation commenced. The purpose of the Navy HAOA testing was to evaluate the flying qualities and engine operability of the T-45A airplane, and determine its suitability for the undergraduate jet trainer mission in the HAOA flight regime. Areas investigated included departure resistance, vertical maneuvering and tailslides, operational maneuvering, Air Combat Maneuvering (ACM), and an evaluation of upright spins. Due to the possibility of entry into a potentially unrecoverable inverted spin mode, intentional inverted spins were prohibited and upright spin testing was restricted.

This thesis discusses the events and background that lead up to the Navy's HAOA flight testing, the tests and their results, and any appropriate recommendations that ensued with specific concern on airplane design changes and/or modifications.

In summary, the T-45A was not in compliance with the Test and Evaluation Master Plan (TEMP) due to: (1) technical characteristics associated with out-of-control flight (OCF) training, and (2) the T-45A was not capable of the upright rudder-induced or lateral stick-induced departures required by the TEMP, reference 1. The following major deficiencies were identified during the testing: the inability to perform all phases of the out-of-control flight training mission, and the airplane's susceptibility to inadvertent entry into unrecoverable inverted spins. However, the noted major deficiencies are not enough to stop the introduction of the airplane into the fleet but should be considered significant enough to be corrected as soon as possible.

PREFACE

The basis for this thesis includes years of testing performed by both the contractor and the US Navy. Many reports exist documenting the results and outcome of all of the different testing periods, including the testing which was the foundation for this document. Although this thesis is founded on the same results and presentation as that which exists in reference 10, the information provided, discussion of results and recommendations are the author's point of view and in no way reflects the United States Navy's point of view or the point of view of the Navy's Flight Test Center.

Due to the high content of technical matter in this thesis, a list of applicable and commonly referred to terms and abbreviations has been included in a glossary. Some aerodynamic theory, although used only in discussion, will be addressed in the text. However, the principles of aerodynamics will not be expounded upon within the context of this thesis. If there is a need to receive further clarification on basic aerodynamic principles, the reader should refer to the local engineering library and investigate on his or her own time.

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GLOSSARY

ACM - Air Combat Maneuvering
AFB - Air Force Base
AOA - Angle of Attack
APO - Abrupt Push Overs
APU - Abrupt Pull-Ups
CG - Center of Gravity
Cl_{max} - Maximum Coefficient of Lift
Cl_{min} - Minimum Coefficient of Lift
CR - Cruise Configuration
EP - Emergency Procedure
ETPS - Empire Test Pilot School
FTEG - Flight Test and Engineering Group
FSD - Full Scale Development
HAOA - High Angle of Attack
HYD 1 - Hydraulic System #1
HYD 2 - Hydraulic System #2
KIAS - Knots Indicated Airspeed
KCAS - Knots Calibrated Airspeed
LAU - Launch Rail
MAC - Mean Aerodynamic Chord
MDA - McDonnell Douglas Aircraft
MIL - Military Thrust
MSL - Mean Sea Level
NASA - National Aeronautics and Space Administration
NATOPS - Naval Aviator Training and Operations Source
NAVAIRSYSCOM - Naval Air Systems Command
NAWCAD - Naval Air Warfare Center Aircraft Division
NROTC - Naval Reserve Officer Training Corps
OBOGS - On Board Oxygen Generating System
OCF - Out-of-Control Flight
PA - Power Approach Configuration
PMBR - Practice Multiple Bomb Racks
PSG - Post-Stall Gyration

RAT - Ram Air Turbine
RFT - Recommend Further Testing
RPM - Revolutions Per Minute
SAHRS - Standard Attitude and Heading Reference System
SATD - Strike Aircraft Test Directorate
SDOF - Six Degree of Freedom
SHSS - Steady Heading Sideslip
SNA - Student Naval Aviator
UHF - Ultra High Frequency (Communications)
USNTPS - United States Naval Test Pilot School
TEMP - Test and Evaluation Master Plan
TGT - Turbine Gas Temperature
TLF - Thrust for Level Flight
TM - Telemetry
TMN - True Mach Number
TO - Takeoff Configuration
WUT - Wind-up Turn
YDC - Yaw Damper Control

INTRODUCTION

HISTORICAL PERSPECTIVE

The issue of why to conduct HAOA testing arises every time a flight test program is undertaken. The usual parties align their arguments for and against the high-risk flight testing evolution, and converge to defend their stance as to why their view point is correct. The bottom line is that the side that actually wins will be determined, or in most cases, pre-determined by factors outside of their control. Some of these factors include, but are not limited to, the following: Airplane role in the fleet, future impact of items done or not done while training in the airplane, safety ramifications of the flight regime, cost of the flight test weighed against the possibility of it generating any useful information that can't be generated by simulation, and many more. However, the final decision will be made by someone or a committee of people. They usually must factor in all the different variables, then decide on the best direction to take in order to achieve the end goal. The end goal being the task of answering the many questions about airplane handling in the designated flight regime. In the next few paragraphs, HAOA flight testing will be addressed from a historical perspective. This will include the impact of successful, or unsuccessful, completion of flight testing relating it to the T-45 flight test program.

After an extensive review of the current airplanes in the tactical US. Navy arsenal, a detailed list of airplanes and their potential for entering HAOA regimes, possibly even spins, was attained. Due to its mission and ordinary flight envelope, the least likely airplane to encounter HAOA or departure from control flight would be the S-3B. Following that, there is a full range of tactical aircraft that routinely enter the HAOA regime and are constantly pushing their flight envelope during day to day operations. In the case of these aircraft (F-18, F-14, A-6), the need to have developed a rigid flight envelope from actual flight test could not be overemphasized. Additionally, the airplane that trained the pilot prior to flying these airplanes was undoubtedly one that trained to that environment. Otherwise, it would not have been a very effective trainer aircraft. Here is where the T-45

enters the picture. It is the strike fighter trainer of the future and as such, designated as the initial training ground for aggressive maneuvering and tactical employment of a high performance airplane.

The T-45 was developed for a myriad of reasons. The list, although long and sometimes complicated, can be boiled down to a few very significant factors. The first of these factors was cost. The current arsenal of training aircraft was designed back in the late 50's and are aging. The fuel costs (and hence savings) of using a new generation aircraft are quite impressive. Additionally, if structured properly, the training pipeline could be streamlined to better employ a single aircraft for all the desired training. Finally, the airplane is "new" technology (at least it was new during the design phase of development) and will more than likely be highly reliable and in most cases more pleasant to fly simply due to its advanced features, handling qualities and avionics integration. These, however, are not guarantees. What is projected, is that the airplane will greatly reduce costs. During modern day financial woes within the Department of Defense, any program that shows a large reduction in operating costs and bottom line figures will be looked upon quite favorably. How to make the rest of the programmatic issues work, such as actual aircraft employment and utilization, will be the direct responsibility of the hierarchy and infrastructure developed to introduce new products into the fleet.

The advent of a new airplane is a large undertaking, especially when the new airplane will be responsible for the training of all strike pipeline future aviators. The program was developed with the goal of replacing the TA-4J and the T-2C airplanes and all of the training that they provided. In other words, the intermediate and advanced phases of flight training for the future tactical Naval Aviator will be covered by the T-45. This was a large undertaking and one that involved a long list of requirements, and by default, a long process of verification and validation. Among the required items to verify and validate were items as basic as takeoff and landings from an airfield, to much more complicated flight test programs involving suitability in the aircraft carrier environment. Finally, the

biggest test of the T-45, as well as any other airplane that will be subject to highly dynamic motion, came in the program developed to test its handling qualities and performance in the HAOA regime.

The HAOA program was extensive. It started prior to actual airplane development through investigating the equations of motion and applying them in theory to the mathematical model of the airplane. Then as a data base was generated, rough simulation of the aerodynamic model was examined. This was the preview and prediction tool used to forecast future results. The simulation process is a necessity in modern day flight test for several reasons. The two biggest are safety and cost savings. However, many factors that are predicted by simulation must be validated in flight. Although there is some dissension amongst the different parties on how deep the investigation should go, it is agreed that a validation of the model must occur in order for it to have credence in the future. Belief in the model is critical if it is to be used for items that might be considered not worthy of flight test. Not worthy of flight testing is usually dictated by cost or safety issues. However if the choice to fly is made, then the model should be there as a tool to assist with predictions and training. When the flight testing evolution gets started, the comparison can begin and a correction to the model can be made with real flight test data.

The best case scenario would be a near perfect match of actual flight to the simulation. Unfortunately, no matter how complex an aerodynamic model, or how intense a rotary balance and spin tunnel test was conducted, the aerodynamic qualities of an airplane can not be truly duplicated by simulation at really high angles of attack. Because of that, you are forced to generate the data for the simulation from actual flight testing and maneuvering. This flight testing is very risky and requires an intense amount of build up, not only from a programmatic perspective, but also from a pilot and team perspective. Among the items required for the build up are the basics surrounding the performance of the airplane related to both the structure and any engine issues. For example, can the structure of the airplane withstand the dynamic motion induced during HAOA

maneuvering. Under those conditions, will the engine remain operable, or will it also influence future maneuvering due to some restrictive envelope. The process can be tedious and slow, but it is important to remain that way due to the extremes that are being investigated.

The need for a team that is fully capable of the task can not be overstated. The team is more than just the test pilot inducing the motion and riding through the aftermath. It involves everybody from the design engineer to the flight test conductor on site during each flight. Our team was formed up by the proper assortment of contractor personnel - McDonnell Douglas Aerospace-East (MDA), the Navy's training command squadron (VT-21), and the testing community from NAVAIRSYSCOM (D.C.) and NAWCAD (Patuxent River).

In order to acclimate the team involved in the T-45 HAOA flight test program, several measures were taken. First of all, a team was designated and changes, although often inevitable, were kept to a minimum. The goal was to have the same corporate knowledge follow the whole program from start to finish, as best as manageable, and to grow naturally with the flow of the desired build up and testing. Additionally, flight testing was performed by both the contractor pilot and by military pilots. After the initial portion of the testing was concluded by the contractor pilot, they could be used interchangeably. Unfortunately there were some legal ramifications to initial flight testing which needed to be conducted by the contractor and not the military service. The basic goal of the team was as fairly simple: to determine the capabilities of the T-45 in the environment it was going to be employed in by the student training squadrons. The bottom line to the success of the testing was the team effort.

In order to successfully achieve the end goal, it needed to be mapped out and outlined. The requirements of the flight test program came from various sources. Major contributions to the list came from the training command and their needs during the student's syllabus, the operational fleet and the quality they required from new aviators,

from historical precedence in airplanes that previously served in the training role, and from the testing community and its corporate knowledge of required and desired testing throughout the course of such a program.

As mentioned, the first voice in the requirements placed on a new training aircraft came from the training command itself. Regardless of the cost savings and other programmatic issues, the new airplane must be able to satisfy the training requirements that were dictated by the training command. It was not sufficient to simply go through the acquisition process to end up with a new airplane that could not conduct the basic elements of the training syllabus required from it. When their input was outlined, it formulated a basic list of needs from the airplane during its service life. Maneuvers such as stalls, vertical maneuvering, spins, ACM, operational maneuvering, departure from controlled flight, and departure resistance maneuvering would be essential. Many other areas of the training syllabus would be developed from other flight testing, but the majority of the more demanding and significant elements of the student training syllabus were contained within the items we would explore during these tests.

The second vote in the requirements wish list was cast by the operational fleet. Under normal circumstances their desires are fed back through the voice of the training command, and the syllabus they formulate for student training reflects those needs. However, the fleet is extremely concerned with the HAOA and spin training the new student aviator is currently receiving. Their concerns were forwarded to the testing community as a wake-up call to prevent more mishaps from lack of suitable airplanes to conduct the appropriate Spin and Out-of-Control training. Additionally, the fleet feels that a new pilot must be able to conduct, at varied levels of proficiency, the basic elements of tactical flying. Once transitioned to the fleet replacement squadrons, they will need to have the ability to apply their flight training and knowledge into their fleet airplane. For the tactical aviators that is usually a basic requirement of being able to employ an airplane to the edge of its envelope in order to maximize its mission worthiness and ultimately

survivability during conflict. Different tactical airplanes place more emphasis on different portions of the student training syllabus. For example, the F-14 community has particular interest in ACM, while the A-6 aviators are more interested in low level maneuvering and air to ground weapon employment. However our Navy has been gradually moving more and more toward the strike-fighter concept of aircraft. The strike-fighter is an airplane that fills both roles: fighter and bomber. The F-18 C/D model, and its follow-on the E/F, are perfect examples of the future direction the Navy will be taking. The bottom line is that the fleet of the future will have a concern for all the elements of tactical flying, and hence a requirement for an airplane that can provide adequate initial training in those flight regimes. However, because the fleet aircraft are changing, so are the fleets concerns and demands from new aviators. The information flow and dissemination was a big item in setting up current and future requirements of training aircraft for the Navy.

After the fleet was finished with their inputs, the requirements list was forwarded to the program managers and decision matrix agencies in Washington, D.C. They developed the final list of requirements and desired aircraft performance. It was within these halls that, thanks to corporate knowledge and secondary sources, a test program was molded for the T-45. Many agencies were involved in this portion of the program, from individuals at the pentagon level all the way down to the actual testing community. However, regardless of where they sat the goal was the same: get the training fleet the aircraft they needed in order to successfully conduct their mission.

Although fairly obvious, it is important to note that it is not uncommon to add testing during the different stages of a program. Some reasons can stem from the incorporation of new requirements along the way, or other reasons such as increased safety, and for desired build up and data gathering. Even though a flight test schedule will hopefully stay fairly rigid in order to make the timeline and budget forecast, it should not be so rigid that it can't handle warranted and significant changes. In the context of HAOA and the development of the T-45 for the goal of becoming the next tactical strike aircraft trainer,

that is exactly how the process worked. All the elements were in place and utilized to successfully develop the next strike trainer.

The primary responsibility of meeting the design and mission requirements of any product is that of the contractor. Because of that basic philosophy, they usually drove the direction of the program with the appropriate amount of coaching from the program management team in the military service. For our testing, MDA was required to demonstrate the high angle of attack (HAA) and spin characteristics of the T-45A airplane, outlined in references 2 through 4. This demonstration was structured in a buildup fashion and was similar in nature to their previous HAA programs on the F/A-18 and AV-8B airplanes. The demonstration was divided into four phases:

Phase I: Maneuvers to C_{lmax} and C_{lmin}.

Phase II: Maneuvers up to full back stick (max trim AOA), full forward stick (min trim AOA), or impending departure.

Phase III: Sustained aggravated inputs up to maximum and minimum trim AOA.

Phase IV: Asymmetric store loadings. Spin entry and recovery investigation. Vertical Maneuvering.

After completing spin and emergency systems functional tests, MDA HAA flight tests began on 18 January 1992. During MDA testing, the airplane encountered a low negative angle of attack inverted spin mode. After updating the T-45A Six Degree of Freedom (SDOF) simulation, MDA predicted that this inverted spin mode was potentially unrecoverable and that additional rotary balance wind tunnel data was required in order to develop new recovery controls. The rotary balance testing would not be completed until the Full Scale Development (FSD) program was over. Therefore, a decision was made by NAVAIRSYSCOM and MDA that no additional inverted spin testing would be conducted during the remainder of FSD. The remaining inverted spin testing would be completed during follow on testing. The major Navy evaluation was conducted at Edwards Air Force Base in California, from 28 August to 19 October 1993.

STUDENT TRAINING AND REQUIREMENTS

The purpose of developing the flight test program was to evaluate the HAOA characteristics of the T-45A and to determine the airplane's potential to fulfill the requirements of the undergraduate jet training mission in the HAOA flight regime. The basic list of required flight test was generated, not only from the basic airplane flight test guide, but also from a list of requirements created by those who will eventually get to employ the new assets. It was a simple request, the testing community needed to forward an aircraft that could successfully train students in the following areas applicable to HAOA: Stalls, post-stall gyrations, spin dynamics, inertia coupled maneuvers, tailslides, zero airspeed maneuvers, Out-of-Control Flight (OCF) maneuvers, operational maneuvers and finally Air Combat Maneuvering (ACM). All that sounds very official and flattering but what does it really mean.

The training command had an outline of their requirements which are described in their Flight Training Instruction, reference 5. This document dictates the basic and advanced training syllabus that the student will be expected to complete. The mission, as stated in their handbook, is to provide Navy strike flight training. In order to do that task, the airplane must provide the capability to train student naval aviators for high performance jet aircraft and to qualify students for standard instrument ratings and initial carrier qualifications. In addition, the airplane must support the fundamental tactical skills training, emphasizing the development of habit patterns, self confidence, and judgment required for safe and efficient transition to fleet aircraft with more advanced technology systems. The T-45 needed to provide that training.

HAOA TESTING AND CONCERNS

All tactical and training aircraft must undergo extensive HAOA testing. Although spin training offers little tactical value to the competency of a pilot, the awareness of spin like motion and how to counter it has been instrumental in preventing several aircraft mishaps. Additionally, the confidence and preparation this knowledge gives a young pilot will translate to his/her ability to effectively maneuver their tactical aircraft to the edge of the envelope. Tactical aircraft will be, and should be, flown to the edges of their envelopes. In that not all pilots are created equal, some will inadvertently stall their aircraft while flying at the boundaries of controlled flight. Others will go further and might even encounter an inadvertent spin. For scenarios such as those, an airplane must display the ability to consistently recover from normal stalls, accelerated stalls, departure from controlled flight and spins. If it does not display these desired characteristics, it will lead to a significant degradation in the effectiveness it has as a platform to complete it's tactical mission.

In the case of the T-45, the mission is to serve as a tactical training aircraft. It must prepare the new pilot for any flight condition he/she might encounter while in the conduct of their future mission. Tactical aircraft are flown on the edge of controlled flight. This often leads to spins. If an aircraft can spin, then the pilot must know how to recover it. In order to execute the proper recovery, the pilot must be able to recognize the developed motion and make the appropriate (often timing critical) flight control inputs to execute a recovery. In order to make that analysis, the pilot must have the proper training (both from theory as well as from practical experience). That training is currently handled in the training squadrons and the airplane they will be training in is the T-45. Therefore a HAOA and Spin flight test program was conducted to demonstrate that the T-45 could be employed as a tactical training aircraft and that it could satisfactorily recover from post-stall gyrations, and any incipient and steady state spins (assuming those could be achieved by the aircraft). Additionally, those recoveries needed to adhere to the concepts of having reasonable,

consistent, and repeatable piloting techniques for all the different types of motion which could be encountered during the aircraft's expected use.

During the T-45 Full Scale Developmental (FSD) program, the need for HAOA and spin testing was obvious. However, due to the intrinsic hazards that abound in HAOA and initial spin testing, caution was a prudent virtue. Although flight test programs such as flutter testing and structural demonstrations are very extensive and demanding, they are precursors to HAOA testing. With respect to build up and preparation, there is no other type of flight testing which comes close to HAOA and initial spin testing. This is due primarily to the following concerns during HAOA testing: (1) you are subject to frequent unpredictable and disorienting aircraft motion, (2) occasionally you encounter unforeseen spin modes, (3) it is paramount to have a pilot who is qualified and competent to analyze any motion in order to apply the appropriate recovery controls during all maneuvers, and (4) the aircraft and engine are undergoing some of the highest loads and disturbances possible during the routine of day to day flight test.

As discussed in reference 6, the generic concerns that are covered by spin programs include, but are not limited to, the following: explore stall, post-stall (or deep stall), incipient phase of spins, and fully developed spin characteristics. That generic list will tend to include items such as: defining aircraft motion and effects during spins, determining external loading effects on spins, determining if a critical spin direction exists, developing anti-spin control inputs while examining the effects of poorly or misapplied recovery controls. Throughout the testing a careful eye is placed on the engine and its ability to withstand the rigors of such a highly dynamic environment. If necessary, creating a flight test program to examine its limitations and the effect that it has on the overall airplane envelope. Ultimately the team will be generating the required data and qualitative information required to supplement the pilot handbook with respect to actual flying and handling qualities, as well as the more important items of procedures and limitations.

In order to properly conduct the required testing, the following elements must be accomplished: (1) The test team must be prepared to conduct their roles, (2) The test airplane must be outfitted to withstand the rigours of HAOA testing, and (3) Safety related measures must be addressed with respect to adequate data telemetry and safety chase airplane roles. The basic school of thought was that the pilot was not alone during a spin flight, even though he may be the only one at the controls of the aircraft. The pilot is obviously a critical element for team success, but so is the engineering team and the test aircraft. The engineering support needs to be qualified in the rigors of dynamic flight test and must be a cohesive unit that is comfortable with their individual roles. A more comprehensive discussion of test pilot preparation is covered in its own section. The specific description of the changes incorporated into our test airplane is covered in its own section. However, it is important to document all of the items and concerns that led to some of those modifications. Safety issues dictated the use of emergency recovery and additional aircraft subsystems. Our modifications were in the areas of: fuel, hydraulics, electrical, oxygen, visual recording, flight controls, restraint systems, engine relight capacity, and communications systems. The most significant aircraft modification dealt with the backup and emergency recovery systems. Our implementation efforts were driven by the following criteria: simplicity, adaptability, reliability, minimal effects to airplane moments of inertia, cockpit displays and controls for proper operation, and safety mechanisms. Although many external devices such as canards and strakes could have been used to enhance recovery from spin, they tend to have a negative effect on the adaptability of the data to a fleet representative airplane, and were therefore discarded. Because moment of inertia effects could be minimized by strategic relocation of other aircraft systems, a spin parachute was the simplest device to install and implement. Many factors played an important role in the selection of the appropriate spin chute such as: airplane structure, airflow around the parachute pack, primary and secondary deployment methods, and jettison functions. The spin chute we selected had a maximum guaranteed envelope up

to approximately 160 KIAS. Through simulation and data review it was considered sufficient for our needs and succeeded during operational tests in level flight up to its described limits.

Finally, as with all flight testing efforts, the need for additional safety items was incorporated in our testing criteria. These items included the need for a designated safety chase airplane, ground based video for total airplane coverage, and internal cameras for post-flight video review.

TEST PILOT TRAINING AND CURRENCY

All test pilots undergo substantial training in the modern day flight test techniques of performance and flying qualities. One of the elements of the flying qualities portion of a test pilot's training covers the area of spin theory and dynamics. Although a fairly inclusive course of study, it should not be assumed that once complete with the training, the test pilot is imminently qualified to become a HAOA and Spin Flight test pilot. Because of the hazards, a test pilot expecting to conduct HAOA flights will solidify his/her knowledge of HAOA theory, as well as increase the awareness and adaptability to the HAOA/Spin flight regimes. This is usually performed by doing several spin flights in a known airplane and by maintaining a desired currency window between those practice spin flights.

In general, a test pilot should have enough flight time in the spin test airplane to be completely familiar with its flight characteristics, emergency procedures and special instrumentation and equipment. Assuming the pilots are identified early enough, constant spin refresher flights in approved aircraft are always prudent, as well as any other airplane that could provide insight in to the expected handling qualities of the test airplane. Subsequently, the test pilot will be better oriented for spin tests and more adapted to analyze and describe the aircraft motion once performing the testing. Ultimately there should be a minimum cadre of pilots involved in the testing. Currency and safety of flight are paramount for the ultimate success of a spin program. In the T-45 program, one contractor pilot and two military pilots were used.

In order to solidify the pilots training prior to the Navy testing, a trip to England and the British Test Pilot School was scheduled. Through the international flight testing community many benefits can be realized, especially when they have an airplane remarkably similar to the one you are attempting to test. Through this international exchange, the British Test Pilot School was very willing to allow a one week evaluation of

the British Hawk airplane. At ETPS, a fully telemetered Hawk was made available to show off its HAOA and spin handling characteristics. Although differences certainly existed between the T-45 and the Hawk, there was no comparison for that type of training and build-up. The opportunity to fly a remarkably similar airplane prior to our own flight test proved to be extremely beneficial and rewarding.

During our trip we not only had the opportunity to talk first hand with some of the pilots who conducted the Hawk's spin test program, we also got to fly with them. Our visit and the flights were as follows: From 1-8 May 1993, the T-45A High Angle of Attack (HAOA) Test Team conducted a spin evaluation on the British Aerospace (BAe) Hawk airplane at Empire Test Pilot School (ETPS), Boscombe Down, England. The Hawk airplane was utilized because the T-45A exhibited a low angle of attack spin mode identical to the Hawk spin mode during initial contractor flights. The purpose of the ETPS Hawk spin evaluation was to familiarize the Navy T-45A HAOA test pilot with the Hawk spin mode to better prepare for Navy T-45A HAOA testing.

The evaluation consisted of testing in the areas of spin entries, control sampling during the spin, and spin recovery techniques. A total of two flights were flown in the Hawk and two additional sorties were flown in the Hunter and the Tucano. During the Hawk spin flights, the Navy pilot conducted the spin evaluation from the front cockpit with an ETPS instructor pilot in the aft cockpit acting as the safety pilot. Additionally, an ETPS instructor and a Navy engineer monitored all flights from a ground data station. All flights were conducted within the aircraft flight handbook limitations and by local standard operating procedures. No inverted spins or tailslide maneuvers were intentionally performed due to the tendency of engine stalls, however, these were the primary objective of the Hunter and Tucano spin flights. The Hawk airplane configuration was clean, with no pylons or external stores. Due to engine related issues, the throttle was at idle during all spins. A summary of Hawk spin test conditions and results is presented in table I.

Table I
HAWK SPIN TEST CONDITIONS AND RESULTS

Configuration: CR

Loading: Clean

Test Aircraft : #343

Spin Number	Entry	Direction	Aileron during Spin	Recovery Technique	Indicated AOA (deg)	Yaw Rate (deg/sec)	Roll Rate (deg/sec)
1	Level	Left	Neutral	Normal	37 ± 8	30 ± 10	70 ± 30
2	Left Turn	Left	Neutral	Normal	36 ± 12	35 ± 10	70 ± 45
3	Right Turn	Left	Neutral	Normal	36 ± 10	35 ± 10	70 ± 45
4	Level	Right	Neutral	Normal	34 ± 10	35 ± 6	60 ± 60
5	Level	Left	In-Spin	Normal	36 ± 10	30 ± 10	70 ± 40
6	Level	Left	Out-of-Spin	Neutral Rudder	36 ± 10	30 ± 15	65 ± 35
7	Level	Left	Out-of-Spin	Normal	36 ± 12	25 ± 20	55 ± 50
8	Level	Left	Neutral	Relax Rudder	34 ± 14	25 ± 15	55 ± 50
9	Level	Left	Neutral	Relax Longstick	36 ± 10	30 ± 10	65 ± 30
10	Level	Right	Neutral	Relax Longstick	36 ± 12	65 ± 10	170 ± 25
11	Level	Left	Neutral	Normal	35 ± 15	35 ± 15	50 ± 50
12	Level	Left	Neutral	Stick Free	36 ± 12	40 ± 10	55 ± 50
13	Level	Right	Neutral	Normal	35 ± 5	30 ± 5	60 ± 10
14	Right Turn	Right	Neutral	Normal	35 ± 5	35 ± 5	70 ± 10
15	Right Turn	Right	Neutral	Normal	35 ± 5	40 ± 5	80 ± 40
16	Right Turn	Right	In-Spin	Normal	35 ± 8	35 ± 10	80 ± 40
17	Right Turn	Right	Out-of-Spin	Normal	N/A	N/A	N/A
18	Right Turn	Right	Out-of-Spin	Normal	35 ± 5	35 ± 5	60 ± 20
19	Right Turn	Right	In-Spin	Normal	35 ± 10	30 ± 10	65 ± 50
20	Level	Right	Neutral	Normal	40 ± 15	40 ± 20	60 ± 60
21	Level	Right	Neutral	Normal	35 ± 8	35 ± 10	50 ± 50
22	Level	Left	Neutral	Normal	35 ± 10	35 ± 5	70 ± 30

Spin entry technique consisted of simultaneous inputs of full aft stick and full rudder pedal input. Spins were attempted from two different entry conditions: a wings level entry at approximately 150 KIAS, and a turning entry (left or right 30 degree bank angle) at 165 KIAS. Minimum spin entry altitude was 25,000 ft MSL. The 30 degree right angle of bank with bottom rudder spin entry resulted in the most stable spin. Leading slightly with the rudder pedal during the entry also produced a slightly less oscillatory spin (although this effect was not consistently repeatable). Spin controls were applied as the airplane decelerated through the target airspeed and applied as "step" inputs. A step input is defined as a control input applied within 0.2 seconds from its initiation. If entry conditions were off slightly, this appeared to result in a more oscillatory spin, or at least would affect the repeatability of the spin motion. Both left and right spins were entered from level and left and right turning entries. In general, the airplane would quickly roll through 180-270 degrees as angle of attack increased towards the average value of 35 degrees. Roll rate would immediately become oscillatory as would the yaw rate. Yaw rate was slightly low. In fact the average value for yaw rate was only 40 degrees per second. Due to the oscillatory character of the spin, the disparity between roll rate and yaw rate, and the constantly increasing airspeed, the pilot had the sensation of being more in a spiral motion than in a spin.

All spins displayed the characteristics of a very steep, rapid roll rate spiral. Average roll rates were high (65 deg/sec). Yaw rates during the spin were low (35 deg/sec). Average angle of attack was 35 degrees. All spins were extremely oscillatory in roll and yaw with a steep nose down attitude (50 -60 deg) developing after 1 to 2 turns. Due to the dynamic nature of the spin and the oscillatory roll and yaw rates, it was difficult to adequately identify the later phases of a conventional spin (i.e. incipient spin and steady-state spin).

Aileron effects as well as longitudinal stick effects were evaluated during the spin. Due to the airplane dynamics, the pilot had to carefully time the lateral control input (in-spin

or out-spin) programming in the desired stick input. If the aileron input was improperly applied, the input could result in an inverted spin. Some traditional effects were seen during both lateral and longitudinal stick applications. In-spin aileron tended to create a more oscillatory spin and out-spin aileron tended to reduce the oscillatory nature of the spin.

Spin recovery was initiated at 180 KIAS (vertical tail loads), or 4 turns, or if sideforce and sideslip became excessive - whichever occurred first. The 180 KIAS limit was usually reached before the 4 turn limit. Two different recovery techniques were used. The normal recovery technique consisted of neutralizing the stick and the rudder. The second recovery technique consisted of releasing the stick and rudder pedal after going to controls neutral. During spin recovery, too much forward stick could result in progressive spin entry, or entry to an inverted spin. During the controls free recovery, the airplane had a tendency to unload. This was uncomfortable the first time it was experienced due to the concern of an inverted spin entry. However, once it had been experienced, it was not as uncomfortable in subsequent recoveries. Recovery was within 1 to 2 turns with either the normal or controls free technique. Total altitude loss during the spin and pullout was approximately 10,000 ft MSL.

The Hawk spin evaluation was an excellent build-up tool for the test pilot. Discussions with the ETPS instructors provided insight on how the Hawk was utilized as a spin trainer and on the potential US Navy uses of an airplane with Hawk spin characteristics. From the evidence seen in our short evaluation, employing the Hawk as a spin trainer for our primary jet students would have to be considered marginal. Difficult non-repeatable spin entry, tendency for inverted spin entry with misapplied flight controls, and poor steady-state spin performance result in a platform that would require a considerable number of sorties to adequately introduce the student to Out-of-Control and

Spin flight regimes. Although no engine anomalies were noted during the Hawk spin evaluation, it remained a major concern for the T-45 during those types of maneuvers during our testing.

BUILD UP FLIGHT TEST

During the course of a full scale program, a test team will need to map out the flight envelope of their airplane for several reasons. The most significant reasons come in terms of the effects this envelope has on the type of maneuvering and motion that you expect to encounter while conducting the mission of the airplane. Out of the development of the envelope one will know the allowable extremes an airplane can be taken to, and what lies beyond those limits. The two major areas that set up those boundaries are the structure of the airplane and the engine. As one can imagine, the testing that is involved in these phases is quite involved. They will not be covered within the context of this document, however, it is important to note what lengths were taken to ensure the appropriate knowledge of the airplane was known prior to undertaking the most important phase of the airplanes testing - HAOA.

The two build-up programs consisted of a major structural demonstration where the basic envelope and capacity of the airframe and systems was realized. The second major hurdle was to develop a usable flight envelope for the engine. This was performed by incrementally increasing the angles of attack and side slip on the engine and analyzing the effect that they had on proper airplane operation. The structural demonstration was conducted well before the HAOA evaluation, but as one can imagine, the engine and HAOA testing ran almost concurrently. The only way to generate some of the parameters desired for the testing was by inducing them in the air and that is where concurrent HAOA and Engine testing occurred. Once complete, the final test plan could be laid out and HAOA completion could be realized.

DESCRIPTION OF TEST AIRCRAFT

DESCRIPTION OF TEST AIRPLANE AND EQUIPMENT

GENERAL AIRPLANE DESCRIPTION

The T-45A Goshawk airplane, manufactured by McDonnell Aircraft Company (MDA), is an all-weather, high altitude, multi-purpose trainer aircraft capable of flight up to 40,000 feet, load factors in excess of 7.0, and speeds in excess of Mach 1. The airplane is a tandem seat, light weight, high performance, fully aircraft-carrier compatible version of the British Aerospace Hawk. A color picture of the airplane is presented in appendix A, figure 1. For a better visual representation of the basic airplane and its dimensions, a three-view drawing of the airplane is presented in appendix A, figure 2.

The test airplane, T-45A serial number 163599 (T003), was powered by an instrumented production Rolls Royce F405-RR-401 engine (S/N 6004/2) with a hydro-mechanical fuel control unit containing the largest approved fuel restricting cavity (0.45 flow number E-restrictor). This non-afterburning, turbofan engine was rated at 5,600 pounds military static thrust at sea level. The basic operational gross weight (zero fuel) of the airplane without any external stores was approximately 10,400 pounds. This included provisions for trapped and unusable fuel, oil and two aircrew.

The aerodynamic design includes a low mounted, moderately swept, laminar flow design wing exhibiting a 2 degree dihedral. The wing has full span leading edge slats, double slotted trailing edge flaps and an integral fuel tank. The mirror-image intakes sit on the forward fuselage above and slightly forward of the leading edge of the wing. The single vertical stabilator is mounted slightly forward on the empennage, and the stabilators, are both of swept design. The stabilator exhibits a ten degree anhedral. Mounted on the fuselage below the stabilator are opposing speed brakes and a corresponding flow stabilizer below the stabilator, affectionately referred to as the "*Smurf*". The sole purpose of the *Smurf* is to reduce the effects of the disturbed air flow going across the stabilator when the speed brakes are deployed.

The primary flight control system consisted of hydraulically powered ailerons, an all moveable irreversible hydraulically powered horizontal stabilator, and a reversible rudder with a no-float mechanism designed to maintain the rudder within 3 to 4 degrees of neutral when it not in use. Except for the rudder, all of the surfaces were powered by a tandem, 3000 pounds per square inch (psi) hydraulic system. Additionally, a Ram Air Turbine (RAT) was available to provide emergency hydraulic power to the flight controls in case of an engine fire or hydraulic pump failure. A detailed description of the T-45A airplane is presented in the T-45A NATOPS manual, reference 7. Further modifications to the test aircraft are outlined in the following section, however for the purposes of this evaluation, the test airplane was considered representative of the standard airplane in the operational fleet.

AIRPLANE MODIFICATIONS FOR HAOA TESTING

T003 was extensively modified in order to provide an increased margin of safety during the HAOA test program. The spin and emergency systems incorporated into T003 are summarized below.

SPIN RECOVERY PARACHUTE SYSTEM

Spin recovery parachute system (appendix A, figure 3) utilized was a modified version of a British Aerospace Hawk brake chute. The spin chute was attached to the normal tailhook attach point through the parachute beam assembly. Two independent spin chute release systems were installed. Primary release was by a mechanical system and the backup by explosive bolt. The spin chute system status was fully instrumented and displayed to pilot on the spin chute control panel and the engineers at the telemetry ground station. The effect of the spin chute system on airplane inertia was minimal. I_x and I_y were increased by approximately 6%. Aerodynamic effects of the spin chute system were

also predicted to be negligible. Maximum airspeed for spin chute deployment was 158 KIAS.

CREW STATION MODIFICATIONS

Various modifications were made to the forward crew station. The stall warning tone and pedal shaker were disconnected. Specific items added included:

- a. Head-up AOA and yaw rate gauges (appendix A, figure 5)
- b. Full control deflection cockpit indicators in place of the production AOA indicator(appendix A, figure 5)
- c. Spin chute system control panel (appendix A, figure 5)
- d. Spin chute system circuit breakers (appendix A, figure 4)
- e. Spin chute system master power switch (appendix A, figure 5)
- f. An additional torso restraint
- g. Over-the-shoulder video camera.

OXYGEN SYSTEM MODIFICATIONS

In order to provide the pilot with an uninterrupted supply of oxygen in the event of an engine surge, the production On Board Oxygen Generating System (OBOGS) was replaced with an oxygen bottle in the aft crew station. This oxygen system could provide up to a six hour supply for a single pilot.

EMERGENCY ARRESTING HOOK

Parachute beam assembly replaced the production tailhook. The spring deployed emergency arresting hook was installed below the parachute beam assembly and was limited to on deck extension (appendix A, figure 6). Maximum engaging speed of the

emergency arresting hook was a function of gross weight and is presented in appendix A, figure 7.

ELECTRICAL SYSTEM MODIFICATIONS

The essential services bus was split to provide each half of the bus and its respective ignitor with a single battery. Both battery voltages were displayed to the pilot and the telemetry ground station. Battery voltages were checked airborne at the beginning of each flight. The modified electrical system demonstrated 30 minutes of electrical power available.

HYDRAULIC SYSTEM MODIFICATIONS

Two additional hydraulic accumulators were installed in the HYD 2 (flight control) system. The speedbrake was moved from the HYD 1 to the HYD 2 system. With no Ram Air Turbine pressure available, ground test results had demonstrated 5.5 stick cycles (stick cycle defined as full forward, full left, full aft, full right, centered) with one speed brake retraction while operating on the additional hydraulic accumulators.

FUEL SYSTEM MODIFICATIONS

Individual fuel tank quantities were instrumented and displayed to the pilot and data center. During flight testing, the inverted flight capability of the production fuel system had been demonstrated for 60 seconds at idle power.

PROPULSION SYSTEM MODIFICATIONS

The essential services bus was split to provide each half of the bus and its respective ignitor with a single battery. Continuous ignition (right ignitor only) was available with backup fuel system selected.

FLIGHT TEST DEVELOPMENT

FLIGHT TEST DEVELOPMENT

CONCEPTUAL DEVELOPMENT

GENERAL CONCEPTS

The information provided up to this point indicated a large packet of required testing, or at least a large generic list of desired testing. In order to pursue the final answer, a detailed outline of required testing was generated and it flowed as follows:

I. STALL CHARACTERISTICS

A. Normal Stalls

1. Stall Warning
2. Configuration Effects
3. Power Effects
4. Angle of Attack trends
5. Control input effects
6. Deep stall characteristics
7. Stall Recovery (Optimized recovery procedure)

B. Accelerated Stalls (same concerns as A)

C. Inverted Stalls (same concerns as A)

II. Post-stall Gyration

A. Deep stall investigation

B. Accelerated stall entries

III. Spins (Erect/Inverted *)

A. Entries

B. Incipient Spin Mode

1. Description
2. Recovery

*** (inverted spins became unauthorized until further review of the data)**

- C. Steady State Spins (same concerns as B)
- IV. Departure Resistance
 - A. Rudder-only maneuvers
 - B. Lateral stick-only maneuvers
 - C. Coordinated control input maneuvering
 - D. Cross control input maneuvering
- V. Tailslides and Zero Airspeed evaluation
- VI. Operational Maneuvers
 - A. Basic Familiarization Stage Maneuvers
 - B. Basic Fighter Maneuvers
 - C. Basic Air to Ground Maneuvers
- VII. Out-of-Control Flight Maneuvering
 - A. Lateral Stick induced departures
 - B. Rudder induced departures
- VIII. Air Combat Maneuvering (ACM)
 - A. Individual Maneuvering
 - B. One vs One Maneuvering
 - 1. One-circle fight
 - 2. Two-circle fight

Additionally, there were several items of concern that are present throughout testing. The following lists a few of those concerns: thrust effects, configuration effects, engine operation, Stability or Control Augmentation System (flight control system) effects, structural integrity and robustness, pilot restraint and comfort, and any side effects to the aircrew (usually dealing with displays or aircraft systems / downgrades). Armed with this list of information, the test team was able to set out and define a detailed method to accomplish the goals and to retrieve the required data. The following two sections

will truly define the exact steps taken to accomplish the tasks.

SPECIFIC METHODOLOGY

Test Procedures

Test maneuvers included upright 1-g stalls, inverted negative 1 g stalls, wind up turns (WUT's), 180 deg bank-to-bank pedal rolls, 180 deg bank-to-bank lateral stick rolls, 180 deg bank-to-bank coordinated rolls (lateral stick and pedal), aggravated (through 360 deg or departure) control inputs, operational maneuvers, ACM, and upright spin entry attempts limited to using longitudinal stick and pedal inputs (Hawk Mode). A detailed description of each of the test maneuvers is presented in appendix B. A detailed listing of all maneuvers is provided in appendix, tables I through X.

Instrumentation And Data Extraction/Processing

T003 was instrumented with both airframe and propulsion critical parameters. Real-time monitoring of test data and flight critical parameters was provided by UHF TM of signals encoded by a pulse-code modulation multiplex system. All TM data were also recorded on an onboard magnetic tape recorder. In the event of an engine shutdown, the safety-of-flight instrumentation and the TM transmitter were powered by the batteries, allowing for continuous monitoring of critical instrumentation. A detailed description of the test instrumentation system can be found in the Flight Test Program Demonstration Instrumentation Report For T-45A Aircraft, reference 8. Film and video coverage, including ground-based cameras, an over-the-shoulder video camera, and the Heads-Up-Display recorder, were available during selected flights.

Range Of Tests

Testing And Conditions

The evaluation was completed in 47 solo flights covering over 52 flight-hours.

Military testing during this evaluation was considered Standard Participation, as defined in the T45TS Memorandum of Agreement, reference 9. Test areas included departure resistance, vertical maneuvering, fleet representative operational maneuvers, and a limited evaluation of upright Hawk Mode spin characteristics.

Envelope

Flight tests were conducted within an envelope established by MDA and NAVAIRSYSCOM prior to the Navy HAOA flying qualities evaluation. Operating limitations for the test airplane were established by an appropriate flight clearance. Additional restrictions were identified by MDA to minimize the possibility of inverted spin entry. The final test envelope essentially authorized unlimited maneuvering with the following exceptions:

- a. No intentional departures which would unload to negative AOA's.
- b. No cross control inputs in excess of 90 deg bank angle change.
- c. No upright spin attempts using lateral stick (i.e., longitudinal stick and rudder only spin attempts).
- d. No intentional inverted spins.
- e. No rolls at less than negative 1.0 g.

Loadings

A total of 40 flights were conducted in the clean loading, 1 flight was conducted with symmetric practice multiple bomb racks (PMBR's), 3 flights were conducted with symmetric LAU's, and 3 flights were conducted in the asymmetric loading with one PMBR on the left wing station. Gross weight varied from 11,640 to 13,980 lb, and the Center of Gravity (CG) position varied from 16.4% to 18.9% Mean Aerodynamic Chord (MAC), which was within the contractor CG limits of 12% to 21% MAC.

Test loadings are presented in table II.

Table II
TEST LOADINGS

Loading	Left Wing Station	Right Wing Station
Clean	Clean	Clean
PMBR	Pylon + PMBR (1)	Pylon + PMBR
LAU	Pylon + LAU-68 (2)	Pylon + LAU-68
Asym	Pylon + PMBR (3)	Clean

- NOTES: (1) Practice Multiple Bomb Rack with six inert MK-76 bombs each. The bombs were bolted onto the PMBR.
(2) LAU-68 rocket launcher with seven inert 2.75 in. rockets. Launcher nose and tail fairings not installed.
(3) Maximum asymmetry of 2,550 ft-lb.

Configurations

Test configurations are presented in table III.

Table III
TEST CONFIGURATIONS

Configuration	Gear	Flaps	Speed Brakes	Thrust
Cruise (CR)	Up	Up	Retracted (1)	As required, IDLE - MIL
Power Approach (PA)	Down	Full	Out	TLF(2)
Takeoff (TO)	Down	Half	In	TLF

- NOTES: (1) Speed brakes retracted unless otherwise noted.
(2) TLF - Thrust for Level Flight.

Test Standards

The T-45A, defined as a Class IV-C airplane per Military Specification MIL-F-8785C, reference 3, hereafter referred to as the Specification, was evaluated with regard to its potential and suitability for the undergraduate jet training mission. Additional specification requirements are contained in the T-45A Detailed Specification, reference 4. The T-45A was also evaluated for compliance with the Test and Evaluation Master Plan (TEMP), reference 1.

CHRONOLOGICAL PERSPECTIVE

BASIC CHRONOLOGY

The following is a basic chronology of the evaluation:

- | | |
|---|------------------|
| a. Flight Test Plan and required documentation approved | 23 February 1993 |
| b. ETPS Hawk Spin Evaluation | 1-5 May 1993 |
| c. Aircraft arrived Edwards AFB, California | 17 August 1993 |
| d. Navy flight testing commenced | 28 August 1993 |
| e. Navy flight testing completed | 18 October 1993 |

RESULTS

FLIGHT TEST RESULTS

GENERAL

The following discussion of results is based on actual testing of the T-45 airplane and is equally presented in the Navy's High Angle of Attack flight test report, reference 10. An important item to note is that, during the testing, the data station did not have the capability to apply real-time corrections to the test data. As a result, the data provided in the tables presented in appendix D presents uncorrected noseboom AOA and sideslip values.

Generally, the uncorrected noseboom AOA is a minimum of 15% higher than true AOA based on known upwash error during normal flight conditions. Other errors include boom bending and pitch rate. Uncorrected noseboom sideslip is approximately 20% higher than true sideslip at uncorrected sideslips of greater than approximately 20 deg. The tables are provided for use as a tool for determining relative severity of a particular maneuver with regard to AOA and sideslip. Unless otherwise noted, the time histories presented in appendix E, figures 1 through 10, utilize plots of true AOA and sideslip as calculated by the Standard Attitude and Heading Reference System (SAHRS). Unless specifically noted, all references to AOA and sideslip in the following paragraphs reflect the true AOA and sideslip values provided from final data.

CONFIGURATION CRUISE DEPARTURE RESISTANCE

GENERAL

Departure resistance was evaluated in configuration CR at 30,000 ft pressure altitude during symmetric and asymmetric maneuvers selected from MDA's Phase II, III, and IV demonstration program. Detailed descriptions of the departure resistance maneuvers are presented in appendix B. A summary of test conditions and results for the departure

resistance maneuvers is presented in appendix D, tables I through V. The departure resistance tests were initially conducted with thrust for level flight. However, an engine surge with overtemp during an abrupt longitudinal stick pull at 0.7 TMN drove the remaining maneuvers to throttle fixed at IDLE power. The departure resistance phase of testing was flown primarily to familiarize the Navy test pilots with the T-45A's HA OA flight characteristics prior to performing the operational maneuvers.

SPECIFIC

Longitudinal Stick Inputs

Upright 1-g Stalls

Departure resistance characteristics during upright 1-g stalls to full back stick were evaluated in all test loadings. Test conditions and results are presented in appendix D, table I. A representative time history for an upright 1-g stall is presented in appendix E, figure 1. The upright stalls were fairly benign maneuvers. As full back stick was achieved, the airplane began to slowly roll off in one direction. Peak AOA during the stalls was approximately 23 deg. Sideslip excursions were minimal throughout the maneuver, with peak values between 8 and 12 deg. Peak roll rate during the stall roll-off ranged from 30 to 52 deg/sec and was not considered objectionable. If no pilot input was made thereafter, the roll rate would cause the airplane to slowly roll in excess of 90 deg. No attempts to minimize roll off during the stalls was attempted. Full back stick was generally held for approximately 5 sec. Although the airplane was in heavy buffet and mild pitch bucking during the full back stick portion of the stall, the airplane quickly recovered from the stalled flight condition once aft stick was released. Symmetric and asymmetric stores had no adverse effects on the stall characteristics. The Student Naval Aviator (SNA) will be able to employ the full back stick stall as an OCF training maneuver without any adverse handling qualities or departures from controlled flight.

Inverted Stalls

Departure resistance characteristics during inverted -1 g stalls to full forward stick were evaluated in all test loadings. Test conditions and results are presented in appendix D, table I. Inverted stalls in all loadings were characterized by a slow to moderate roll with light airframe buffet. The stall was defined by full forward stick since no distinct stall characteristic was observed. During the approach to stall and at full forward stick, a light airframe buffet was present and a slow roll rate was apparent. No attempts to minimize roll off during the inverted stalls was attempted. Maximum negative AOA during the inverted stalls was approximately -11 deg. Once full forward stick was achieved, the nose dropped below the horizon and the airplane accelerated quickly. Peak roll rates in the clean and symmetric store loadings ranged between 20 and 35 deg/sec. Peak roll rate during the asym loading inverted stall was somewhat higher than the clean loading at approximately 65 deg/sec into the store. Maximum sideslip excursions were approximately 5 deg in all loadings. The airplane recovered quickly when the forward stick was reduced. No adverse flying qualities were encountered during the full forward stick stalls. The SNA will be able to perform full forward stick stalls without any adverse handling qualities or departures.

Accelerated Stalls

Departure resistance characteristics during constant Mach WUT's were evaluated in all loadings from 0.4 to 0.9 TMN. Test conditions and results are presented in appendix D, table I. A representative time history of a 0.5 TMN WUT is presented in appendix E, figure 2. During most WUT's, full back stick was held for approximately 5 sec. The constant Mach WUT's were flown to buffet onset AOA (approximately C_{lmax}), which equated to approximately 15 deg AOA at 0.4 TMN to 9 deg at 0.90 TMN. At that point, a mild to moderate pitch bucking motion would commence. Once the mild pitch bucking motion began, longitudinal stick was smoothly pulled to the aft stop. Peak AOA's during

the WUT's ranged from 25 deg at 0.5 TMN to 24 deg at 0.9 TMN. Maximum AOA oscillations during the most severe pitch bucking motion were approximately ± 10 deg. Once the pitch bucking motion started, lateral-directional oscillations, or wing rock, would begin. Peak roll and yaw rate oscillations were ± 50 and ± 15 deg/sec, respectively. These lateral-directional oscillations were not divergent. Although the magnitude of the pitch bucking motion and wing rock was somewhat higher in the 0.8 TMN region, no objectionable flying qualities were encountered during any of the WUT's. The SNA will be able to employ the full back stick accelerated stalls up to 0.9 TMN without any adverse handling qualities or departure.

Abrupt Pulls/Pushes

Departure resistance characteristics during abrupt longitudinal stick inputs in the clean loading were evaluated during abrupt pull-ups (APU's) from 1 g to full back stick between 0.4 and 0.9 TMN and abrupt push overs (APO's) from 1 g to full forward stick between 0.4 and 0.6 TMN. Test conditions and results are presented in appendix D, table I. The APU's were characterized by an initial peak AOA that was generally 10 to 15 deg higher than the maximum attainable trim AOA. Following the initial overshoot in AOA, the airplane continued with the characteristic pitch bucking motion until the longitudinal stick was released. During the pitch bucking motion, the airplane would tend to oscillate in roll, with roll rates as high as 60 deg/sec observed. No attempt was made during the APU's to arrest this roll rate, resulting in bank angle changes of up to 360 deg. The APO's were characterized by little or no overshoot in AOA. Although no intentional attempt was made during the APO's to arrest the roll rate, the pilot inadvertently used up to half lateral stick during the APO's. This inadvertent lateral stick input was typical due to the difficulty of reaching the full forward longitudinal stick position. Once stabilized at an AOA of approximately -15 deg, the airplane would roll off in the direction of any inadvertent lateral stick input at roll rates as high as 130 deg/sec. During both the APU's and APO's, the

airplane quickly recovered once longitudinal stick was released. At no time during the APU's or APO's did the pilot feel close to departure. The SNA will be able to aggressively pull to full back stick or push to full forward stick without any adverse handling qualities or departure.

Pedal Only Inputs

Departure resistance during pedal only control inputs was evaluated at positive and negative AOA's in all loadings. Test conditions and results are presented in appendix D, table II. A representative time history of a 0.7 TMN pedal roll at full back stick is presented in appendix E, figure 3. The objective of the pedal only inputs was to evaluate airplane handling qualities following the most aggravated pedal input. For this reason, rudder pedal forces during all the full pedal roll maneuvers were high (250-400 lb). For some flight conditions, these high pedal forces did not correspond to full pedal deflection. Actual rudder deflection varied with Mach number, with a maximum deflection of approximately 15 deg attainable at 0.4 TMN, decreasing to approximately 4.5 deg at 0.90 TMN. Positive AOA pedal rolls in all loadings were characterized by slow roll rates (50-100 deg/sec) with mild hesitations. Some pedal roll attempts resulted in roll rates as low as 0-10 deg/sec. The maximum roll rate achieved was 140 deg/sec, which occurred during full pedal rolls at full back stick at both 0.7 and 0.9 TMN. Yaw rates were generally moderate, averaging between 20 and 35 deg/sec, with a maximum of 48 deg/sec observed during the 140 deg/sec roll rate pedal roll at 0.7 TMN. Sideslip (uncorrected testboom) excursions were generally small (less than 15 deg) with a maximum of 20 deg observed during the 0.5 TMN pedal roll at full back stick. At no time during any of the positive AOA pedal rolls did the pilot perceive an impending departure condition developing.

During full forward stick maneuvering, the pedal roll was characterized by yaw rate in the direction of the pedal input and roll rate opposite to the pedal input, with a continuous buildup in sideslip. The large sideslip excursions when maneuvering at full forward stick

appeared to be a slow nose slice. The pilot felt that if the sideslip was left unchecked, the airplane would encounter a more violent nose down departure. The nose down departure is described in paragraph 35. The tendency of the rudder to lock out (i.e., be driven by aerodynamic forces from neutral) as a result of the sideslip was an additional cue of a departure condition. This sideslip departure will have minimal impact on fleet operations, as sustained maneuvering at negative AOA's is rare. The SNA will be able to maneuver the airplane with the rudder pedal without any adverse handling qualities or departures.

Lateral Stick Only Inputs

Departure resistance during abrupt full lateral control inputs in all loadings was evaluated from 0.4 to 0.9 TMN at positive and negative AOA's. Test conditions and results are presented in appendix D, table III. A representative time history of lateral stick bank-to-bank roll at 0.9 TMN is presented in appendix E, figure 4. The maximum entry AOA of 24 deg was encountered during the full back stick 180 deg bank-to-bank roll at 0.4 TMN. Achieving full lateral stick deflection was easy at all entry conditions. Lateral stick bank-to-bank rolls were characterized by peak roll rates of 50-250 deg/sec and peak yaw rates of 30 to 48 deg/sec. Roll rate oscillations were as high as ± 75 deg/sec, which occasionally resulted in roll rate reversals. Peak sideslip excursions were approximately 20 deg throughout the envelope. During maneuvers near full back stick, a large amount of sideslip was usually present as the lateral stick was neutralized at the end of the maneuver. With the lateral stick held neutral, this sideslip would either damp out with no significant airplane motion, result in an additional 180-270 deg of roll in the direction of the initial lateral stick input, or exhibit a slight nose down motion/unload. Neither motion was considered a departure for two reasons: (1) the motion was not representative of total loss of control and was certainly not disorienting, and (2) the generated roll rate or nose down motion, when countered with an opposing lateral stick input, could be reduced or dampened out. The effect of AOA on maneuver characteristics was minimal. At positive

AOA's, no significant increase or decrease in average roll rate with increasing AOA was observed. The roll rate and yaw rate oscillations did increase with increasing AOA. The increasing magnitude of the roll oscillations reduced the pilot's ability to generate a smooth and predictable roll rate.

Rolls at negative AOA's were always smooth, with no significant roll rate oscillations. A half lateral stick roll at full forward stick did result in a sideslip departure similar to the pedal roll departure described in paragraph 30. The peak sideslip seen during the departure was approximately 20 deg. No tendency for the rudder to lock out was noted during the departure. The airplane recovered quickly from the sideslip departure once the lateral stick was neutralized. MDA had predicted that lateral stick and coordinated lateral stick and pedal rolls of greater than 180 deg of bank angle change at full forward longitudinal stick would result in a coupled roll with peak roll rates greater than 400 deg/sec. The roll rate limit of the T-45A due to structural concerns was 270 deg/sec. Due to the contractor prediction and the structural roll rate limitation, lateral stick rolls with bank angle change of greater than 180 deg at AOA's less than -5 deg were not attempted. Although this placard did reduce the scope of the evaluation, it should not have a significant impact on operational use.

The most significant impact of Mach on lateral stick bank-to-bank roll characteristics was the increase in peak roll rates with increasing Mach. Additionally, the magnitude and the frequency of the roll rate and yaw rate oscillations increased at Mach above 0.70 TMN. Full lateral stick rolls at 0.8 TMN at some AOA's were not attempted due to the high roll rates experienced during the contractor's HAOA demonstration program. The 270 deg/sec roll rate limit will be exceeded if full lateral stick is utilized at some AOA's in the 0.8 TMN region. Occasionally during the lateral stick rolls, the rudder would try to lock out due to high sideslip; however, the pilot never felt any other indications of impending departure during the lateral stick rolls. Since the rudder locking out was considered to be the first indication of a nose down departure, the maneuvers were always terminated when this

occurred. Although the roll rate oscillations and rudder lock out tendencies during the lateral stick rolls were not very comfortable to the pilot, no adverse HAOA flying qualities or departures were encountered during lateral stick bank-to-bank rolls. Aggressive lateral stick inputs during normal training maneuvers should result in a suitable airplane response without concern for departure.

Coordinated Lateral Stick and Pedal Inputs, Positive AOA

Departure resistance during coordinated lateral stick and pedal inputs was evaluated at positive AOA's in all loadings. Test conditions and results are presented in appendix D, table IV. A representative time history of a coordinated input at 0.4 TMN at 8 degrees AOA is presented in appendix E, figure 5. In general, coordinated input maneuver dynamics were very similar to the lateral stick maneuvers. Coordinated input maneuvers at positive AOA's were characterized by slightly higher roll rates when compared to the lateral stick bank-to-bank rolls with slightly smaller roll and yaw oscillations. The benefits of coordinating the lateral stick with the pedal decreased as the available rudder deflection decreased with increasing Mach. As with the pedal only and lateral stick maneuvers, neither the symmetric or asymmetric stores had a significant effect on the coordinated input maneuver characteristics. Coordinated inputs at positive AOA's to maneuver the airplane should not cause departure.

Coordinated Lateral Stick and Pedal Inputs, Negative AOA

Departure resistance during coordinated lateral stick and pedal inputs was evaluated at negative AOA's in all loadings. Test conditions and results are presented in appendix D, table IV. Maneuver dynamics associated with aggravated coordinated inputs at negative AOA's were degraded from those at positive AOA's. Although none of the negative AOA coordinated input 180 deg bank-to-bank rolls departed, the rudder did lock out during some

maneuvers. The fact that the rudder locked out during the 180 deg bank-to-bank rolls was a strong indication of impending departure. During an aggravated coordinated input through 360 deg of roll at 0.60 TMN at -4.5 deg AOA, a violent nose down departure occurred. The departure resulted in a locked engine surge and subsequent flameout. The nose down departure occurred extremely rapidly, with no significant warning to the pilot. During the departure, AOA remained negative for approximately 7 sec with a peak value of -75 deg. Sideslip was oscillatory throughout the departure with a peak value of ± 40 deg. The first indication to the pilot of an impending departure was the rudder locking out to full deflection; however, the departure followed so quickly that the rudder locking out did not provide a truly usable warning of the departure. Pilot response immediately following the departure was to attempt to center the lateral stick and aggressively neutralize the rudder. Although the pilot felt the rudder was neutralized based on the 300 lb of pedal force input, the rudder actually remained locked out to full deflection. As sideslip changed signs, the rudder locked out in the opposite direction, at which point the airplane began to recover. The departure consisted of two 360 deg rolls, which the pilot identified as the first two turns of an inverted spin. The departure was extremely disorienting to the pilot. This departure was typical of the numerous nose down departures from cross control inputs at positive AOA's experienced by the contractor during the HAOA demonstration program. One of those departures resulted in a four-turn inverted spin/spiral, and was the basis for the placard against such departures during Navy testing. As with the coordinated inputs at positive AOA's, neither the symmetric or asymmetric stores had a significant effect on the coordinated input maneuver characteristics. This nose down departure during a negative AOA 360 deg coordinated roll will have minimal impact on fleet operations, as sustained maneuvering at negative AOA's is rare and maneuvering in excess of 180 deg bank angle change is prohibited. Due to the unpredictable nature of flight below negative one g, and the limitations placed on the airframe in that regime, rolls at less than negative one g should be prohibited.

Cross Control Inputs

Departure resistance was evaluated during abrupt full cross control inputs through 90 deg bank angle change in the clean and asym loading from 0.4 to 0.7 TMN. Test conditions and results are presented in appendix D, table V. A representative time history of a 0.7 TMN cross control input through 90 deg bank angle change is presented in appendix E, figure 6. Bank angle change was limited to 90 deg to prevent an inadvertent nose down departure. Airplane response to cross control inputs in the clean loading was characterized by low to moderate roll rate (40-140 deg/sec), low to high yaw rates (4-36 deg/sec), and low to high sideslip angle (2-24 deg). Except for the cross control inputs at full back stick, all rolls were in the direction of the lateral stick. Cross control inputs at full back stick resulted in rolls in the direction of the pedal. Response to cross control inputs in the asym loading was characterized by moderate roll rate in the direction of the lateral stick (90-100 deg/sec), low to high yaw rate (8-34 deg/sec), and moderate to high sideslip excursions (12 to 26 deg). Although the maneuvers were over fairly quickly, the tendency of the rudder to lock out was a strong indication of an impending nose down departure. The rudder was forcibly neutralized during the recovery portion of the maneuver to minimize the risk of a nose down departure. None of the cross control inputs through 90 deg bank angle change resulted in a nose down departure. Although full cross control inputs held for greater than 90 deg of roll may result in a nose down departure, these full cross control inputs are not mission relateable. The SNA who inadvertently uses a cross control input will not depart if the bank angle change is limited to less than 90 deg. However, in order to maintain the safety margin desired for controlled flight, intentional rolling cross control maneuvers beyond 90 deg bank angle change should be prohibited.

CONFIGURATIONS PA AND TO DEPARTURE RESISTANCE

Departure resistance during abrupt full lateral stick inputs in the clean loading was evaluated in configurations PA and TO between 100 and 130 KIAS at 25,000 ft pressure

altitude. A detailed description of the configurations PA and TO departure resistance testing is presented in appendix B. Test conditions and results are presented in appendix D, table VI. Lateral stick rolls were performed with Yaw Damper Control (YDC) engaged (ALL) and disengaged (SBI). Lateral stick rolls in both configurations were characterized by low to moderate roll rates (45 to 60 deg/sec). Configuration TO rolls were smooth with no hesitations observed. Configuration PA rolls had a slight hesitation in roll after 45 deg of bank angle change. Once past the 45 deg angle of bank change, the roll angle would smoothly increase until the lateral stick was neutralized. Sideslip generally increased throughout the maneuver to a maximum of 12 deg. The sideslip quickly damped out once the lateral stick was neutralized. Although the maneuvers with the YDC in SBI generally resulted in somewhat higher sideslips than those with YDC in ALL, the overall characteristics of the maneuver were not significantly different. The full lateral stick maneuvers were not uncomfortable or disorienting to the pilot. Because the lateral stick rolls performed did not lead to an impending departure, it is considered possible to aggressively roll the airplane with lateral stick without concern for departure.

OCF DEPARTURE TRAINING MANEUVER

The contractor-recommended departure techniques of full lateral stick at full back stick and full pedal at full back stick were evaluated for suitability as OCF training maneuvers. After 180 deg of bank angle change, a full opposite lateral stick or full opposite pedal input was made in an attempt to stop the roll and maintain the angle of bank. These maneuvers were performed at 0.40, 0.50, and 0.60 TMN at 25,000 ft pressure altitude. Test conditions and results are presented in appendix D, table VII. The effect of power setting, speed brake position, and YDC were also evaluated. The full left pedal input resulted in a left roll which was stopped with the pedal check at 200 deg of bank angle change. The maneuver was not a departure and would not provide any usable OCF training. The full left lateral stick input resulted in a left roll. A representative time history for the full lateral

stick maneuvers is presented in appendix E, figure 7. After 200 deg of bank angle change, a full right lateral stick input was made in an attempt to stop the left roll rate. Following the right stick input, the left roll rate accelerated slightly, resulting in an additional 180 deg of left bank angle change. The full lateral stick at full back stick maneuver could be interpreted by strictest definition as a departure; however, the artificial setup results in a very benign and almost imperceptible departure that would not provide the SNA with any significant OCF training. Although the high degree of departure resistance exhibited by the T-45A is generally considered a beneficial characteristic, this departure resistance has a significant impact on training effectiveness in the case of OCF training. A more dynamic departure, entered through sustained application of cross controls was identified during contractor testing; however, this departure was not explored during Navy testing because of questions concerning recoverability of an inverted spin mode that could be entered during the departure. If the inverted spin recoverability issue could be resolved, possibly by incorporating a powered rudder, this departure might prove to be a suitable training maneuver. The T-45 failed to meet the intent of the requirements outlined in references 1,4 and 5 in that a suitable training maneuver does not exist to demonstrate the principles of Out-of-Control Flight. The lack of an adequate OCF training maneuver will prevent the SNA from receiving the necessary training on the fundamentals of tactical aircraft departure recognition and recovery techniques.

UPRIGHT HAWK MODE SPINS

The British Aerospace Hawk airplane has a spin-like motion which results from longitudinal and rudder inputs. This motion is not an actual spin mode; however, the dynamics are similar enough to a spin that the Royal Air Force utilizes the maneuver as a spin training maneuver. Although the maneuver is not truly a spin, it is nonetheless identified as the Hawk Mode spin. The upright Hawk Mode spin was evaluated for its effectiveness as a training maneuver during OCF flight training. A detailed description of

the upright spin entry techniques is presented in appendix B. Full back stick and full pedal inputs were initiated at or above 32,000 ft pressure altitude between 0.4 and 0.5 TMN. All spin attempts were conducted with power at IDLE. Test conditions and results are presented in appendix D, table VII. Both wings level and turning (up to 30 deg angle of bank) entries were attempted. During spin entries from turns, pedal input in the direction and opposite the direction of the original turn were used. Effects of speed brakes, YDC, and control input timing were also evaluated. Cross lateral stick inputs were not authorized during these tests and this effect was not evaluated. A representative time history of an upright Hawk Mode spin is presented in appendix E, figure 8. Although a true 360 degree heading change did not occur during the maneuvers, the pilot did observe spin-like motion. Regardless of input timing, YDC, speed brake position, or entry Mach, the Hawk Mode attempts resulted in a motion that was very oscillatory in roll rate and sideslip. Average AOA during the spin was 27 deg with oscillations of approximately ± 10 deg. Average roll rate was approximately 70 deg/sec with oscillations as high as 80 deg/sec prior to terminating the maneuver. Sideslip oscillations were as large as ± 25 deg. Relative to roll rate, yaw rate was fairly steady throughout the maneuver at approximately 25 deg/sec. The frequency of the roll rate oscillations was moderate and fairly predictable to the pilot. The magnitude of the oscillations increased as the maneuver progressed. When the roll rate reversals became large (greater than 20 to 40 deg/sec opposite the pedal input), the maneuver was terminated. Two or three reversals typically occurred prior to terminating the maneuver. During contractor testing, the airplane demonstrated a tendency to depart into an inverted post-stall gyration (PSG) when roll rate reversals increased to greater than approximately 50 deg/sec. The purpose of Navy HAOA testing was not to explore the inverted spin region; therefore, upright maneuvers were terminated when roll rate reversals exceeded 30 deg/sec. During the spin entries that were terminated due to airspeed exceeding 180 KIAS, roll rate was very oscillatory as well. Initiating the maneuver with pedal followed by longitudinal stick resulted in a higher yaw rate during the entries when

compared with other input phasing. Smooth application of the inputs over 1 to 2 sec resulted in a slightly less oscillatory spin. Abrupt inputs would result in a higher initial AOA and yaw rate, but the remaining portion of the spin was more oscillatory than the smooth control input spins. Most upright spins were entered with the YDC in SBI and considered to be oscillatory spins. When YDC was in ALL, the spin appeared to the pilot simply as a pedal roll, with no spin-like motion observed by the pilot. Speed brakes had little effect on spin dynamics; however, spin recovery was slowed noticeably with speed brakes extended. The oscillatory nature and likelihood of a nose down departure during the Hawk Mode Spin does not lend itself to use as an OCF training maneuver. However, it might be possible to enhance the use of this maneuver for a portion of student training if a powered rudder is incorporated to enhance the airplane's recovery from dynamic departures. The spin characteristics of the T-45A failed to meet the requirements of reference 8 in that the airplane does not have a repeatable spin with consistent recovery.

VERTICAL MANEUVERING

GENERAL

HAOA flying qualities and spin susceptibility were evaluated during 44 nose high, low airspeed vertical maneuvers. The 70 deg pitch attitude vertical maneuvers were also evaluated for suitability as an OCF training maneuver. All vertical maneuvers were flown in configuration CR in the clean loading. A detailed description of the vertical maneuvers are presented in appendix B. Test conditions and results for the vertical maneuvers are presented in appendix D, table IX. All vertical maneuvers were flown with the YDC in ALL. The effect of speed brake position on the vertical maneuvers was also evaluated. Vertical maneuvering tests were conducted by establishing a pitch attitude within 20 deg of the vertical and allowing the airplane to slow to 100, 50, or 0 KIAS. Abrupt control inputs in the vertical at airspeeds of 50 and 100 KIAS resulted in an initial airplane response which decayed to little or no motion as the airspeed approached zero. Generally, lateral and

longitudinal stick were held neutral and rudder pedals were forcibly centered once the nose fell below the horizon. Some attempts were made, including full aft longitudinal stick, to minimize adverse airplane motion during the recovery. The effect of not forcibly centering the rudder during the recovery was not evaluated during these tests per recommendations from the contractor. If the rudder was not forcibly centered and was allowed to lock out, the risk of encountering an inverted spin was increased. In an attempt to reduce the chance of entering an inverted spin, the rudders were forcibly centered for all vertical maneuvering. Neither the control inputs in the vertical, control inputs as the nose fell below the horizon, or speed brake position had a significant impact on the recovery portion of the maneuver.

SPECIFIC

Pitch Attitudes of 75 deg or Less-Using Proper Recovery Technique

Vertical maneuvers initiated at 75 deg pitch attitude or less, upright and inverted, using the correct vertical recovery technique, presented in appendix B, with the control inputs initiated at 100 KIAS were characterized by moderate AOA's (± 20 deg), low sideslips (± 20 deg), and very low roll and yaw rates, 25 and 15 deg/sec, respectively. Vertical recoveries were made at both IDLE and MIL power. Using aft longitudinal stick to capture 17.5 units AOA when inverted or forward longitudinal stick to capture 5 to 10 units (-3 to $+2$ deg) AOA when upright resulted in the airplane pitching towards the horizon. As the nose fell below the horizon, flight controls were neutralized. Pitch rates encountered during these maneuvers were moderate and predictable by the pilot. Once the nose fell below horizon and the controls were neutralized (including retracting the speed brake if extended), some roll and yaw oscillations were present but these oscillations damped out as the airspeed increased. Once airspeed increased above 130 KIAS, the recovery was considered complete. No inverted PSG's or incipient inverted spins were encountered

during vertical recoveries when the correct recovery technique was used. Additionally, no engine anomalies occurred.

Pitch Attitudes of 75 deg or Less-Improper Recovery Techniques

Vertical maneuvers using neutral controls or misapplied controls (full back stick upright or full forward stick inverted) at 100 KIAS were characterized by higher AOA's (± 60 deg), sideslips (± 40 deg), roll rates (± 80 deg/sec) and yaw rates (± 40 deg/sec) when compared to the vertical maneuvers using the correct vertical recovery technique described above. In all cases, where the improper recovery techniques were attempted, the nose fell through the horizon in a ballistic profile with no tendency to enter a PSG or incipient inverted spin. No engine anomalies were experienced during vertical maneuvers at pitch attitudes of 75 deg or less when using the improper recovery technique. The vertical maneuvers at pitch attitudes of 75 deg or less were primarily flown with the power at IDLE; however, a small sample of maneuvers were flown at MIL. The maneuvers at MIL were not as dynamic as those flown at IDLE. This effect was attributed to the variable nature of the maneuver itself, not the power setting. Had the dynamics associated with the IDLE maneuvers been experienced at MIL, the result would most likely have been an engine surge. At pitch attitudes of 70 deg or less, all maneuvers were well-behaved at IDLE or MIL. The SNA will not encounter a departure or spin if an improper recovery technique is used to recover from a nose high, slow airspeed flight condition with pitch attitudes of less than or equal to 75 deg.

Pitch Attitudes Greater Than 80 deg

Vertical maneuvers within 10 deg of the vertical both upright and inverted at airspeeds of 100 KIAS or less were not characterized by a ballistic profile but by the airplane slowing to zero airspeed, or near zero airspeed in the vertical. A representative time history of a vertical maneuver within 10 deg of the vertical is presented in appendix E, figure 9.

Abrupt control inputs in the vertical at airspeeds of 50 and 100 KIAS resulted in an initial airplane response which decayed to little or no motion as the airspeed approached zero. After the nose rapidly fell through the horizon, the airplane would usually recover with no adverse roll and yaw oscillations. The oscillations were somewhat larger than those experienced at the 70 and 75 deg pitch attitude maneuvers. Peak roll and yaw rate oscillations during the recovery were 140 and 82 deg/sec, respectively. Generally, lateral and longitudinal stick were held neutral and rudder pedals were forcibly centered once the nose fell below the horizon. Some attempts were made, including full aft longitudinal stick, to reduce the pitch rates and thereby minimize adverse airplane motion during the recovery. Neither the control inputs in the vertical or control inputs as the nose fell below the horizon had a significant impact on the recovery portion of the maneuver.

Approximately 10% of the vertical maneuvers at pitch attitudes within 10 deg of the vertical at airspeeds of 100 KIAS or less resulted in either a negative AOA PSG or an incipient inverted spin. In addition to adverse airplane dynamics, approximately 50% of the maneuvers within 10 deg of the vertical resulted in either a self-recovering engine surge, a locked engine surge, or an engine flameout. A time history of a vertical maneuver that resulted in an incipient inverted spin is presented in appendix E, figure 10. The negative AOA PSG's and incipient spins were very uncomfortable and disorienting to the pilot. The initial portion of the incipient inverted spin was characterized by an abrupt lock out of the rudder. The pilot countered this lock out with an immediate and forceful (in excess of 300 lb) opposite rudder input. The sideslip was such that even rudder pedal forces in excess of 300 lb did not result in a centered rudder. An attempt to inject a mission relatable 2 sec pilot reaction time prior to countering the locked out rudder was rejected by the contractor, presumably because this might further aggravate the inverted spin. The fact that the airplane encountered incipient inverted spins during vertical maneuvering testing and that the contractor predicts that the negative 25 deg AOA inverted spin is potentially unrecoverable demonstrates that the SNA may encounter an unrecoverable inverted spin

during an inadvertent tailslide. The potential for the SNA to enter an unrecoverable inverted spin from a nose high, low airspeed flight condition could result in loss of aircraft and aircrew. The inverted spin characteristics failed to meet the requirements of reference 7 for several reasons. These reasons include: (1) The airplane exhibits an uncommanded motion which cannot be arrested promptly by simple application of pilot control, (2) Recovery was not possible without exceeding 175 lb of pedal force, (3) The airplane does not have a single technique which provides recovery from all post-stall gyrations and incipient spins without requiring the pilot to determine the direction of motion and without tendency to develop a spin, (4) The recovery from the spin was not attainable within two turns measured from the initiation of recovery action, and (5) The airplane does not have control authority and hinge moment capability to assure safety throughout the combined range of all attainable angles of attack (both positive and negative) and sideslip. The contractor should investigate and take corrective action as soon as possible. The contractor should also identify and demonstrate a recovery technique for the negative 25 deg inverted spin mode. Consideration should be given to installing a powered rudder in the T-45A airplane to preclude rudder lock-out and assist in inverted spin recovery.

OPERATIONAL MANEUVERS

GENERAL

HAOA flying qualities during operational maneuvers were evaluated in configuration CR. All operational maneuvers were flown in the clean loading. A detailed description of all the operational maneuvers are presented in appendix B. Test conditions and results for the operational maneuvers are presented in appendix D, table X. All operational maneuvers were flown with the YDC in ALL. The maneuvers were flown using normal flight control inputs building up to more aggravated control inputs. During maneuvers where large AOA and/or sideslip was expected, the maneuver was first flown with the engine fixed at an intermediate power setting less than MIL and then flown with normal to aggressive throttle

inputs. During the most aggravated maneuvering, commanded flight control and throttle inputs were well outside normal student representative inputs in order to evaluate the worst case piloting techniques. Within the envelope investigated, the airplane performed all maneuvers without any departures or engine anomalies. The operational maneuvers were characterized by AOA's in the 15 to 30 deg range, low sideslip (5-10 deg), moderate roll rates (50-180 deg/sec), and low yaw rates (5-35 deg/sec). Peak AOA, sideslip, roll rate and yaw rate values were all much less than those experienced during the departure resistance maneuvers. The operational maneuvers were considered well inside the region where the T-45A is departure resistant. No events of the rudder locking out or the desire to couple down to negative AOA occurred. Natural airplane cues in maneuvering flight, such as light buffet at optimum turn rate AOA and a pitch bucking at an accelerated stall condition, should teach airplane "feel" to the SNA vice reliance on cockpit indicators for turn performance evaluation. The T-45 can safely conduct the designated operational maneuvers without risking departures or engine anomalies.

SPECIFIC DISCUSSION OF OPERATIONAL MANEUVERS

Inadvertent Longitudinal Trim Actuation During Maneuvering Flight

High AOA flying qualities and longitudinal control forces were evaluated during inadvertent trim actuation during a barrel roll in configuration CR at 20,000 ft pressure altitude, 350 KIAS. Full nose up trim at the apex of the barrel roll resulted in the aircraft entering heavy buffet. Full nose down trim resulted in an unload in normal acceleration. The inadvertent trim actuation was quite evident to the pilot due to increased longitudinal stick forces and the resulting airplane motion. Recovering the airplane to wings level flight from both the nose up and nose down trim was easily accomplished without retrimming. The SNA will not encounter any adverse flying qualities during inadvertent trim actuation or during a runaway trim condition.

Training Command Vertical Recovery Training Maneuver

Correct Recovery Technique

The training command vertical recovery training maneuver was evaluated for HAOA flying handling and control effectiveness. The vertical recovery maneuver was initiated from 20,000 ft pressure altitude at airspeeds between 300 to 325 KIAS. At approximately 180 KIAS and a 60 deg pitch attitude, the pilot commenced the recovery by selecting MIL power and pushing forward on the stick to intercept 5 to 10 units (-3 to +2 deg) AOA. Capturing and maintaining 5 to 10 units AOA was easy. The push to 5 to 10 units equated to approximately 0.1 g and was easy for the pilot to discern without reference to cockpit instruments. Although the minimum airspeed during the push was as low as approximately 95 KCAS, the push portion of the maneuver was comfortable and controllable. Once the nose was below the horizon and airspeed was above 150 KIAS, a 17.5 unit AOA pull was commenced. During the 17.5 unit AOA pull up, the airplane encountered a light airframe buffet. This light buffet allowed the pilot to maintain the desired AOA during the pull without reference to cockpit instruments.

Incorrect Recovery Technique

The use of up to full forward longitudinal stick during the push portion of the maneuver did not result in any adverse flying qualities. With the push initiated at approximately 100 KIAS, minimum airspeed during the maneuver was 59 KCAS. At an airspeed less than safe flying speed, approximately 120 KIAS, the pilot aggressively pulled to full back stick. During the pull, the use of full back stick simply resulted in a pitch bucking motion, heavy buffet, and wing rock. If full back stick was not released, the airplane remained in the pitch bucking motion with no tendency for departure. AOA varied from 0 to 27 deg during the vertical recovery maneuver using the incorrect technique. The peak sideslip excursion during the full back stick portion of the maneuver was -9 deg. Although altitude loss was not completely arrested during the aggravated full back stick

pull, it was not extremely high. The airplane motion made it obvious to the pilot that using full back stick was an incorrect longitudinal stick input. Once the pilot relaxed the full back stick longitudinal stick input, the airplane quickly recovered. Although the input increased the time and altitude to recover the airplane, it did not result in adverse flight characteristics. Sampling other controls during this maneuver proved that they remained effective. No abnormal flying qualities were encountered throughout the entire vertical recovery maneuver. The SNA will be able to perform the training command vertical recovery training maneuver with confidence.

Loop - Slow Over-the-Top

Low airspeed and HAOA flying qualities were evaluated during loops at 20,000 ft pressure altitude and at initial airspeeds of 325 to 350 KIAS. Airspeeds less than 125 KIAS were considered slow over-the-top for the purpose of this test. Very low speeds, such as those associated with vertical maneuvers or tailslides, were not evaluated during the loops due to the extensive evaluation during HAOA vertical maneuvering tests. The slowest airspeed attained during the loops was approximately 82 KCAS. The minimum airspeed was encountered halfway through the loop, with the airplane wings level and inverted. The loop was completed without difficulty. Although the airplane was ballistic during portions of the slow over-the-top loop, control effectiveness in all axis was good throughout the maneuver. The second type of aggravated input evaluated during a loop was the use of full back stick as the airplane reached a 90 deg nose down attitude in an attempt to aggressively overcontrol the recovery portion of the loop. Immediately following the full back stick input, the airplane quickly encountered an accelerated stall condition. The most significant impact that the use of full back stick had on the recovery was to increase altitude loss. Once the full back stick was released the airplane quickly recovered. The airplane showed no tendency for departure during any of the loops. The SNA will be able to inadvertently get slow over-the-top during overhead maneuvers

without departing the airplane. This region does not include the previously reported area of concern within 20 degrees from the vertical at less than 100 knots.

Nose Low/Unusual Attitude Recovery

High AOA flying qualities during nose low/unusual attitude recoveries were evaluated in configuration CR at 22,000 ft pressure altitude at initial airspeeds between 130 to 150 KIAS. Lateral stick and longitudinal stick were effective throughout the entire recovery. During the roll to wings level, some minor roll oscillations were experienced but they did not adversely affect gross capturing of a wings level attitude. Other than the potential to overshoot the desired wings level attitude, the use of full lateral stick during the roll to wings level had no adverse effect on the recovery. When using up to full back stick to bring the nose up to the horizon, the usual pitch bucking motion and wing rock ensued, which only delayed the recovery. A peak AOA of approximately 32 deg and a peak sideslip of 15 deg was achieved during the full back stick pull to wings level. The SNA should be able to fly the nose low/unusual attitude recovery maneuver using extremely aggravated control inputs without departing the aircraft.

Break Turn

HAOA flying qualities during break turns were evaluated at 20,000 ft pressure altitude, and initial airspeeds of 250 to 450 KIAS. Additionally, break turns were evaluated for their effectiveness as a maneuver during ACM training. Power setting during the break turn maneuver varied from IDLE to MIL. The break turns were fairly similar at all airspeeds tested. Peak AOA and sideslip were approximately 24 and 6 deg, respectively. Buffet was encountered quickly at g's ranging from 4.8 g at 400 KIAS down to 3.1 g at 250 KIAS. During the aggravated input break turns using full back stick, heavy buffet and wing rocking were present; however, at no time did the pilot feel the airplane was

approaching an impending departure condition. The SNA will be able to aggressively initiate a break turn without risk of departure.

Jink-Out

HAOA flying qualities during jink-outs were evaluated at 20,000 ft pressure altitude and initial airspeeds of 250 and 300 KIAS. Peak positive and negative g during the 300 KIAS jink-out were 4.0 g and -2.0 g, respectively. During the jink-outs, the airplane exhibited no tendency for departure or other adverse flying qualities. ACM training should not be hampered by the airplane's characteristics during a jink-out maneuver while attempting to nullify a guns tracking solution from an attacking airplane.

Displacement Roll

HAOA flying qualities during displacement rolls were evaluated at 20,000 ft pressure altitude and initial airspeeds of 250 to 350 KIAS. The displacement roll was also evaluated for its effectiveness as a maneuver during ACM training. Peak AOA achieved during the displacement roll was approximately 14 deg. Peak g during the maneuver was 3.7 g. Peak roll rate, achieved by using a combination of both rudder pedal and lateral stick inputs, was approximately -90 deg/sec. Peak sideslip and yaw rate were 8 deg and -28 deg/sec, respectively. No adverse flying qualities were encountered during the normal or aggravated input displacement rolls. Closure on the target airplane was approximately 50 KIAS for all displacement rolls performed. The target airplane maintained approximately 2 to 2.5 g's during the maneuver. The first task in a displacement roll is to align fuselages. The lack of usable g was very apparent to the pilot in that the pilot could not align fuselages. Therefore, a proper displacement roll could not be performed. The result of the lack of usable g was that the pilot performed a modified displacement roll which was more like an aileron roll. The result of the maneuver was to place the airplane in a position too far outside the radius of turn at the completion of the maneuver. The SNA may find

himself performing aileron rolls when attempting displacement rolls which will require more time to train the student in proper ACM maneuvering.

Barrel Roll Attack

HAOA flying qualities during barrel roll attack maneuvers were evaluated at 20,000 ft pressure altitude and initial airspeeds of 300 to 350 KIAS. The barrel roll attack was also evaluated for its effectiveness as a maneuver during ACM training. Longitudinal stick and lateral stick were the primary control inputs throughout the roll and were effective throughout the maneuver. Peak roll rate during the barrel roll attacks was 40 deg/sec, with minimal sideslip excursions of less than 5 deg. Performing the barrel roll attack using normal control inputs was not difficult. Although the aggravated longitudinal stick inputs simply resulted in excessive separation between the airplane performing the barrel roll attack and the defensive airplane, the inputs did not result in adverse flying qualities or departure tendencies. The aircraft is suitable for this portion of its mission.

High-G Roll - Over-the-Top

The high-g roll over-the-top was evaluated for HAOA flying qualities and for its effectiveness as a last ditch maneuver in a defensive engagement during ACM training. The maneuver was initiated at 20,000 ft pressure altitude and at airspeeds of 250 and 300 KIAS. During the 250 KIAS maneuver, with approximately 240 lb of pedal force, the pilot was only able to deflect the rudder 11 deg. This rudder deflection generated a maximum sideslip of 8 deg, which resulted in less than 50 deg/sec roll rate. The amount of sideslip generated will decrease as airspeed increases. At no time during either the normal or aggravated high-g roll over-the-top did the airplane encounter adverse HAOA flying qualities. The maneuver is used as a last ditch attempt to cause the opposing airplane to overshoot during an ACM engagement. At these speeds the inability to significantly deflect the rudder (250 lb of pedal force resulted in only 8 deg of sideslip) greatly reduces

the amount of roll rate generated by the pedal input. The result was a maneuver very slow in developing and unusable for the desired maneuver. Rather than creating an overshoot, the maneuver was a slow roll that could be easily countered by the opposing airplane. Coordinating the pedal input during the maneuver did not improve its effectiveness. In the current aircraft configuration, the high-g roll over-the-top was not an effective last ditch maneuver during ACM. Consideration should be given to the incorporation of a powered rudder to increase the rudder control power at higher airspeeds in order to increase the maneuvering capabilities of the T-45 during ACM training. The T-45 failed to meet the requirements of reference 5 in that it could not effectively perform a high-g roll over-the-top maneuver. SNA training will be degraded due to the lack of an appropriate over-the-top last ditch maneuver.

High-G Roll - Underneath

The high-g roll underneath was evaluated for HAOA handling qualities and for its effectiveness as a last ditch maneuver in a defensive engagement during ACM training. The maneuver was initiated at 20,000 ft pressure altitude and at initial airspeeds of 250 and 300 KIAS. While attempting this maneuver at the slower airspeed, the natural tendency of the airplane was to roll off to one direction as it reached accelerated stall. This roll off enabled the pilot to roll the airplane with pedal only, lateral stick only, or combination of both, to complete the maneuver, and end up with a possible neutral setup after the roll. It is possible to use the high-g roll underneath as an effective last ditch maneuver, transitioning from a defensive position to a neutral position.

Flat Scissors

Flat scissors maneuvering was evaluated for HAOA flying qualities and for its efficiency and capacity as a suitable regime for slow flight during ACM training at 22,000 ft pressure altitude and an initial airspeed of 150 KIAS. Power setting during the flat scissors

varied from IDLE to MIL. Stall airspeed with a clean wing is approximately 120-125 KIAS. Post stall flight is not a workable regime; however, flight at full back stick is usable. Lateral and directional control is available even at full back stick. At these slow speeds (between 130-140 KIAS), coordinated lateral stick and pedal was required to keep the desired angle of bank. Full back stick resulted in a steady 135 KIAS descent of approximately 1500 fpm. Smooth lateral stick and pedal inputs were required to properly fly this profile. The SNA should be able to gain experience in slow flight during ACM training.

Rolling Scissors

High AOA flying qualities during rolling scissors were evaluated at 20,000 ft pressure altitude and initial airspeeds of 300 to 350 KIAS. A rolling scissors was also evaluated for its effectiveness as a maneuver during ACM training. Smooth longitudinal stick inputs were very important to execute the maneuver properly. Any attempt at over-controlling the longitudinal inputs resulted in pitch bucking and a loss of energy; however, there was no departure tendency noted. The diameter of the rolling scissors was very large due to the lack of g available and accompanying large turn radius and slow turn rate. If the pilot attempted to decrease the size of the rolling scissors by decreasing airspeed, the rolling scissors could no longer be executed properly. Additionally, the airplane exhibited the tendency to enter an accelerated stall when the pilot attempted to rapidly point the nose toward the target airplane. This tendency reduces the opportunity for the instructor pilot to teach the SNA the fundamentals of position/energy considerations during ACM.

AIR COMBAT MANEUVERING

GENERAL

High AOA flying qualities and the ability of the T-45A to effectively perform all phases of the ACM training mission was evaluated during neutral (one circle and two circle

engagements), offensive, defensive setups, and during last ditch maneuvering with another T-45A as the threat airplane. Airspeed ranged from 120 to 350 KIAS at pressure altitudes between 10,000 and 25,000 ft. All ACM engagements were flown in configuration CR, in the clean loading, and with the YDC in ALL. A detailed description of the ACM setups is presented in appendix B. A summary of test conditions and results for the ACM evaluation is presented in appendix D, table X. The primary focus during the flights was to determine the suitability of the T-45 to be employed as an ACM platform during a radius/position fight, a rate/energy fight, a neutral fight (as in a flat or rolling scissors), as well as during last ditch maneuvers. The basic setup was from a neutral head on pass with either a turn into or away from the opposing airplane in order to generate the desired geometry. Flight control or throttle movement was not restricted in any way during ACM. All HAOA characteristics observed during ACM had been previously observed during the operational maneuvers. The airplane performed all maneuvers without any departures or engine anomalies. The T-45 can safely conduct ACM without risk of departure or engine anomalies. During the ACM portion of the evaluation, two specific problems associated with the ability of the T-45A to be effectively used for ACM training were encountered. These specific problems associated with ACM are presented below. Although the two problems listed below will limit the capability of the T-45A as an ACM trainer, it is still recommended for fleet use in the ACM training environment.

SPECIFIC

Available G

Generally, the airplane was utilized to its maximum performance while maneuvering just at the onset of slight airframe buffet. This buffet appeared to correspond to the maximum g available and maximum sustained g in a slightly nose low (10-15 deg below the horizon) turn. The approximate g-levels at which buffet was encountered is

presented in table IV.

Table IV
MAXIMUM AVAILABLE LOAD FACTOR

Airspeed (KIAS)	Load Factor Available (g)
350	4.8
300	3.5
250	2.7
200	2.1

Any attempt to maneuver beyond the onset of slight airframe buffet in an attempt to increase g and turn rate resulted in an accelerated stall characterized by a pitch bucking motion. The pitch transients were difficult to avoid anytime the airspeed decreased to below 300 KIAS due to the extremely small difference between onset buffet and limit buffet g levels. During ACM engagements, any attempt to transition from an energy fight to a position fight in order to achieve a guns solution or missile shot by aggressively attempting to convert some available energy (KIAS) into instantaneous turn rate resulted in the pitch bucking motion and a reduction in actual turn rate. During the pitch bucking motion, fine tracking of an intended target is not possible. The extremely small difference between maximum sustained g in a slightly nose low turn and maximum g available will seriously degrade the SNA from learning the fundamental ACM technique of energy management, including when to transition from an energy fight to a position flight. The limitation this characteristic will place on ACM training will limit the training opportunities for the SNA and degrade the training effectiveness prior to joining the fleet. In that respect, the T-45 failed to meet the requirements of reference 5. A team should be formulated to investigate how to more effectively gain usable g with the current aircraft wing that does not degrade any other portion of the airplanes flight envelope.

Rudder Pedal Forces

Longitudinal and lateral controls were effective at all airspeeds and provided rapid and desired aircraft response to pilot input. The effect of the rudder, however, was minimal at

all airspeeds evaluated during ACM. Attempting to roll the aircraft using the rudder, as in displacement rolls or high-g over-the-top maneuvers, resulted in roll rates as low as 40 deg/sec and frequently required the pilot to either abort the desired maneuver or attempt to compensate for the lack of rudder-induced roll by coordinating with lateral stick. This coordinating lateral stick input degraded the effectiveness of the initially intended maneuver. Additionally, in order to generate even the minimal amount of roll rate available, the pilot was required to input up to 250 lb of rudder pedal force. The high rudder forces and minimal apparent rudder control power throughout the ACM flight regime will make it difficult to train the SNA in the fundamentals of utilizing all aircraft control axes during ACM. This may result in the SNA entering the fleet with a reduced understanding of the basic principles of slow flight ACM maneuvering, which may require additional training by the Fleet Replacement Squadrons to correct. Additionally, the rudder pedal force characteristics failed to meet the requirements of reference 7 because the airplane could not perform displacement rolls or high-g over-the-top maneuvers with rudder pedal forces of up to 250 lb. These forces exceeded the maximum allowable of 175 lb during any maneuver as stated in reference 3.

ENGINE COMPATIBILITY

GENERAL

In order to determine the suitability of the propulsion system for the operational ACM environment, engine stability was evaluated during a series of worst case operational maneuvers and during ACM. Vertical recovery maneuvers were conducted in order to develop recommendations for fleet limits and recovery procedures. Maneuver descriptions are provided in the respective flying qualities paragraphs. Specific propulsion related discussion follows.

SPECIFIC PROPULSION ISSUES

Abrupt Pulls

Two surges occurred during abrupt pull maneuvers discussed in paragraph 28. The first surge was a double pop surge which occurred at 93% RPM of the high pressure stage turbine, with the surges occurring within one-half second of each other. The second event was a locked-in surge at 96% RPM which required an engine shutdown in order to clear it. The surges are not considered mission relevant because the control inputs and resulting maneuvers were much more severe than expected during the fleet operational maneuvers performed

Vertical Maneuvers

Approximately 50% percent of the vertical maneuvers conducted within 10 deg of the vertical with less than 100 KIAS resulted in either a self-recovering surge, locked-in surge, or flameout. As a result, recommendations for NATOPS vertical maneuvering limits and recovery procedures have been developed and are presented in the recommendations section of the text.

Surge Characteristics

Self-recovering pop engine stalls were characterized by an audible bang with no pilot action required to restore satisfactory engine operation. Locked-in surges at IDLE power were characterized by a TGT rise as slow as 12°C/sec and a gradual decay in RPM, and no audible cues to the pilot. Surges at higher power settings were sometimes indicated by an audible "bang" or "pop". Locked-in surges at higher power settings were characterized by a very rapid temperature rise. The abrupt pull locked surge at 96% RPM had an initial temperature rise of 100°C/sec prior to the pilot retarding the throttle to IDLE. All locked-in surges during the contractor's HAOA demonstration and the Navy's evaluation were successfully cleared by completing the NATOPS procedures, which consisted of retarding

the throttle to IDLE or shutting down the engine and performing an immediate relight. It was obvious that high overfueling levels due to acceleration from low power settings was a factor that can increase engine stall sensitivity and decrease stall margin. Surge characteristics will vary depending on power setting, engine acceleration, and maneuver severity. Self-recovering pop stalls are sometimes indicated by an audible "bang" or "pop" with correct engine operation being immediately restored with no pilot action. Locked-in stalls at low power settings are characterized by a TGT rise as slow as 12°C/sec and a gradual decay in NH rpm, with no audible cue to the pilot. TGT rise during a low power stall will accelerate rapidly if the throttle is advanced. Locked-in stalls at high power settings are sometimes indicated by an audible "bang" or "pop" and are characterized by a very rapid temperature rise. A locked-in stall can sometimes be cleared by positioning the throttle to IDLE. If the stall remains locked-in, the engine must be shut down to clear it.

Operational Maneuvers and ACM

Operational maneuvers and ACM tests were performed without throttle handling restrictions. Maneuvers are discussed in paragraphs 44 through 60. There were no engine anomalies during any of the operational maneuvering and ACM tests. Two surges occurred during contractor full back stick WUT's with IDLE to MIL throttle slams. Analysis of the operational maneuvers indicates that the likelihood of achieving similar conditions during fleet operational maneuvering and ACM is remote. The likelihood of combining an engine acceleration from IDLE to MIL with the maneuver is lower still. Based upon these test results, imposing throttle handling restrictions is impractical. It would be prudent for future flights that when maneuvering at angles of attack at or above heavy buffet, there is an increased risk of engine surge, especially when the engine is accelerating from a low power setting. However, the T-45A propulsion system is considered adequate for the ACM training mission.

CONCLUSIONS

CONCLUSIONS

In general, the T-45A airplane is in compliance with the major portions of the Test and Evaluation Master Plan (TEMP) and the training command's Flight Training Instruction (FTI) with regards to the training objectives in the HAOA flight regime. The T-45 excelled in most areas investigated during the testing. There were some areas where the T-45 failed to meet the requirements outlined in references 1,4 and 5. However, the shortcomings were not severe enough to interfere with the overall success of the airplane as a trainer aircraft for future strike fighter pilots. The T-45A HAOA flight characteristics will be considered completely satisfactory for the undergraduate jet trainer mission upon correction of two major deficiencies which will be highlighted in the next paragraph. However, the T-45 is considered a valuable asset for the training command and should be considered suitable for the mission as an advanced trainer aircraft.

DEFICIENCIES

MAJOR DEFICIENCIES

1. The T-45 lacks an adequate out-of-control flight training maneuver for the desired training. The T-45 failed to meet the intent of the requirements outlined in references 1,4 and 5 in that a suitable training maneuver does not exist to demonstrate the principles of Out-of-Control Flight. The lack of an adequate OCF training maneuver will prevent the SNA from receiving the necessary training on the fundamentals of tactical aircraft departure recognition and recovery techniques. Therefore, the SNA will enter the fleet deficient of any significant OCF training. This might reflect on their ability to appropriately analyze and recover their fleet airplane in the event of encountering departures from controlled flight. The most significant ramification from an improper recovery during uncontrolled flight would be the loss of aircraft, or even worst, the loss of the aircrew.

2. The T-45 is susceptible to inadvertent entry into unrecoverable inverted spins from multiple scenarios. The main area of concern comes from a zero airspeed condition near the vertical. One such scenario is a very conceivable slow loop, or while loosing situational awareness during aggressive maneuvering encountered during ACM. The inverted spin characteristics failed to meet the requirements of reference 7 for several reasons. These reasons include: (1) The airplane exhibits an uncommanded motion which cannot be arrested promptly by simple application of pilot control, (2) Recovery was not possible without exceeding 175 lb of pedal force, (3) The airplane does not have a single technique which provides recovery from all post-stall gyrations and incipient spins without requiring the pilot to determine the direction of motion and without tendency to develop a spin, (4) The recovery from the spin was not attainable within two turns measured from the initiation of recovery action, and (5) The airplane does not have control authority and hinge moment capability to assure safety throughout the combined range of all attainable angles of attack (both positive and negative) and sideslip. The potential for the SNA to enter an unrecoverable inverted spin from a nose high, low airspeed flight condition could result in loss of aircraft and aircrew.

MODERATE DEFICIENCIES

1. The T-45 is not considered to be capable of completely performing all phases of ACM training mission due to lack of available g. The extremely small difference between maximum sustained g in a slightly nose low turn and maximum g available will seriously degrade the SNA from learning the fundamental ACM technique of energy management, including when to transition from an energy fight to a position flight. In that respect, the T-45 failed to meet the requirements of reference 5. The limitation this characteristic will place on ACM training will limit the training opportunities for the SNA and degrade the training effectiveness prior to joining the fleet.

2. The T-45 is not considered to be capable of completely performing all phases of ACM training mission due to low rudder control power. Roll rates as low as 40 deg/sec frequently required the pilot to either abort the desired maneuver or attempt to compensate for the lack of rudder-induced roll by coordinating with lateral stick. Even then, the maneuvers did not effect the desired outcome and were considered ineffective. Additionally, in order to generate even the minimal amount of roll rate available, the pilot was required to input up to 250 lb of rudder pedal force. The rudder pedal force characteristics failed to meet the requirements of reference 7 because the airplane could not perform displacement rolls or high-g over-the-top maneuvers with rudder pedal forces of up to 250 lb. These forces exceeded the maximum allowable of 175 lb during any maneuver as stated in reference 3. Due to insufficient rudder control power during ACM training, many maneuvers such as the displacement roll and the high-g roll over-the-top suffer greatly and therefore will not be as effective for further pilot development.

COMPLIANCE WITH WRITTEN SPECIFICATIONS

This section outlines the exact specifications with which the T-45 does not comply. The T-45A airplane met the specification requirements against which it was tested except those listed as follows:

1. Detail Specification (SD-570-1R4):

- (a) The airplane does not have a repeatable spin with consistent recovery.

2. Military Specification (MIL-F-8785C):

- (a) The airplane exhibits an uncommanded motion which cannot be arrested promptly by simple application of pilot controls.

- (b) The recovery was not possible without exceeding 175 lb of rudder pedal force. The airplane does not have a single technique which provides recovery from all post-stall gyrations and incipient spins without requiring the pilot to determine the direction of motion. The recovery from the spin was not attainable within two turns, measured from the initiation of recovery action.
- (c) The airplane does not have control authority and hinge moment capability to assure safety throughout the combined range of all attainable angles of attack (both positive and negative) and sideslip.
- (d) The airplane could not perform displacement rolls or high-g over-the-top maneuvers even with rudder pedal forces of up to 250 lb, which was greater than the maximum allowable 175 lb.

RECOMMENDATIONS

FURTHER TESTING

1. Recommend the contractor and the Navy develop a team to investigate, identify and demonstrate a recovery technique for the negative 25 degree angle of attack inverted spin mode. This recommendation directly deals with Major Deficiency #2.

AIRPLANE MODIFICATIONS

1. Consideration should be given to increasing the effectiveness of the wing to produce higher usable AOA and g available by incorporating maneuvering flaps/slats that deploy during flight in a tactical airspeed regime - usually less than 325 KIAS. This recommendation directly deals with Moderate Deficiency #1.
2. Recommend the benefits of a powered rudder be considered as a means of expanding the airplane envelope, to preclude lock out and assist in inverted spin recovery,

and to increase the effectiveness of the T-45A as an ACM trainer. This recommendation directly deals with Moderate Deficiency #2.

PILOT HANBOOK ENTRIES

The testing generated many areas of concern which should be addressed in the pilot's handbook. It should be updated with the appropriate discussion of the airplanes handling characteristics as well as the list of recommended additions which are included in appendix C. The areas include prohibited flight regimes, procedures in the event of an inadvertent zero airspeed condition, and several inputs related to the engine and its characteristics.

REFERENCES

REFERENCES

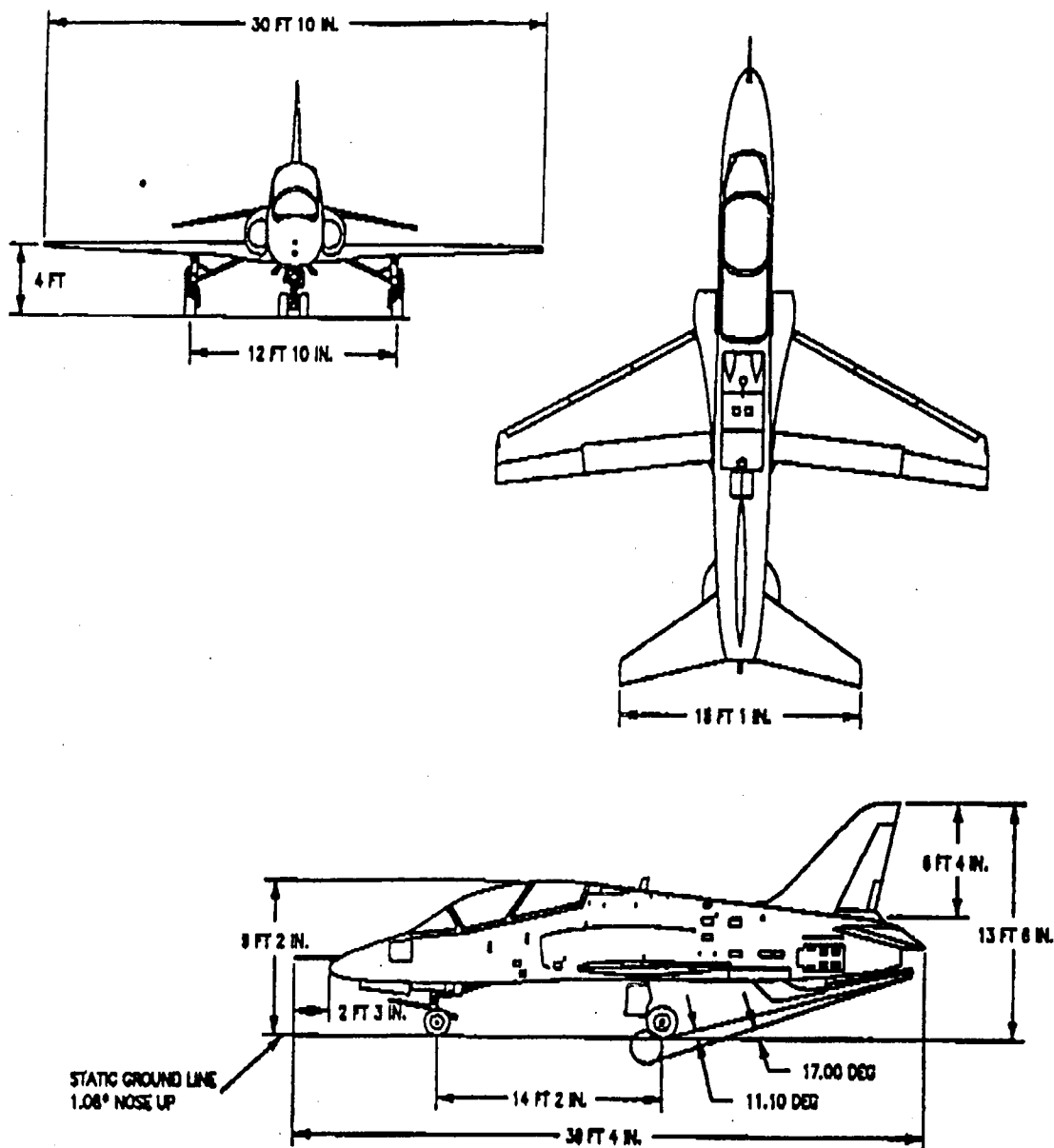
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APPENDICES

FIGURES



Figure 1
T-45 AIRPLANE



OTHER DIMENSIONS

	WING	STABILATOR	VERTICAL STABILIZER
AREA	190.1 SQ FT	47.8 SQ FT	28.1 SQ FT
ASPECT RATIO	8.0	4.8	1.4
SWEEP 1/4 CHORD	23.7°	30.1°	39.5°
DIEDRAL	2°	-10°	0
INCIDENCE			
ROOT	0.6°		
MAC	-0.1°		
TIP	-2.7°		

Figure 2
THREE VIEW DIAGRAM

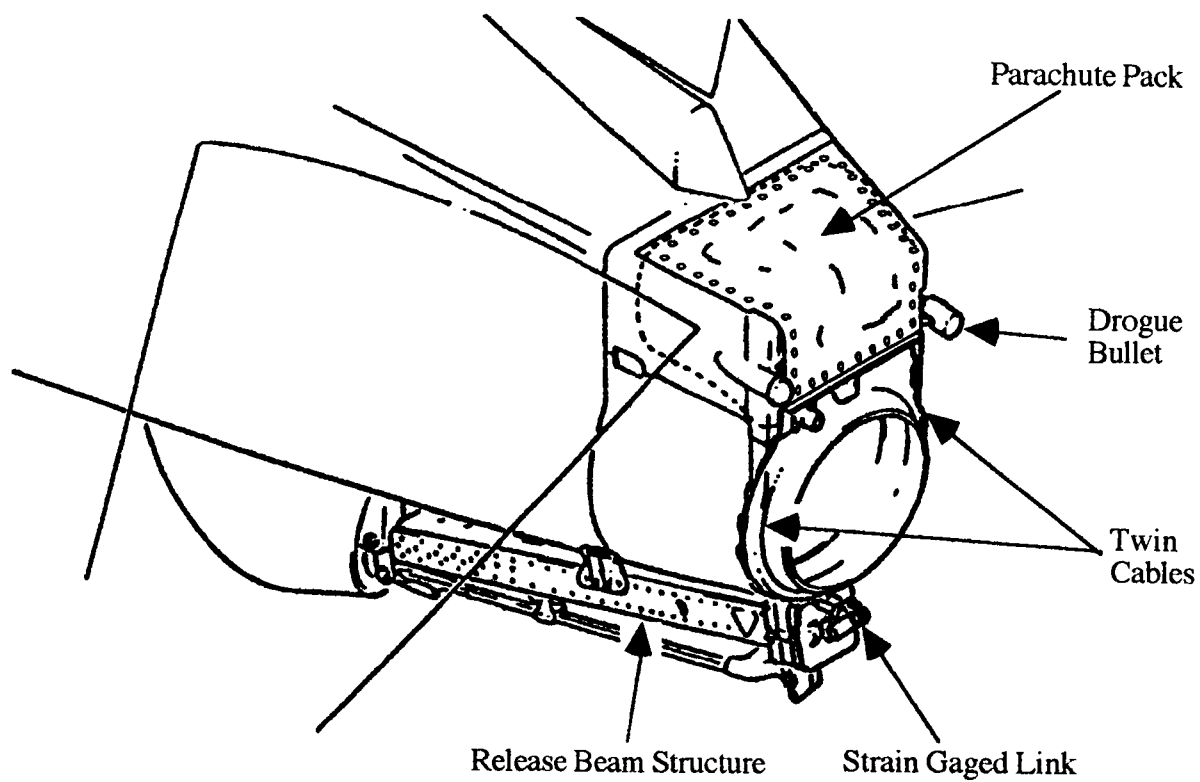


Figure 3
SPIN CHUTE INSTALLATION

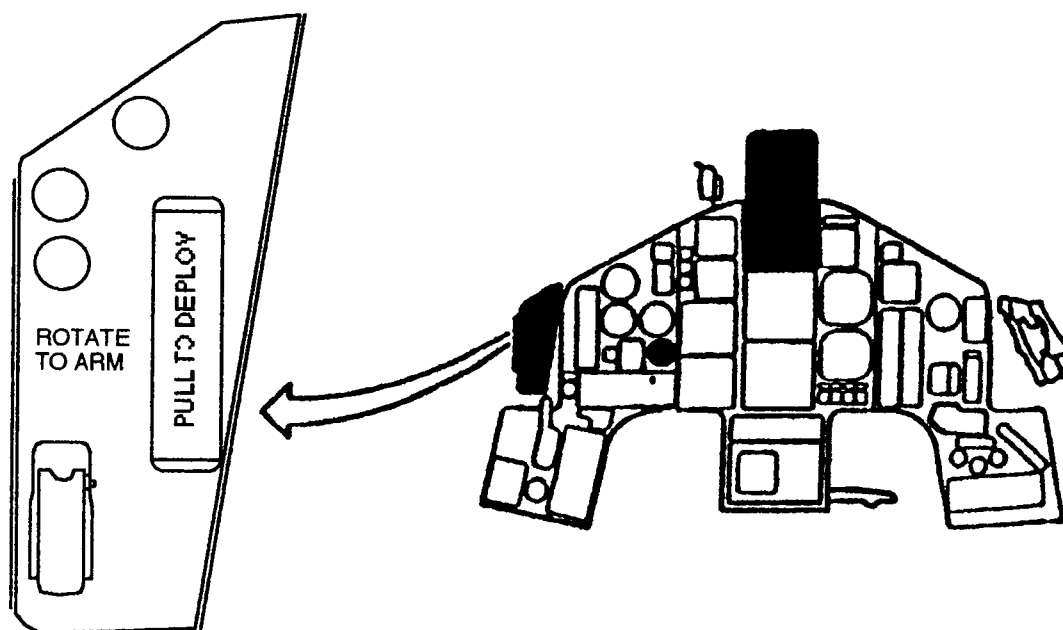


Figure 4
SPIN CHUTE CONTROL PANEL

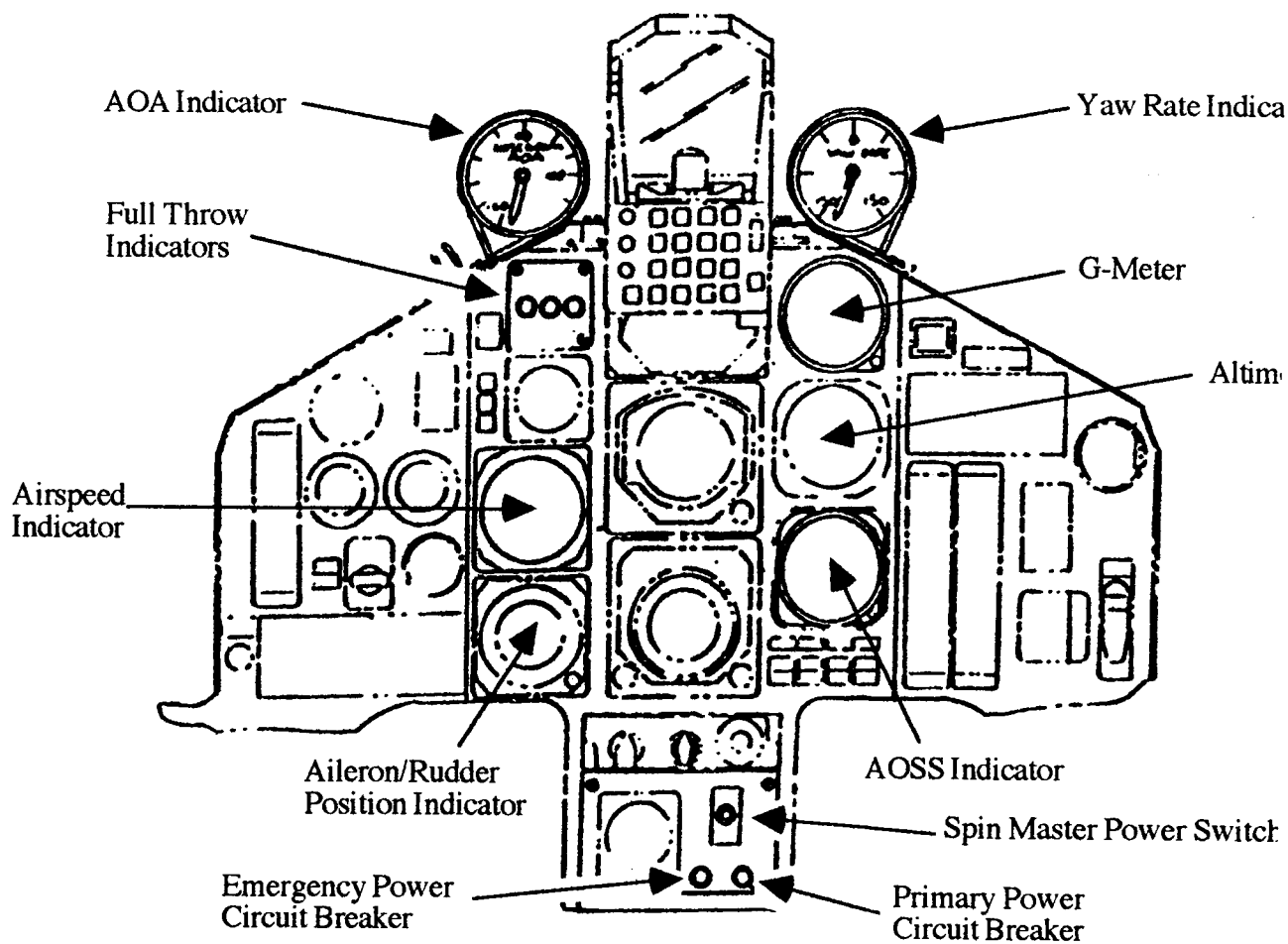


Figure 5
FORWARD COCKPIT MAIN INSTRUMENT PANEL CONFIGURATION

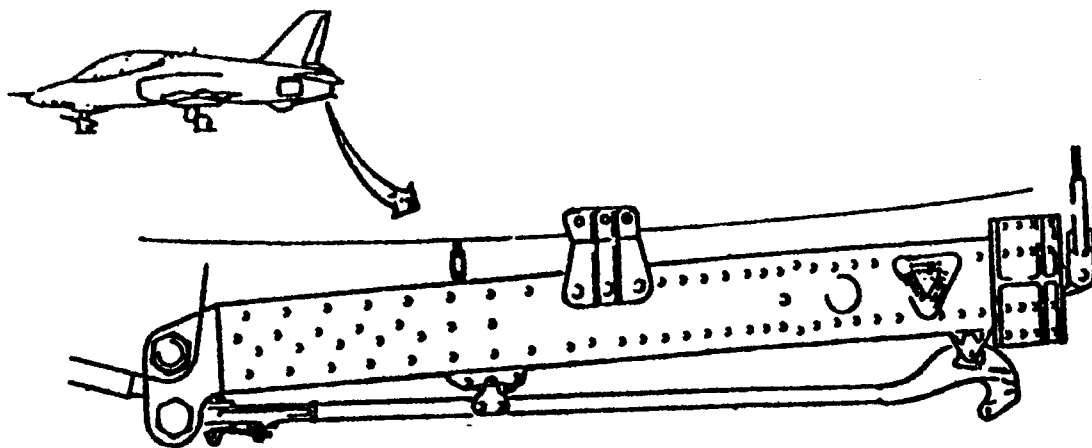


Figure 6
EMERGENCY ARRESTING HOOK INSTALLATION

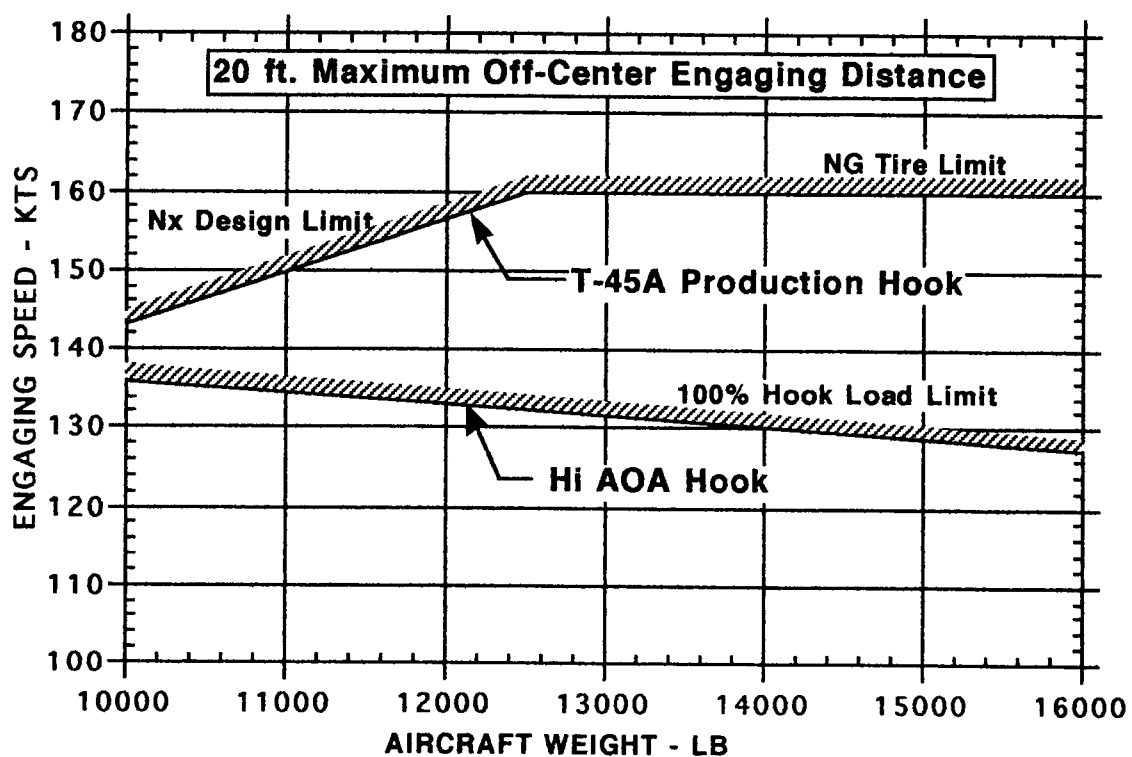


Figure 7
T-45 T003 MAXIMUM ENGAGING SPEED FOR E-28 ARRESTING GEAR

DETAILED METHOD DESCRIPTION

DETAILED METHOD DESCRIPTION

DEPARTURE RESISTANCE MANEUVERS

GENERAL

The cruise configuration departure resistance maneuvers were conducted at approximately 30,000 ft pressure altitude with the YDC in ALL and speed brakes retracted. All high lift configuration departure resistance maneuvers were conducted at approximately 25,000 ft pressure altitude with the Yaw Damper Controller (YDC) both engaged (ALL) and disengaged (SBI) and speed brakes both extended and retracted. Engine power setting for all departure resistance testing was either thrust for level flight or idle power.

SPECIFIC

Normal Stalls

From 1 g, trimmed, wings level flight at approximately $1.2 V_{stall}$, aft longitudinal stick was applied to establish approximately 1 kt/sec deceleration rate. At stall, the longitudinal stick was smoothly pulled to full back stick and held for approximately 5 seconds or departure.

Inverted Stalls

From negative 1 g, wings level flight, longitudinal stick was smoothly pushed to full forward and held for approximately 5 seconds or departure.

Wind-Up Turn

Normal constant Mach wind up turns (WUT's) were flown to full back stick. Full back stick was held for approximately 5 seconds or departure.

Abrupt Pull Up

Full back stick was abruptly applied from wings level, 1-g flight. Lateral stick and pedal were held neutral during the maneuver. Full back stick was held for 15 seconds, 360 degrees of roll, engine surge, or departure.

Abrupt Push Over

Full forward stick was abruptly applied from negative 4 degrees true AOA. Lateral stick and pedal were held neutral during the maneuver. Full forward stick was held for 15 seconds, 360 degrees of roll, engine surge, or departure.

180 degree Bank-to-Bank Rolls with Check

Rolls were performed at positive AOA's building up to full back stick utilizing half and full pedal, half and full coordinated inputs (pedal and lateral stick), or half and full lateral stick. Rolls were performed at negative AOA's building up to full forward stick. A steady turn at the target AOA was established. At the target AOA, an abrupt input was used to roll the airplane through 180 degrees. After approximately 180 degrees of roll, the roll rate was checked with an abrupt input opposite to the original input then back to neutral.

Longitudinal stick position was held constant during the roll. The input was held for 180 degrees of roll, 15 seconds, engine surge, or departure.

360 degree Bank-to-Bank Rolls without Check

Rolls were performed at positive AOA's building up to full back stick utilizing half and full pedal, half and full coordinated inputs (pedal and lateral stick), or half and full lateral stick. Rolls were performed at negative AOA's building up to full forward stick. A steady turn at the target AOA was established. At the target AOA, an abrupt input was used to roll the airplane through 360 degree. After approximately 360 degrees of roll, the controls were neutralized. Longitudinal stick position was held constant during the roll. The input was held for 360 degrees of roll, 15 seconds, engine surge, or departure.

Crossed Control Inputs

Abrupt crossed control inputs were performed at positive and negative AOA's from full back stick to full forward stick utilizing full lateral stick with full opposite pedal. A steady turn at the target AOA was established. At the target AOA, abrupt crossed controls were input. After approximately 90 degrees of roll, the controls were neutralized. Longitudinal stick position was held constant during the roll. The input was held for 90 degrees of roll, 15 seconds, engine surge, or departure.

HIGH LIFT DEPARTURE RESISTANCE

Abrupt full lateral stick rolls were conducted at various AOA's from wings level 1-g entry conditions in configurations PA and TO. The lateral stick input was held for 90 degrees of roll, impending departure, or $\text{Beta} \cdot q$ limit.

OUT-OF-CONTROL FLIGHT TRAINING MANEUVERS

The out-of-control (OCF) maneuvers were initiated at 25,000 ft pressure altitude between 0.40 and 0.6 TMN at IDLE or MIL power. A 180 degree roll with a check at full back stick was used in an attempt to cause a rolling departure. Both full lateral stick or full pedal rolls were evaluated. YDC, speed brakes, and Mach number effects were also evaluated.

UPRIGHT HAWK SPIN ENTRY ATTEMPTS

Configuration CR upright Hawk spin attempts were initiated at 32,000 ft pressure altitude between 0.40 and 0.50 TMN with power at IDLE. The spins were entered from either wings level or from a 30 degree angle of bank turn by simultaneously applying full abrupt pedal in the desired spin direction and full back stick. Lateral stick was held neutral for all spin attempts. The effect of longitudinal stick and pedal control input phasing, speed brake position, and YDC were also evaluated. The spin attempts were terminated at 180 KIAS, significant roll rate reversal, an unexpected unload in g, or if the airplane descended to 25,000 ft pressure altitude. Recovery controls for the upright spin attempts were neutral longitudinal and lateral stick and forcefully centering the rudder pedals.

VERTICAL MANEUVERS

Vertical maneuvers were initiated from 26,000 ft pressure altitude and 350 KIAS. A 4-g pull was initiated until a specified pitch angle and airspeed was achieved. With the engine at idle, the effect of control inputs was evaluated at different airspeeds. These control inputs included neutral controls (forcefully centering the pedals), full back stick, and full forward stick. Control inputs were made at 100 and 50 KIAS. Generally, the

controls were neutralized when the nose fell below the horizon. In order to evaluate control inputs that may reduce the likelihood of encountering a negative AOA post stall gyration or inverted spin, the effect of longitudinal stick as the nose fell below the horizon was also evaluated as a recovery control. The appropriate control inputs were used to recover the airplane to level flight. Maneuvers were flown with the speed brakes extended and retracted and with the YDC in ALL.

OPERATIONAL MANEUVERS AND AIR COMBAT MANEUVERING

GENERAL

The operational maneuvers flown during the high AOA evaluation are all maneuvers flown in fleet training command squadrons. The maneuvers presented below were taken from both the Familiarization Flight Training Instructions (FTI) and ACM FTI. Each maneuver was flown as described in the FTI and then flown using aggravated inputs. During the most aggravated maneuvering, commanded flight control and throttle inputs were well outside normal student representative inputs in order to evaluate the worst case piloting techniques.

SPECIFIC

Training Command Vertical Recovery Maneuver

Vertical recoveries were entered from 20,000 ft pressure altitude and 350 KIAS. A smooth 4-g pull was used to establish a 60 deg nose high attitude. At 180 KIAS, the recovery was initiated by advancing the power to MIL and capturing and maintaining 5 to 10 units AOA. Once the nose fell below the horizon and a safe flying speed was achieved,

the airplane was recovered to wings level at or below 20 units AOA. Improper recovery was evaluated by extending the speed brakes and initiating recovery at 100 KIAS and using full forward stick until the nose was below the horizon. Once the nose was below the horizon, full back stick was initiated to recover the airplane to wings level flight.

Loop - Slow Over-the-Top

Loops were initiated from 20,000 ft pressure altitude and between 300 and 350 KIAS. A normal 4-g entry was quickly relaxed to 2 to 3 g to ensure that airspeed was approximately 100 KIAS over-the-top. The nose was allowed to fall and the loop was completed. Throttle was fixed at MIL during the loop.

Loop - Slow Over-the-Top - Pull to Recover

A normal 4 g loop was performed quickly relaxing the pull to 2 to 3 g to ensure that airspeed was approximately 100 KIAS over-the-top. As the nose came over-the-top, up to full back stick was used in an attempt to pull the nose to the horizon. Throttle was fixed at MIL during the loop.

Barrel Roll with Inadvertent Trim Actuation

Normal barrel rolls were performed from 20,000 ft pressure altitude and 350 KIAS while running the stabilator trim to the full nose up position by the apex of the barrel roll. The maneuver was repeated by running the trim to the full nose down position. Throttle was fixed at MIL during the barrel roll.

Nose Low/Slow Speed Unusual Attitude Recovery

The recovery was initiated from 20,000 ft pressure altitude, between 100 and 150 KIAS, 135 deg angle of bank, 45 deg nose low, and speed brakes extended. Poor recovery technique was evaluated by selecting MIL power, leaving speed brakes extended and rolling to wings level upright by using aggressive lateral and longitudinal stick inputs.

Break Turn

Defensive hard break turns using up to full back stick were initiated at 20,000 ft pressure altitude, airspeeds between 400 and 250 KIAS, and MIL power. Both speed brake position and throttle setting (IDLE to MIL) were used in an attempt to increase the effectiveness of the break turn.

Jink-Out

Jink-Outs were initiated from 20,000 ft pressure altitude and MIL power. Entry airspeeds were 300 and 250 KIAS. From a defensive position, a positive-g turn was used in an attempt to create an overshoot. Assuming that no overshoot occurred, negative g was used in an attempt to push the airplane out of the bogey's tracking solution. Negative g was maintained for approximately 2 seconds immediately followed by a positive-g break turn for 2 to 4 seconds.

Displacement Roll

Displacement rolls were initiated from 20,000 ft pressure altitude at airspeeds between 350 and 250 KIAS, and MIL power. Rapidly closing on bogey with lateral separation, the nose was raised above the bogey and the airplane was rolled away from the inside of the

turn toward the bogey's 6 o'clock position. Aggressive pedal, lateral stick, and longitudinal stick were used to keep the fuselages aligned. Roll rate was varied to arrive in a firing envelope.

Barrel Roll Attack

Barrel roll attacks were initiated at 20,000 ft pressure altitude, 350 KIAS, and MIL power. From a 70 deg perch position, normal control inputs were used to begin the barrel roll attack. Reaching the apex of the barrel roll, aggressive stick and pedal inputs were used to maintain an offensive position.

High-G Roll Over-the-Top

The high-g roll over-the-top was initiated from 20,000 ft pressure altitude at airspeeds of 250 and 300 KIAS at MIL power. From a defensive position, an overshoot was created by increasing back stick, reducing power, and extending the speed brakes. Once the overshoot was established, top pedal and lateral stick were used to roll the airplane opposite the direction of turn while maintaining g. While inverted, roll rate was increased by combining aft stick, and pedal to avoid an extreme nose-low attitude. Through 270 degrees of roll, top pedal and lateral stick were used to control the nose while checking the bogey's position. While recovering nose-high into the bogey, the speed brakes were retracted and MIL power was selected.

High-G Roll Underneath

The high-g roll underneath was initiated from 20,000 ft pressure altitude at airspeeds of 250 and 300 KIAS at MIL power. From a defensive position, an overshoot was created

by increasing back stick, reducing power, and extending the speed brakes. Once the overshoot was established, bottom pedal and lateral stick were used to roll the airplane in the direction of turn while maintaining g. When the lift vector started above the horizon, MIL power was selected and the speed brakes were retracted. Pedal and lateral stick were used to stop the roll while maintaining aft stick to bring the nose above the horizon while checking the bogey's position.

Flat Scissors

The flat scissors was initiated 3,000 ft abeam the target airplane, co-altitude (20,000 ft pressure altitude) and co-airspeed (150 KIAS). Both airplanes attempted to achieve a position of advantage while maintaining high AOA flight and using roll reversal techniques. Up to full longitudinal and full lateral stick was used in an attempt to achieve a position of advantage.

Rolling Scissors

The rolling scissors was initiated at 20,000 ft pressure altitude, with 2,000 to 3,000 ft separation and 30 degrees off the tail of the target airplane and co-airspeed (300 KIAS). Once established, the test airplane commenced the rolling scissors. Both airplanes attempted to gain a position of advantage.

ACM-Offensive Position Setup

The ACM maneuvering was initiated at 20,000 ft MSL at 300 KIAS. The test airplane was established in a perch position at 3,000 - 9,000 ft, with a 2,000 ft altitude advantage

over the target airplane, on a 30 degree bearing line from the target airplane. Both airplanes attempted to maneuver in an attempt to obtain/retain a position of advantage.

ACM-Defensive Position Setup

The target airplane was established in a perch position 3,000 - 9,000 ft above the test airplane, with a 2,000 ft altitude advantage over the test airplane, on a 30 degree bearing line from the test airplane, and at 300 KIAS. Both airplanes attempted to maneuver in an attempt to obtain/retain a position of advantage.

ACM-Neutral Setup

The test and target airplane were set up at 1.5 to 2.0 nmi abeam, co-altitude (20,000 ft pressure altitude), and coairspeed (350 KIAS). From this setup, a turn was executed into a head-on pass. The target airplane maneuvered as necessary to establish a one or two circle engagement. Both airplanes attempted to gain the offensive position.

PILOT HANDBOOK ENTRIES

PILOT HANDBOOK INFORMATION

The following statements should be included in the appropriate sections of the pilot handbook:

Prohibited Maneuvers

1. Rolls at less than negative 1.0 g.
2. Intentional rolling cross control maneuvers beyond 90 deg bank angle change.
3. Intentional maneuvering within 15 degrees of the vertical at airspeeds less than or equal to 100 KIAS due to aerodynamic considerations. Note: Violation of this limit could result in inverted spin entry.

Pilot Procedures

1. The following procedures and depiction be added to the pilot handbook for guidance and direction:

For pitch attitudes within 20 deg of the vertical and less than 100 KIAS:

- a) Throttle to IDLE.
- b) Retract speed brakes, if extended.
- c) Neutralize controls; aggressively center rudder pedals.

For pitch attitudes less than 70 deg and less than 100 KIAS, upright or inverted:

- a) Throttle to MIL (or as desired).
- b) Push to 5 to 10 units AOA, or pull to 17 units to nearest horizon."

Engine Related Information

Include the following discussions in the appropriate section relating to engine handling characteristics:

1. High overfueling levels due to acceleration from low power settings is a factor that can increase engine stall sensitivity and decrease stall margin .

2. Surge characteristics will vary depending on power setting, engine acceleration, and maneuver severity. Self-recovering pop stalls are sometimes indicated by an audible "bang" or "pop" with correct engine operation being immediately restored with no pilot action. Locked-in stalls at low power settings are characterized by a slow TGT rise (approximately 12 deg C/sec) and a gradual decay in NH rpm, with no audible cue to the pilot. TGT rise during a low power stall will accelerate rapidly if the throttle is advanced. Locked-in stalls at high power settings are sometimes indicated by an audible "bang" or "pop" and are characterized by a very rapid temperature rise. A locked-in stall can sometimes be cleared by positioning the throttle to IDLE. If the stall remains locked-in, the engine must be shut down to clear it.

3. When maneuvering at angles of attack at or above heavy buffet, there is an increased risk of engine surge, especially when the engine is accelerating from a low power setting.

TABLES

Altitude: 30,000 ft MSL

Notes:

- (1) Uncorrected test boom angle of attack
- (2) Positive roll rate defined as right wing down
- (3) Positive yaw rate defined as air nose right
- (4) Uncorrected test boom sideslip; positive sideslip defined as air nose left
- (5) Normal stall to full back stick
- (6) Inverted stall to full forward stick
- (7) WUT: Wind-up turn to full back stick
- (8) APU: Abrupt pullup to full back stick
- (9) APO: Abrupt pushover to full forward stick
- (10) Asymmetric PMBR 2,500 ft-lb

TABLE II
PEDAL ROLL MANEUVERS
Configuration: CR Altitude: 30,000 ft MSL
YDC: ALL

Maneuver	Loading	Entry Conditions					Peak Maneuver Conditions					Peak Recovery Conditions							
		Mach (TMN)	AOA (deg) (1)	Nz (g)	Long Stk Defl (deg) (7)	Stab Defl (deg) (2)	Rudder Defl (deg) (3)	Rud Ped Force (lb)	AOA (deg)	Roll Rate (deg/sec) (4)	Yaw Rate (deg/sec) (5)	Sideslip (deg) (6)	Rudder Defl (deg)	Rud Ped Force (lb)	Roll Rate (deg/sec)	Yaw Rate (deg/sec)	Sideslip (deg)	Fit	Run
180 deg Roll With Check	Clean	0.40	-10	-0.6	FFS (7)	6	10	Full (8)	-18	115	-24	-10	-20	290	-30	12	-45	486	9
		0.40	-10	-0.8	FFS	6	6	190	-18	60	-20	7	-4	100	-	-	-4	486	8
		0.40	16	1.0	10	-5	13	240	21	-65	-24	-12	-19	340	-80	-	-7	456	15
		0.40	16	1.0	8	-5	12	200	20	-75	-22	10	-17	200	-	-	-9	456	10
		0.40	18	1.0	FBS	-14	14	200	23	-70	-28	-11	-20	290	-	-	-	456	20
		0.40	24	1.0	FBS	-14	14	330	28	-40	-26	8	-19	330	-	-	-9	459	7
		0.50	12	1.4	6	-2	10	230	19	-70	-21	11	-15	380	-90	-	-6	458	13
		0.50	16	1.6	10	7	-10	250	19	-20	-18	8	-14	400	-60	-	-7	458	18
	0.50	22	-	FBS	-15	12	Full	32	-105	-34	-20	-20	370	-	-	8	461	13	
	0.60	-4	-0.4	-10	3	10	Full	-6	10	-12	14	-	-	-	-	-	469	14	
	0.70	4	-	2	2	-	-	8	-50	-8	8	-	-	-	-	-	463	14	
	0.70	13	-	11	11	9	300	28	-100	-36	-8	-9	Full	100	-	-	463	17	
0.70	25	2.2	FBS	-14	10	Full	26	-80	-24	9	-13	Full	-	-	-18	464	9		
LAU	Clean	0.90	6	3.2	4	-1	4.5	360	6	0	2	4	-	-	-	-	-	466	13
		0.90	8	3.5	5	2	3	270	8	-20	-20	4	-	-	-	-	-	466	14
		0.90	10	4.0	7	-4	4	290	11	-40	-4	-2	-6	Full	-	-	-	468	8
		0.90	13	4.2	10	-5	3	270	14	-35	8	4	1	100	-	-	-	471	7
	0.90	18	5.1	FBS	-14	4	240	27	-140	-26	-8	7	250	-	-	-	471	8	
	0.40	10	1.0	14	-6	13	Full(1)	22	-55	-24	11	-18	Full	-	-	-12	478	10	
	0.40	20	1.0	FBS	-14	15	Full	28	± 10	-8	11	-	-	-	-	-	478	14	
	0.80	8	3.2	8	-1	5	280	10	-80	± 12	5	-6	400	-	-	-6	476	10	
	0.80	24	3.2	FBS	-14	10	300	26	-130	-34	-16	-15	350	-55	-36	6	477	9	
	0.60	10	1.8	9	-1.5	10	Full	14	-70	-12	10	-12	Full	-	-	-14	479	9	
	0.60	6	-0.2	-3	2	9	Full	-5	± 10	-12	12	-	-	-	-	-	479	16	
	0.60	15	2.3	FBS	-14	14	Full	28	50	14	12	-15	Full	-	-	-	479	12	
Asym(9)	0.60	16	1.9	16	-8	9	Full	24	-50	-18	7	-15	Full	-	-	-14	480	10	

TABLE II
PEDAL ROLL MANEUVERS
Configuration: CR Altitude: 30,000 ft MSL
YDC: ALL

Maneuver	Loading	Entry Conditions						Peak Maneuver Conditions						Peak Recovery Conditions					
		Mach (TMN)	AOA (deg) (1)	Nz (g)	Long Stk Defl (deg)	Stab Defl (deg) (2)	Rudder Defl (deg) (3)	Rud Ped Force (lb)	AOA (deg)	Roll Rate (deg/sec) (4)	Yaw Rate (deg/sec) (5)	Sideslip (deg) (6)	Rudder Defl (deg)	Rud Ped Force (lb)	Roll Rate (deg/sec)	Yaw Rate (deg/sec)	Sideslip (deg)	Fit	Run
360 deg Roll Without Check	Clean	0.40	-6	-0.4	-10	4	15	Full	-10	10	12	20	Neutral	Neutral	-	-	-	469	11
		0.40	14	1.1	6	-3	10	230	20	-70	-22	11	Neutral	Neutral	-	-	-	459	13
		0.40	18	1.0	10	-5	12	190	24	-50	-20	12	Neutral	Neutral	-80	-26	-6	459	16
		0.40	28	-	FBS	-14	13	Full	34	-60	-36	-12	Neutral	Neutral	-90	-	13	463	8
		0.50	-2	-0.2	-3	2	12	Full	-4	±10	±12	16	Neutral	Neutral	-	-	-	475	10
		0.50	12	-	6	-3	10	Full	20	-85	-28	9	Neutral	Neutral	-115	-	8	461	19
		0.50	17	1.3	10	-6	10	Full	34	-105	-42	-10	Neutral	Neutral	-125	-	-20	465	8
		0.50	26	1.5	FBS	-14	12	Full	36	-100	-36	-12	Neutral	Neutral	-130	-	3	465	11
		0.70	8	2.5	6	-3	10	Full	14	-130	-24	6	Neutral	Neutral	-	-	-	467	8
		0.70	26	2.8	FBS	-14	13	Full	34	-140	-48	-14	Neutral	Neutral	-	-	-10	467	11
		0.90	17	5.4	FBS	-14	4	270	27	-126	-32	-6	Neutral	Neutral	-	-	7	474	12
		0.60	-2	0.0	-1	2	8	Full	-3	-10	-8	10	Neutral	Neutral	-	-	-	482	16
		Asym	0.60	4	1.0	6	0	9	Full	4	-40	-12	11	Neutral	Neutral	-	-	-	481
	0.60		18	2.0	15	-7	8	Full	22	-70	-26	8	Neutral	Neutral	-	-	-	481	16
	0.60		21	2.0	FBS	-13	10	Full	27	-50	±8	10	Neutral	Neutral	-	-	-	480	15
			0.60	24	2.5	FBS	-14	10	Full	30	-65	-24	12	Neutral	Neutral	-	-	-	482

- Notes:
- (1) Uncorrected test boom angle of attack
 - (2) Stabilator deflection range is -14 deg (full back stick or FBS) to 7 deg (full forward stick)
 - (3) Rudder deflection range is ±20 deg; positive deflection defined as trailing edge left
 - (4) Positive roll rate defined as right wing down
 - (5) Positive yaw rate defined as air nose right
 - (6) Uncorrected test boom sideslip; positive sideslip defined as air nose left
 - (7) FFS: Full forward longitudinal stick
 - (8) Full rudder pedal deflection achieved.
 - (9) Asymmetric PMBR 2,500 ft-lb.

TABLE III
LATERAL STICK ROLLING MANEUVERS
Configuration: CR
Altitude: 30,000 ft MSL
YDC: ALL

Maneuver	Loading	Entry Conditions					Peak Maneuver Conditions						Peak Maneuver Conditions				Comments	Flight Run
		Mach (TMN)	AOA (deg) (1)	Nz (g)	Long Stk Defl (deg)	Stab Defl (deg)	Lat Stk Defl (%) (3)	AOA (deg)	Roll Rate (deg/sec) (4)	Yaw Rate (deg/sec) (5)	Sideslip (deg) (6)	Lat Stk Defl (%)	AOA (deg)	Roll Rate (deg/sec)	Yaw Rate (deg/sec)	Sideslip (deg)		
180 deg Roll with Check	Clean		-10	-0.7	FBS	6	Half	-16	-90	-5	16	Half	-16	30	20	22	Sideslip departure.	486 10
			-4	0.0	-10	3	Full	4	-125	2	13	Full	-10	-	12	-8	469 13	
			15	1.0	6	-3.5	Full	16	-55	-25	-11	Full	-	-	-	12	456 14	
			16	1.0	7	-4	33%	16	-50	-18	-6	33%	-	-	-	-	456 13	
		0.40	16	1.0	7	-4	Half	18	-45	-20	-8	Half	-	-	-	-	456 18	
			16	1.0	10	-6	Half	18	-60	-28	-11	Full	-	-	-	14	456 19	
			22	1.0	FBS	-14	Full	32	-90	-12	-20	Full	-	-	-	28	459 12	
			24	1.0	FBS	-14	Half	32	-45	-20	22	Half	-	-	-	-	459 10	
			28	1.0	FBS	-14	Half	32	-30	-16	-22	Full	-	60	-24	24	459 11	
			-3	-0.2	-3.5	2.5	Full	-4	-120	4	6	Full	-	-	-	-4	475 11	
	0.50		13	1.4	6	-2	Half	18	-60	-18	-8	Half	-	-	-	6	458 16	
			13	1.4	6	-2	Full	18	-80	-18	-12	Full	-	-	-	8	458 17	
			15	-	10	-5	Half	16	-100	-30	-12	Half	-	-	-	8	461 11	
			16	-	11	-6	Full	20	-130	-34	-16	Full	-	-80	-	9	461 12	
			22	-	FBS	-14	Half	26	-100	-22	-18	Half	-	-130	-28	5	Post maneuver roll.	
0.60		24	-	FBS	-14	Full	32	-110	-26	-25	Full	-	-	-	8	Unloaded during recovery to -1.5 g.	461 17	
		-5	-0.6	-11	4	Full	-10	-140	6	12	Full	-	-	18	-10	469 16		
	0.70		8	-	5	5	Full	18	-130	-26	-10	Full	-	100	-	12	463 16	
			14	-	11	11	Full	19	-140	-44	-15	Full	-	-	-	16	463 19	
			17	-	12	12	Full	22	-190	-44	-20	Full	-	-	-	-	463 20	
		24	2.6	FBS	-14	Full	36	-100	-32	-22	Full	-	-	-	16	Locked Surge. Peak TGT 580" C.	464 12	
	0.90		10	4.2	7	-4	Full	10	-180	-30	-14	Full	-	140	-	8	468 10	
			13	4.4	10	-7	Half	15	-180	-40	-14	Half	-	130	-	12	468 15	
			20	5.0	FBS	-14	Half	27	-110	-30	-9	Half	-	-190	-30	12	471 11	
		20	5.3	FBS	-14	Full	30	-180	-38	16	Full	-	150	-	-20	471 12		
0.40		2	-0.2	-4	2.5	Full	0	-110	±4	8	Full	-	-	-	-6	478 18		
		18	1.1	17	-13	Full	28	-70	-32	-16	Full	-	-	-	17	478 13		
		19	1.0	16	-9	Full	25	-50	-22	-11	Full	-	-	-	13	478 12		
		28	1.0	FBS	-14	Full	28	-60	-32	-22	Full	-	-	-	21	478 16		
	0.80		12	3.4	14	-5	Half	19	-170	-32	-12	Half	-	-	-	8	476 12	
			13	3.2	15	-6	Full	21	-185	-40	-17	Full	21	70	25	12	476 13	
			17	3.4	16	-7	Half	21	-140	-45	-14	Half	-	-	-	13	477 7	
			17	3.6	FBS	-14	Full	26	-95	-48	-18	Full	-	±80	28	21	477 8	
			22	3.9	FBS	-14	Full	27	-115	-42	-25	Full	-	-170	-	15	477 11	

TABLE III
LATERAL STICK ROLLING MANEUVERS
Configuration: CR Altitude: 30,000 ft MSL
YDC: ALL

Maneuver	Loading	Entry Conditions						Peak Maneuver Conditions						Comments	Flight Run		
		Mach (TMN)	AOA (deg) (1)	Nz (g)	Long Stk Defl (deg)	Stab Defl (deg)	Lat Stick Defl (%) (3)	AOA (deg)	Roll Rate (deg/sec) (4)	Yaw Rate (deg/sec) (5)	Sideslip (deg) (6)	Lat Stick Defl (%)	AOA (deg)			Roll Rate (deg/sec)	Yaw Rate (deg/sec)
180 deg Roll with Check	PMBR	0.60	-4	-0.4	-4	2	Full	-1	-130	4	6	Full	-	-	-	-6	479 17
			16	1.8	15	-5	Full	20	-90	-34	-13	Full	-	-	-	17	479 11
	Asym (7)		23	2.2	FBS	-14	Full	36	-90	-28	-19	Full	-8	-	-	12	Used long stick to minimize unload. 479 14
		0.60	17	2.0	15	-7	Full	21	-130	-44	-17	Full	-	-	-	17	482 9
360 deg Roll without Check	Clean		18	1.9	15	-6	Full	24	-110	-40	-20	Full	-	-	-	18	480 12
			25	2.0	FBS	-14	Half	34	-100	-28	-23	Half	-	-	-	8	481 8
			28	2.2	FBS	-14	Full	40	-80	-14	-32	Full	-8	80	-28	18	481 9
			-5	-0.2	-10	3	Full	1	-110	4	12	Full	-10	-	16	-8	469 19
			16	1.0	7	-4	Full	18	-60	-18	-9	Neutral	-	-90	-	8	459 15
	Asym (7)		20	-	5	-14	Full	36	-110	-24	-22	Neutral	-	-	-34	-29	463 11
			12	-	6	-3	Full	18	-125	-24	-18	Neutral	-	-	-	8	461 21
			18	1.5	9	-4	Full	18	-100	-23	-12	Neutral	-	-	-	8	465 10
			25	1.5	FBS	-14	Full	37	-110	-20	-28	Neutral	-12	-50	-	16	465 13
			-4	-0.4	-9	3	Full	-6	-130	6	8	Neutral	-	-	18	-6	472 10
Asym (7)		10	2.4	8	-4	Full	16	-180	-44	-14	Neutral	-5	-	-	-12	467 10	
		20	2.9	11	-10	Full	31	-130	-32	-22	Neutral	-	-170	-	9	465 16	
		24	3.0	FBS	-14	Full	34	-160	-32	-26	-	-9	-	-	20	467 13	
		12	4.0	FBS	-14	Half	32	-240	-40	-26	Neutral	-	-	-	10	467 17	
360 deg roll	Asym (7)	0.80	16	3.5	14	-10	Half	18	-175	-39	-12	Neutral	-	-	-	-6	466 10
			18	3.8	FBS	-14	Full	34	-200	-39	-25	Neutral	-	-	-	16	467 18
			24	4.0	FBS	-14	Full	40	-170	-28	-30	Neutral	-9	100	-	12	466 11
			10	4.7	10	-2	Half	11	-150	-25	-4	Neutral	-	-	-	4	474 10
360 deg roll	Asym (7)	0.90	10	4.4	13	-4	Full	13	-216	-44	-15	Neutral	-	-	-	11	474 11
			20	5.4	FBS	-14	Full	32	-150	-39	-18	Neutral	-6	100	22	10	475 8
		0.60	0	0.2	0	1	Full	1	-135	±4	4	Neutral	-	-	-	-	482 17
			4	1.0	7	-1	Full	5	-130	-8	-10	Neutral	-	-	-	-20	481 14

- Notes:
- (1) Uncorrected test boom angle of attack
 - (2) Stabilator deflection range is -14 deg (full back stick or FBS) to 7 deg (full forward stick)
 - (3) Aileron deflection range is ±12.5 deg with gear retracted; positive deflection defined as right wing down
 - (4) Positive roll rate defined as right wing down
 - (5) Positive yaw rate defined as air nose right
 - (6) Uncorrected test boom sideslip; positive sideslip defined as air nose left
 - (7) Asymmetric PMBR, 2,500 ft-lb

TABLE IV
COORDINATED LATERAL STICK AND PEDAL INPUT ROLLING MANEUVERS
Altitude: 30,000 ft MSL
Configuration: CR
YDC: ALL

Maneuver	Loading	Entry Conditions										Peak Maneuver Conditions										Peak Recovery Conditions										Comments	Fit	Run																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						
		Mach (TMN)	AOA (deg)	Nz (g)	Long Stk Defl (deg)	Stab Defl (deg)	Lat Stk Defl (%)	Rudder Defl (deg)	Rud Ped Force (lb)	AOA (deg)	Roll Rate (deg/sec)	Yaw Rate (deg/sec)	Sideslip (deg)	Lat Stk Defl (%)	Rudder Defl (deg)	Rud Ped Force (lb)	AOA (deg)	Roll Rate (deg/sec)	Yaw Rate (deg/sec)	Sideslip (deg)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				
180 deg Roll with Check	Clean		-5	-0.2	-9	3	Full	14	Full (8)	-11	-115	-16	16	Full	-7	Full	-	-	-	-16																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				

TABLE IV
COORDINATED LATERAL STICK AND PEDAL INPUT ROLLING MANEUVERS
Altitude: 30,000 ft MSL
Configuration: CR
YDC: ALL

Maneuver	Loading (TMN)	Entry Conditions						Peak Maneuver Conditions						Peak Recovery Conditions						Comments	Fit	Run	
		Mach	AOA (deg. (1))	Nz (g)	Long Ssk Defl (deg)	Stab Defl (deg)	Lat Ssk Defl (%)	Rudder Defl (deg)	Rud Ped Force (lb)	AOA (deg)	Roll Rate (deg/sec)	Yaw Rate (deg/sec)	Sideslip (deg)	Lat Ssk Defl (%)	Rudder Defl (deg)	Rud Ped Force (lb)	AOA (deg)	Roll Rate (deg/sec)	Yaw Rate (deg/sec)				Sideslip (deg)
360 deg Roll without Check	Clean	0.40	-6	-0.4	-10	3	Full	1	Full	20	-230	-40	16	Neutral	Neutral	Neutral	-	-	-	-12	469	18	
			13	1.0	6	-3	Full	6	170	20	-85	-22	-8	Neutral	Neutral	Neutral	-	-80	-30	10	459	14	
			18	1.1	10	-5	Full	10	220	30	-90	-36	-14	Neutral	Neutral	Neutral	-	-90	-	10	459	17	
			26	-	FBS	-14	Full	12	Full	30	-110	-34	-20	Neutral	Neutral	Neutral	-	-	-	12	463	9	
		0.50	12	-	7	-3	Full	13	Full	20	-145	-38	-17	Neutral	Neutral	Neutral	-	-140	-36	5	461	20	
			18	1.5	11	-7	Full	10	Full	32	-140	-44	-21	Neutral	Neutral	Neutral	-	-100	-	16	465	9	
			26	1.6	FBS	-14	Full	12	Full	34	-165	-38	-24	Neutral	Neutral	Neutral	-	-100	-	16	465	12	
		0.60	-4	-0.5	-10	4	Full	16	240	-82	-140	-100	50	Neutral	0	290	-	-	-	-	Nose down dep. Rud locked out in both directions. Locked surge/windmill airstart.	472	9
		0.70	10	2.5	7	-4	Full	4	310	16	-180	-48	-15	Neutral	Neutral	Neutral	-5	-	-	10	467	9	
			23	3.0	FBS	-13.5	Full	6	-290	32	-160	-38	-27	Neutral	-	-	-9	25	-	14	465	15	
360 deg Roll without Check	Clean		26	2.9	FBS	-14	Full	18	350	38	-200	-40	-27	Neutral	Neutral	Neutral	-17	30	-	22	467	12	
		0.80	14	3.6	FBS	-14	Half	3	220	30	-125	-40	-13	Neutral	Neutral	Neutral	-	-	-	-	467	15	
			14	4.0	FBS	-14	Full	10	340	36	-215	-52	-26	Neutral	Neutral	Neutral	-	-	-	2	467	16	
			20	3.9	FBS	-14	Full	8	-310	28	-220	-40	-20	Neutral	Neutral	Neutral	-	-	-	6	466	9	
			24	3.4	FBS	-14	Half	4	-200	30	-200	-40	-18	Neutral	Neutral	Neutral	-	-	-	10	466	8	
			6	4.5	10	-3	Half	0.5	190	6	-180	-33	-4	Neutral	Neutral	Neutral	-	-	-	6	474	8	
		0.90	11	4.4	7	-4	Half	3	-180	12	-40	-40	-10	Neutral	Neutral	Neutral	-	-	-	6	473	8	
			11	4.8	10	-3	Full	1	300	12	-252	-36	-9	Neutral	Neutral	Neutral	-	-	-	5	474	9	
			16	5.4	FBS	-14	Half	3	250	24	-135	-46	-10	Neutral	Neutral	Neutral	-	-	-	10	474	13	
			18	5.3	FBS	-14	Full	4	310	26	-144	-44	-18	Neutral	Neutral	Neutral	-	-	-	11	475	7	
Asym	Asym	0.60	4	1.0	7	-1	Full	4	Full	12	-170	-22	-10	Neutral	Neutral	Neutral	-	-	-	-6	481	13	
			14	2.0	14	-6	Full	5	280	22	-160	-39	-18	Neutral	Neutral	Neutral	-	-	-	15	482	8	
			24	2.4	FBS	-14	Full	11	240	33	-135	-40	-24	Neutral	Neutral	Neutral	-	-	-	20	482	11	

Note:

- (1) Uncorrected test boom angle of attack
- (2) Stabilator deflection range is -14 deg (full back stick or FBS) to 7 deg (full forward stick)
- (3) Aileron deflection range is ± 12.5 deg with gear retracted; positive deflection defined as right wing down
- (4) Rudder deflection range is ± 20 deg; positive deflection defined as trailing edge left
- (5) Positive roll rate defined as right wing down
- (6) Positive yaw rate defined as air nose right
- (7) Uncorrected test boom sideslip; positive sideslip defined as air nose left
- (8) Full: Full rudder pedal deflection achieved
- (9) Asymmetric PMBR, 2,500 ft-lb

TABLE V
90 DEG BANK ANGLE CHANGE CROSS CONTROL MANEUVERS
Configuration: CR
YDC: ALL
Altitude: 30,000 ft MSL

Loading	Entry Conditions (1)										Peak Maneuver Conditions						Peak Recovery Conditions (2)						Fit	Run
	Mach (TMN)	AOA (deg)	Nz (g)	Long Stick Deflection (deg)	Stabilator Deflection (deg)	Rudder Deflection (deg)	Rud Ped Force (lb)	AOA (deg)	Roll	Yaw	Sideslip (deg)	Rudder Deflection (deg)	Rud Ped Force (lb)	Roll	Yaw	Sideslip (deg)								
									Rate (deg/sec)	Rate (deg/sec)				Rate (deg/sec)	Rate (deg/sec)		Rate (deg/sec)							
Clean	0.40	-4	0.0	2	-5	-15	230	-11	-75	20	-10	Neutral	Neutral	-	-	-	8	472	14					
	0.40	4	0.2	0	1	-20	290	-11	-65	-18	-15	-10	0	-	-	8	472	11						
	0.40	12	1.0	6	-3	-20	290	3	-40	12	-22	0	280	-	-24	10	472	12						
	0.40	24	14.0	FBS	-14	-20	290	30	70	24	-16	Neutral	Neutral	80	-	-	-	472	13					
	0.50	-6	-0.4	-4	4	-14	310	-13	-100	22	-2	Neutral	Neutral	-	-	-10	475	15						
	0.50	0	0.0	-1	1	-5	100	-3	-90	4	-6	Neutral	Neutral	-	-	3	475	12						
	0.50	0	0.0	4	1	-14	Full(9)	-8	-90	12	-12	Neutral	Neutral	-	-	6	475	16						
	0.50	10	1.2	10	-4	-20	Full	-5	-70	14	-24	0	220	-	-	8	475	13						
	0.50	22	1.6	FBS	-15	-20	330	32	140	32	-18	Neutral	Neutral	-	-	8	475	14						
	0.70	1	0.6	-2	1	-7	280	-2	-95	8	-5	Neutral	Neutral	-	-10	4	472	15						
Asym (10)	0.70	14	3.0	FBS	-14	-19	300	28	90	24	-13	Neutral	Neutral	-	-	4	472	18						
	0.70	15	2.0	10	-5	-16	310	18	-60	-24	-16	Neutral	Neutral	-	-	10	472	16						
	0.70	24	3.2	FBS	-14	-20	280	31	140	36	-14	Neutral	Neutral	-	-	-	472	19						
	0.60	5	1.0	5	-1	-12	370	0	-90	8	12	Neutral	Neutral	-	-	6	482	14						
	0.60	16	2.4	FBS	-14	-20	260	34	-100	-18	-26	0	280	-	-	-	482	12						
	0.60	16	2.2	15	-7	-18	280	20	-85	-34	-19	Neutral	Neutral	-	-	14	482	13						

Notes: (1) All maneuvers full left stick/right pedal
(2) Neutral lateral stick for recovery
(3) Uncorrected test boom angle of attack
(4) Stabilator deflection range is -14 deg (full back stick or FBS) to 7 deg (full forward stick)
(5) Rudder deflection range is ±20 deg; positive deflection defined as trailing edge left
(6) Positive roll rate defined as right wing down
(7) Positive yaw rate defined as air nose right
(8) Uncorrected test boom sideslip; positive sideslip defined as air nose left
(9) Full rudder pedal deflection
(10) Asymmetric PMBRs, 2,500 ft-lb

TABLE 6
 CONFIGURATION PA AND TO LATERAL STICK ROLLING MANEUVERS
 Technique: Full Left Lateral Stick Roll, Neutral Lateral Stick on Recovery
 Loading: Clean Altitude: 25,000 ft MSL

Config	YDC	Entry Conditions					Peak Maneuver Conditions				Recovery	Flt	Run
		Airspeed (KIAS)	AOA (deg) (1)	Nz (g)	Long Stick Deflection (deg)	Stabilator Deflection (deg) (2)	AOA (deg)	Roll Rate (deg/sec) (3)	Yaw Rate (deg/sec) (4)	Sideslip (deg) (5)	Sideslip (deg)		
PA	SBI	100	16	1.0	15	-6	12	-40	-16	-12	-12	487	17
	SBI	100	18	1.0	15	-7	18	-40	-12	-10	-10	487	16
	ALL	100	21	1.0	15	-9	29	-35	-18	-11	-	503	10
	SBI	120	6	1.0	11	-3	8	-65	-8	-7	-	486	18
	SBI	120	7	0.9	10	-3	8	-60	-6	-2	-	486	17
TO	ALL	100	21	1.0	15	-7	27	-35	-18	-13	-	503	9A
	SBI	115	14	1.0	12	-4	10	-40	-10	-9	-9	487	14
	SBI	115	16	1.0	13	-5	12	-45	-19	-12	-16	487	15
	ALL	115	16	1.0	13	-5	20	-45	-17	-15	-	503	9
	SBI	130	10	1.0	11	-3	12	-60	-6	-5.5	-	486	15
	SBI	130	10	1.0	12	-3	12	-65	-10	-9	-	486	16

- Notes: (1) Uncorrected test boom angle of attack
 (2) Stabilator deflection range is -14 deg (full back stick or FBS) to 7 deg (full forward stick)
 (3) Positive roll rate defined as right wing down
 (4) Positive yaw rate defined as air nose right
 (5) Uncorrected test boom sideslip; positive sideslip defined as air nose left

TABLE VII
OUT-OF-CONTROL FLIGHT TRAINING MANEUVERS
Configuration: CR Altitude: 25,000 ft MSL
Power: IDLE, unless otherwise noted Speedbrakes: Retracted, unless otherwise noted
Loading: Clean

Maneuver	Entry Conditions				Peak Maneuver Conditions					Peak Recovery Conditions						Comments	Flight Run		
	Mach (TMN)	AOA (deg)	Nz (g)	Rudder Defl (deg)	Rud Ped Force (lb)	AOA (deg)	Roll Rate (deg/sec)	Yaw Rate (deg/sec)	Sideslip (deg)	Lat Stick Defl (%)	Rudder Defl (deg)	Rud Ped Force (lb)	AOA (deg)	Roll Rate (deg/sec)	Yaw Rate (deg/sec)			Sideslip (deg)	
180 deg Full Lateral Stick Roll	0.35	22	1.0	-	-	22	-40	12	-11	Neutral	-	-	-	-	-	-	8	90% Power	501 15
		23	1.0	-	-	29	50	24	16	Neutral	-	-	-	-	-	-	-1	501 9	
		24	1.0	-	-	24	50	34	18	Neutral	-	-	-	-	-	-	-18	501 7	
		24	1.0	-	-	24	60	38	18	Neutral	-	-	-	-	-	-	-16	501 8	
		24	1.0	-	-	24	-30	-14	-12	Neutral	-	-	-	-	-	-	10	501 10	
	0.4	24	1.0	-	-	21	-20	18	-10	Neutral	-	-	-	-	-	-	11	501 11	
		24	1.0	-	-	27	80	20	-8	Full	-	-	-	-	-	-	-8	501 12	
		24	1.0	-	-	26	-10	21	-13	Neutral	-	-	-	-	-	-	6	501 14	
		29	1.0	-	-	16	30	-20	12	Neutral	-	-	-	-	-	-	-10	501 16	
		30	1.0	-	-	20	30	12	-8	Neutral	-	-	-	-	-	-	6	501 13	
	0.5	20	1.5	-	-	25	-55	-32	-12	Full	-	-	-	33	-120	-	16	492 11	
		24	1.6	-	-	34	-80	-24	-15	Full	-	-	-	-	-	-	-	492 19	
		28	1.4	-	-	33	-55	-28	-15	Full	-	-	-	0	-110	-	16	492 12	
		20	1.9	-	-	31	-100	-20	-20	Full	-	-	-	-2	-	-	25	492 9	
		20	2.0	-	-	34	-90	-24	-21	Full	-	-	-	-7	-	-	12	495 7	
S/B Extended	0.5	20	1.7	-	-	28	-65	-28	-13	Full	-	-	32	-140	-	10	S/B Extended	495 9	
		22	2.0	-	-	27	-100	-32	-20	Full	-	-	-	-	-	15	495 14		
		24	1.8	-	-	30	-80	-39	-16	Full	-	-	31	-120	-30	15	492 8		
		24	2.0	-	-	31	-130	-44	-24	Full	-	-	31	-180	-40	28	492 10		
		24	2.0	-	-	32	-100	-40	-21	Full	-	-	-	-110	-	16	492 16		
	S/B Extended	24	2.0	-	-	32	-85	-22	-16	Full	-	-	-	80	-	12	492 18		
		24	2.2	-	-	26	-100	-39	13	Full	-	-	-	-	-	-15	492 20		
		24	1.8	-	-	32	-100	-40	-22	Full	-	-	32	-180	-30	22	495 8		
		26	2.0	-	-	30	-75	-28	-20	Full	-	-	-	-3	-	14	495 15		
		28	2.0	-	-	30	-60	-24	-14	Full	-	-	-	-	-100	-	14	492 17	

TABLE VII
OUT-OF-CONTROL FLIGHT TRAINING MANEUVERS
Configuration: CR Altitude: 25,000 ft MSL
Power: IDLE, unless otherwise noted Speedbrakes: Retracted, unless otherwise noted
Loading: Clean

Maneuver	Entry Conditions				Peak Maneuver Conditions					Peak Recovery Conditions						Comments	Flight Run
	Mach (TMN)	AOA (deg)	Nz (g)	Rudder Defl (deg)	Rud Ped Force (lb)	AOA (deg)	Roll Rate (deg/sec)	Yaw Rate (deg/sec)	Sideslip (deg)	Lat Stick Defl (%)	Rudder Defl (deg)	Rud Ped Force (lb)	AOA (deg)	Roll Rate (deg/sec)	Yaw Rate (deg/sec)	Sideslip (deg)	
180 deg Full Lateral Stick Roll (cont'd)	0.6	20	2.6	-	-	30	-100	-38	-16	Full	-	-	30	-210	-	22	495 11
		20	2.7	-	-	24	-110	-38	16	Full	-	-	-6	-	-	-	495 12
		20	2.6	-	-	32	-90	-40	-21	Full	-	-	-4	-	-	17	495 13
		22	2.9	-	-	24	-100	-40	-16	Full	-	-	32	60	-	22	495 10
		22	3.0	-	-	28	-100	-38	-18	Full	-	-	-2	-	-	18	495 17
		24	2.9	-	-	26	-130	-40	-22	Full	-	-	-4	-	-	16	495 16
180 deg Full Pedal Roll	0.5	18	2.0	10	200	34	-110	-40	-12	-	6	-	-	80	-	16	492 15
		20	2.0	20	250	42	-100	-42	20	-	Neutral	Neutral	-	-	-	-	492 13
		24	2.2	13	220	34	-90	-32	24	-	-17	-	-	-	-	-	492 14

Notes: (1) Uncorrected test boom angle of attack

(2) Rudder deflection range is ± 20 deg; positive deflection defined as trailing edge left

(3) Positive roll rate defined as right wing down

(4) Positive yaw rate defined as air nose right

(5) Uncorrected test boom sideslip; positive sideslip defined as air nose left

(6) Aileron deflection range is ± 12.5 deg with gear retracted; positive deflection defined as right wing down

TABLE VIII
HAWK MODE SPINS
 Entry: Full Back Stick, Neutral Lateral Stick, Full Rudder Pedal
 Recovery: Neutral Lateral Stick, Neutral Rudder Pedal
 Configuration: CR
 Loading: Clean
 Altitude: 32,000 ft MSL

Entry Conditions				Peak Maneuver Conditions				Peak Recovery Conditions				Comments	Flight Run
Mach (TMN)	AOA (deg)	Nz (g)	Rudder Deflection (deg)	Speed Brake Position	Yaw Damper Status	AOA (deg)	Roll Rate (deg/sec)	Yaw Rate (deg/sec)	Sideslip (deg)	Roll Rate (deg/sec)	Yaw Rate (deg/sec)		
0.40	17	1.0	-20	OUT	SBI	42	120	36	±24	-	-	Oscillatory. Simultaneous abrupt long stick and pedal.	509 8
0.50	10	1.0	-20	OUT	SBI	42	145	35	±24	-	-	Oscillatory. Slight unload. Simultaneous abrupt long stick and pedal.	509 9
0.40	20	1.0	-20	OUT	SBI	36	150	22	±22	150	42	Oscillatory. Lead with pedal.	509 10
0.40	16	1.0	-20	OUT	SBI	38	110	24	±25	160	42	Oscillatory. Lead with long stick.	509 11
0.40	20	1.0	-20	IN	SBI	38	140	36	±20	-	-	Not as oscillatory.	509 12
0.50	24	1.0	-20	IN	SBI	34	90	32	±22	-	-	Oscillatory.	509 13
0.45	11	1.0	20	IN	SBI	46	-140	-44	±26	-	-	150 kt, wings level entry to the left. Oscillatory.	509 14
0.45	8	1.0	-20	IN	SBI	50	110	42	±28	-	-	150 kt, wings level entry to the right. Oscillatory.	509 15
0.50	12	1.0	-20	IN	SBI	42	120	42	±24	170	-	166 kt 30° right turn with left pedal. Oscillatory.	509 16
0.45	14	1.0	14	IN	ALL	43	-120	-44	±20	-	-	Wings level, left pedal entry. Oscillatory.	510 7
0.45	12	1.0	-17	IN	ALL	35	150	36	±26	200	-	Wings level, right pedal entry. Oscillatory.	510 8
0.50	10	1.0	-20	IN	ALL	42	110	40	±22	-	-	30° left turn, left pedal entry. Oscillatory.	510 9
0.50	12	1.0	12	IN	ALL	36	-100	-36	±12	-	-	30° right turn, left pedal entry. Oscillatory.	510 10
0.48	12	1.0	14	IN	SBI	26	-50	-18	±11	-	-	30° left turn, right pedal entry. Oscillatory.	510 11
0.50	11	1.0	18	IN	SBI	34	135	38	±22	200	42	30° left turn, left pedal entry. Oscillatory.	510 12
0.45	11	1.0	15	IN	SBI	42	-130	-39	±18	-	-	Wings level, left pedal entry. Oscillatory. Closest to Brit Hawk Spin.	510 13
0.45	11	1.0	-20	IN	SBI	37	110	32	±26	-	-	Wings level, right pedal entry. Oscillatory.	510 14

Notes: (1) Uncorrected test boom angle of attack

(2) Rudder deflection range is ±20 deg; positive deflection defined as trailing edge left

(3) Positive roll rate defined as right wing down

(4) Positive yaw rate defined as air nose right

(5) Uncorrected test boom sideslip; positive sideslip defined as air nose left

TABLE IX
VERTICAL RECOVERY MANEUVERS

Configuration: CR
YDC: ALL
Loading: Clean

Altitude: 25,000 ft MSL
Entry Airspeed: 350 KIAS

Entry Conditions				Input	Peak Maneuver Conditions				Comments	Flight	R
Input A/S (kts)	Pitch (deg)	Roll (deg) (1)	Speed Brake Position	Stabilator Deflection (deg) (2)	AOA (deg) (3)	Roll Rate (deg/sec) (4)	Yaw Rate (deg/sec) (5)	Sideslip (deg) (6)			
50	70	0	OUT	6	34	20	18	-28		483	1
		180	OUT	-14	24	-35	8	24		483	1
	80	0	IN	6	82	20	25	-46		484	
		180	IN	-14	56	-60	18	-19		484	
100	70	0	OUT	6	-9	-10	4	-8		483	
		0	IN	-14	64	20	20	-36		490	
		0	IN	3	20	10	4	-7	IDLE Power at 100 kts.	502	
		0	IN	3	10	5	4	-7	MIL Power at 100 kts.	502	
		180	OUT	-14	34	-35	8	30		483	1
		180	IN	-1	-5	-5	-4	1	IDLE Power at 100 kts.	502	1
	75	180	IN	-4	-6	-10	-4	-5	MIL Power at 100 kts.	502	1
		0	IN	2	44	15	12	-20	IDLE Power at 100 kts.	502	1
		0	IN	2	28	-25	12	-14	90% Power at 100 kts.	502	1
		0	IN	2	24	15	8	-17	MIL Power at 100 kts.	502	1
		180	IN	-3	-17	-10	-4	10	IDLE Power at 100 kts.	502	1
		0	OUT	6	58	-50	24	-22		483	1
	80	0	IN	-14	68	-140	-40	27	Self recovering surge.	484	1
		0	OUT	-14	-16	-110	-40	41	Locked surge.	484	1
		0	IN	-14	-25	-30	8	-22	Control Aug failed.	490	1
		0	IN	-14	-48	40	-26	26	FBS passing through horizon.	500	
		180	IN	-14	-76	100	-60	16	Surge/Flameout.	483	1
		180	IN	6	26	-120	-36	29		484	1
		180	OUT	6	-56	-60	-36	20		484	1
		180	IN	-14	-60	50	-42	40		490	1
		180	IN	-	44	-50	-16	-25	Locked surge.	500	1
	90	-	IN	6	-72	-75	60	50	Rudder locked out. Locked surge.	484	1
		-	IN	-14	50	135	60	40	Rudder locked out. Locked surge.	490	1
		-	IN	-14	-76	-50	-12	-20	Aft stick in vert. FBS passing through horizon.	500	
(7)	70	0	OUT	-	44	-80	-20	50		483	1
		0	IN	-	44	15	10	20		490	
		0	IN	-	48	20	12	-16	FBS passing through horizon.	500	
		180	OUT	-	-18	20	40	40		483	1
		180	IN	-	-60	-40	12	-19		490	1
	80	0	OUT	-	-72	-100	68	-46	Surge/Flameout.	484	
		0	IN	-	-30	25	-28	-48	Rudder locked out.	490	
		0	IN	-	-4	30	-34	32	FBS passing through horizon.	500	1
		0	IN	-	-32	30	-25	-40	FBS passing through horizon.	500	1
		0	IN	-	66	120	36	-24	Self-recovering surge.	500	1
		0	IN	-	-82	-140	82	50	FBS through horz. Pop surge. Incipient inv spin. Rud lock.	500	1
		180	IN	-	-68	-75	24	30	Rudder centered during recovery.	484	1
		180	IN	-	47	130	24	-22		490	1
	90	-	IN	-	84	110	45	-20	Self recovering surge.	490	1
		-	IN	-	72	-70	-38	46	Locked surge.	500	1
		-	IN	-	60	-85	-36	30	Self-recovering surge.	500	1

- Notes: (1) Positive roll defined as right wing down
(2) Stabilator deflection range is -14 deg (full back stick or FBS) to 7 deg (full forward stick)
(3) Uncorrected test boom angle of attack
(4) Positive roll rate defined as right wing down
(5) Positive yaw rate defined as air nose right
(6) Uncorrected test boom sideslip; positive sideslip defined as air nose left
(7) No control inputs; pilot allowed aircraft to fall through.

TABLE X
OPERATIONAL MANEUVERS
Configuration: CR/P Altitude: 20,000 - 25,000 ft MSL
Loading: Clean

Maneuver	Entry Conditions						Peak Maneuver Conditions						Comments	Flight Run
	Airspeed (KIAS)	AOA (deg)	Nz (g)	Long Stick Deflection (deg)	Stabilator Deflection (deg)	Lat Stick Deflection (deg)	Rudder Deflection (deg)	Rud Ped Force (lb)	AOA (deg)	Roll Rate (deg/sec)	Yaw Rate (deg/sec)	Sideslip (deg)		
Barrel Roll Attack	300	3	3.4	-	-3	-3	-	-	14	-40	-4	2		491 22
	350	0	3.5	-	-2	-3	-	-	10	-30	-8	2		489 11
	350	3	4.0	-	-5	-3	-	-	12	-10	4	1		489 12
	350	0	4.2	-	-7	-3	-	-	16	15	8	4		491 21
Barrel Roll with Trim	350	4	4.0	-	-10	2	-	-	18	50	18	2	Full nose up trim.	486 11
	350	4	4.0	-	-1	2	-	-	8	25	6	2	Full nose down trim.	486 12
Break Turn	250	3	2.9	FBS (8)	-14	Half	-	-	24	80	8	2		488 16
	250	3	3.5	-	-11	2	-	-	20	40	8	6		491 17
	300	1	4.2	FBS	-14	Half	-	-	23	60	18	-6		488 15
	300	2	3.8	-	-12	-7	-	-	22	-50	12	4		491 16
	350	2	4.5	FBS	-14	Half	-	-	25	110	16	7		488 11
	350	2	4.5	-	-9	Half	-	-	20	100	8	4		488 12
	350	2	4.8	-	-5	-7	-	-	16	-70	-12	-4		491 14
	400	0	4.9	-	-12	Half	-	-	24	110	-17	-2		488 13
	400	0	5.5	-	-12	Half	-	-	21	50	20	-5		488 14
	400	0	5.8	-	-8	4	-	-	12	-60	12	4		491 15

TABLE X
OPERATIONAL MANEUVERS
Configuration: CR/P Altitude: 20,000 - 25,000 ft MSL
Loading: Clean

Maneuver	Entry Conditions						Peak Maneuver Conditions					Comments	Flight Run
	Airspeed (KIAS)	AOA (deg)	Nz (g)	Long Stick Deflection (deg)	Stabilator Deflection (deg)	Lat Stick Deflection (deg)	Rudder Deflection (deg)	Rud Ped Force (lb)	AOA (deg)	Roll Rate (deg/sec)	Yaw Rate (deg/sec)	Sideslip (deg)	
Displacement Roll	250	2	3.3	-	-9	-4	6	240	21	-45	-16	-3	488 20
	250	3	2.8	-	-14	-4	6	230	24	-80	-24	4	489 10
	250	4	3.4	-	-6	-8	-	-	16	-110	-26	6	491 20
	300	4	4.0	-	-5	-2	5	210	16	-60	-16	4	488 19
	300	2	3.8	-	-6	-5	6	270	14	-90	-28	8	489 9
	300	5	3.5	-	-3	-10	-	-	18	-100	-20	8	491 19
	350	2	5.0	12	-6	-2	2	140	16	-60	-16	-2	488 17
	350	2	4.9	-	-5	-3	2	170	14	-85	-7	-2	488 18
	350	0	4.4	-	-4	-10	4	250	13	-175	-24	6	489 7
	350	0	4.2	-	-7	-4	3	240	17	-75	-18	2	489 8
	350	2	4.1	-	-8	9	-	-	18	110	-10	2	491 18
	150	10	1.0	-	-7	-12	-	-	21	20	10	5	493 12
	150	10	1.0	-	-8	12	2	-	22	25	-10	5	493 13
	150	10	1.0	-	-5	-5	1	-	18	20	-4	3	493 14
Flat Scissors	150	10	1.0	-	-10	-7	2	-	24	30	8	6	494 8
	150	10	1.0	-	-14	7	10	140	26	20	8	-6	494 9
	150	10	1.0	-	-14	-12	5	-	26	15	-8	-4	494 10
	150	10	1.0	-	-14	-12	-12	130	28	60	20	10	496 8
	150	10	2.2	-	-14	12	5	-	30	100	22	16	497 7
	150	10	-1.0	-	-14	12	6	-	30	65	18	8	497 7A
	150	10	1.0	-	-10	9	5	-	28	50	12	10	497 8
	150	10	1.9	-	-14	-12	-12	-	28	15	12	11	498 6
	250	4	3.1	-	-13	-5	8	220	26	-70	-20	6	489 15
	250	2	3.0	-	-12	-7	9	280	22	-50	-16	-5	489 16
	250	4	3.2	-	-14	4	-10	240	26	90	32	-8	491 25
	250	5	3.3	-	-14	-5	-12	210	28	60	20	-5	491 26
	300	0	3.6	-	-14	3	7	260	24	-60	-18	8	489 13
	300	0	4.1	-	-13	-3	7	240	22	-45	-18	2	489 14
High G Roll Over Top	300	2	4.0	-	-9	-4	6	250	20	-60	-20	8	491 23
	300	4	4.0	-	-14	5	-7	310	28	80	25	-4	491 24
	300	3	4.2	-	-10	-8	4	-	23	60	12	6	496 9
	300	2	2.5	-	-10	-3	2	-	20	40	20	6	497 9
	250	4	3.1	-	-13	-5	8	220	26	-70	-20	6	489 15
	250	2	3.0	-	-12	-7	9	280	22	-50	-16	-5	489 16

Held FBS for more than 40 sec.

TABLE X
OPERATIONAL MANEUVERS
Configuration: CR/P Altitude: 20,000 - 25,000 ft MSL
Loading: Clean

Maneuver	Entry Conditions						Peak Maneuver Conditions					Comments	Flight Run
	Airspeed (KIAS)	AOA (deg) (1)	Nz (g)	Long Stick Deflection (deg)	Stabilator Deflection (deg) (2)	Lat Stick Deflection (deg) (3)	Rudder Deflection (deg) (4)	Rud Ped Force (lb)	AOA (deg)	Roll Rate (deg/sec) (5)	Yaw Rate (deg/sec) (6)	Sideslip (deg) (7)	
High G Roll Underneath	250	0	3.2	-	-12	-2	5	170	22	70	22	4	489 17
	250	1	3.2	-	-13	-2	8	210	22	100	20	6	489 18
	250	3	3.3	-	-14	-7	9	230	26	90	16	9	489 19
	250	2	3.2	-	-13	-2	-4	170	22	90	18	4	489 20
	250	2	3.2	-	-14	-3	4	200	22	4	12	4	489 21
	250	4	2.9	-	-14	-10	-14	260	25	110	32	-10	493 9
	250	4	2.9	-	-14	-12	-12	240	32	120	32	-10	493 10
	250	4	3.2	-	-14	-4	10	240	25	-90	-28	5	493 11
	250	3	3.2	-	-14	12	11	240	34	-100	-36	-8	496 10
	250	4	2.2	-	-14	-4	4	-	28	-40	-12	2	497 10
	300	1	3.8	-	-14	-3	-6	240	22	50	12	4	493 8
	250	3	3.0	-	-12	-7	-	-	22	30	20	6	486 14
Jink-Out	250	8	2.8	-	-12	-	-	-	20	10	5	2	491 12
	300	2	4.5	-	2	-	-	-	6	5	2	2	491 11
Loop-Pull to Recover	350	2	4.5	-	-9	-5	-	-	17	-40	-10	4	486 13
	300	1	4.0	-	-14	-	-	-	24	20	8	4	491 10
Loop-Slow Over Top	350	0	3.7	18	-12	7	-	-	26	70	19	10	487 12
	350	0	3.5	16	-7	3	-	-	22	50	12	8	487 13
Nose Low/Unusual Att	300	1	3.8	-	-3	-	-	-	16	5	2	1	491 9
	350	0	4.0	12	-4	-	-	-	14	5	-4	4	487 11
	125	20	2.0	-	-10	12	-	-	22	40	9	6	491 13
	130	14	1.0	FBS	-14	Half	-	-	32	-85	-20	-15	488 9
	130	16	2.0	FBS	-14	Full	-	-	28	-120	-26	-13	488 10

TABLE X
OPERATIONAL MANEUVERS
Configuration: CR/P Altitude: 20,000 - 25,000 ft MSL
Loading: Clean

Maneuver	Entry Conditions							Peak Maneuver Conditions				Comments	Flight Run	
	Airspeed (KIAS)	AOA (deg) (1)	Nz (g)	Long Stick Deflection (deg)	Stabilator Deflection (deg) (2)	Lat Stick Deflection (deg) (3)	Rudder Deflection (deg) (4)	Rud Ped Force (lb)	AOA (deg)	Roll Rate (deg/sec) (5)	Yaw Rate (deg/sec) (6)			Sideslip (deg) (7)
Rolling Scissors	150	10	1.0	-	-14	-12	2	-	22	50	16	-8	498 7	
	300	2	3.5	-	-6	-3	1	-	18	45	-10	4	493 15	
	300	2	3.2	-	-10	-12	2	-	22	45	16	-5	493 16	
	300	2	4.5	-	-10	-20	3	-	18	-20	-12	-4	493 18	
	300	2	3.9	-	-4	-12	1	-	20	60	8	4	494 11	
	300	2	3.2	-	-14	-7	5	-	24	40	-8	-5	494 12	
	300	2	3.5	-	-14	7	3	-	26	60	12	8	496 7	
	300	2	3.4	-	-14	7	10	-	28	70	16	12	497 6	
	300	2	5.0	-	-14	-12	5	-	26	30	-8	-6	498 8	
Vertical Rec-Correct	300	0	2.0	-2	2	-	-	-	10	5	-5	2	Min airspeed 104 KCAS.	487 7
	300	0	2.6	0	1	-	-	-	9	5	5	-3	Min airspeed 63 KCAS.Speed brakes out.	487 8
	350	2	3.0	-	-7	-	-	-	6	5	2	2		491 7
Vertical Rec-Incorrect	300	0	2.8	FFS (9)/FBS	6/-14	-	-	-	27	10	4	4	Min airspeed 59 KCAS.Speed brakes out.	487 9
	300	0	2.7	FFS/FBS	6/-14	-	-	-	19	5	-5	-9	Min airspeed 82 KCAS.	487 10
	350	2	3.8	-	-8	-	-	-	20	5	3	6		491 8
Air Combat Maneuvering	300	4	3.6	-	-14	12	7	130	28	70	8	10		496 12
	250	8	3.2	-	-14	12	-17	-	26	-110	-18	8		496 16
	325	4	4.5	-	-14	12	4	-	24	75	20	6		496 15
	350	4	3.5	-	-11	12	3	-	18	-30	8	-8		496 13
	350	5	4.0	-	-14	12	-3	-	26	-40	12	5		496 14
	350	2	4.9	-	-3	3	1	-	14	30	8	1		497 12
	350	2	3.6	-	-14	12	7	-	26	30	12	10		497 13
	350	2	3.2	-	-5	-8	3	-	18	30	10	6		497 14
	350	1	3.2	-	-14	-7	3	-	26	80	18	-4		498 9
	350	1	3.5	-	-7	-12	2	-	20	15	8	-6		498 10
	350	1	4.0	-	-6	12	2	-	18	-20	-8	-6		498 11
	350	1	4.2	-	-9	12	7	-	21	-40	-20	7		498 12
	300	2	4.0	-	-11	12	6	190	18	100	12	6		496 11
300	2	4.1	-	-4	-7	1	-	14	-100	-22	-4		497 11	

TIME HISTORIES

MODEL T-45A AIRPLANE
BuNo 163599

Control Aug: ALL
Gross Weight: 13,100 lb
Thrust: IDLE

Configuration: CR
CG: 18.1% MAC
Speed Brakes: Retracted
Loading: Clean

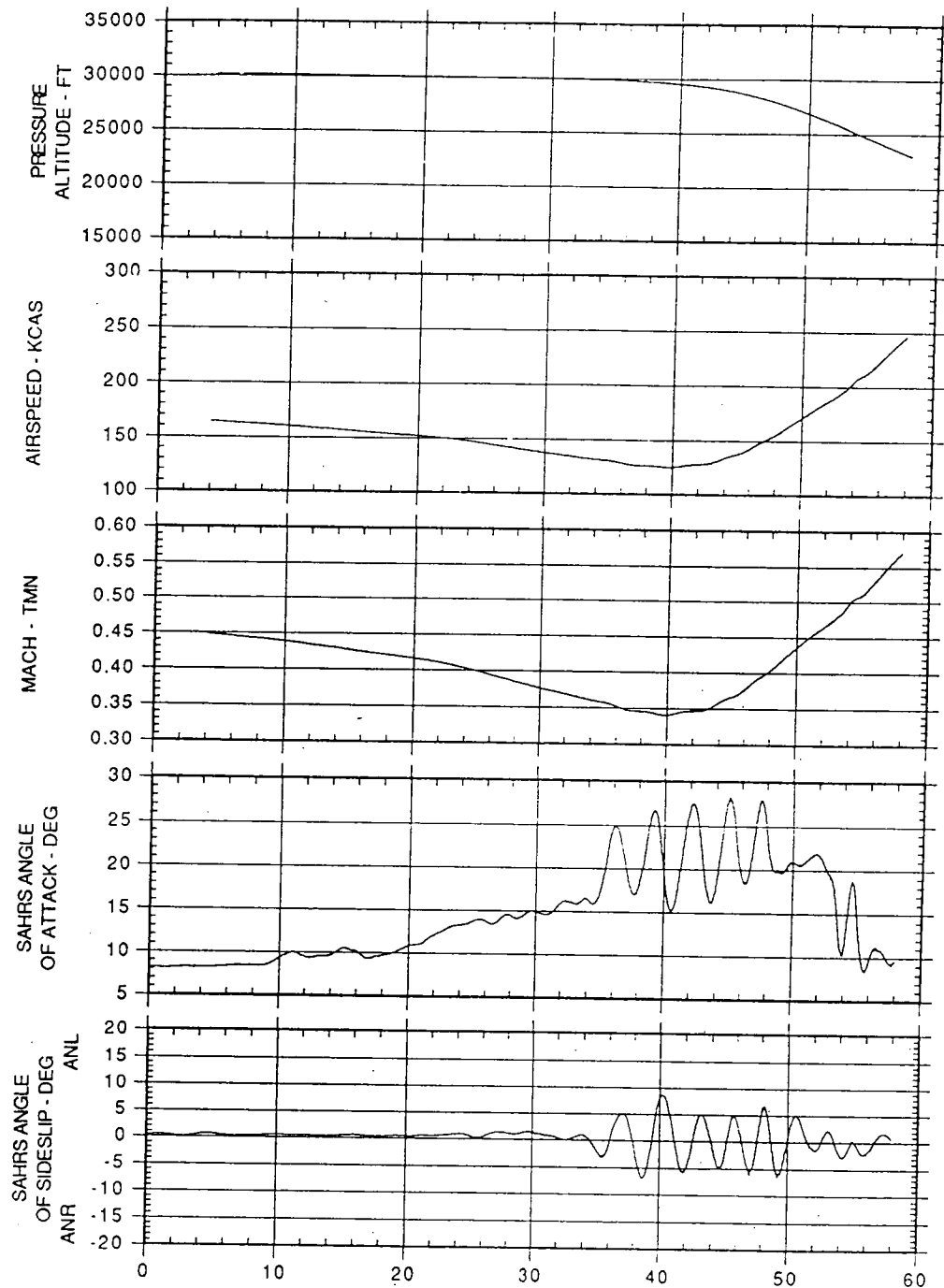


Figure 1
FULL BACK STICK 1-G STALL

MODEL T-45A AIRPLANE
BuNo 163599

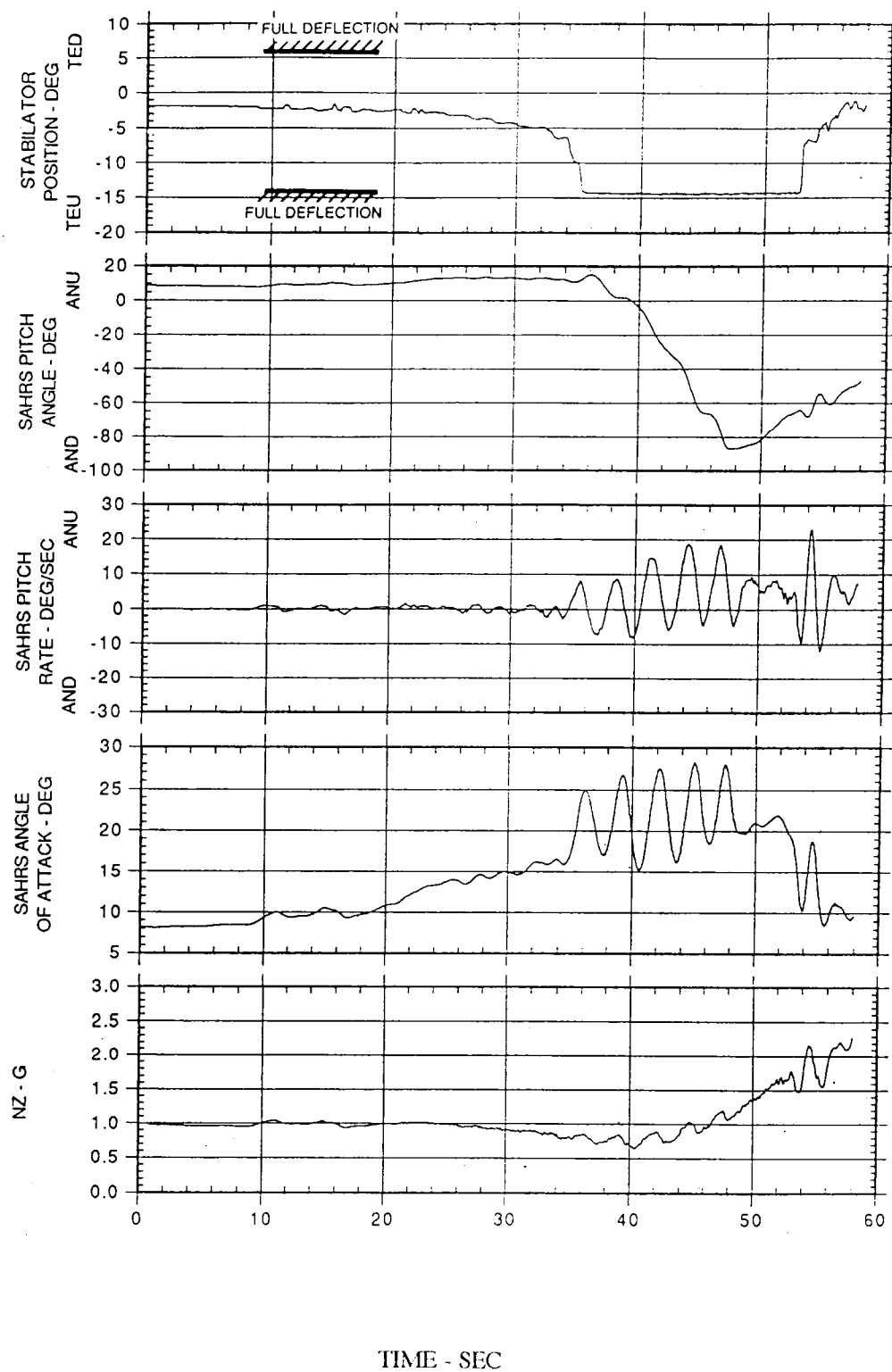
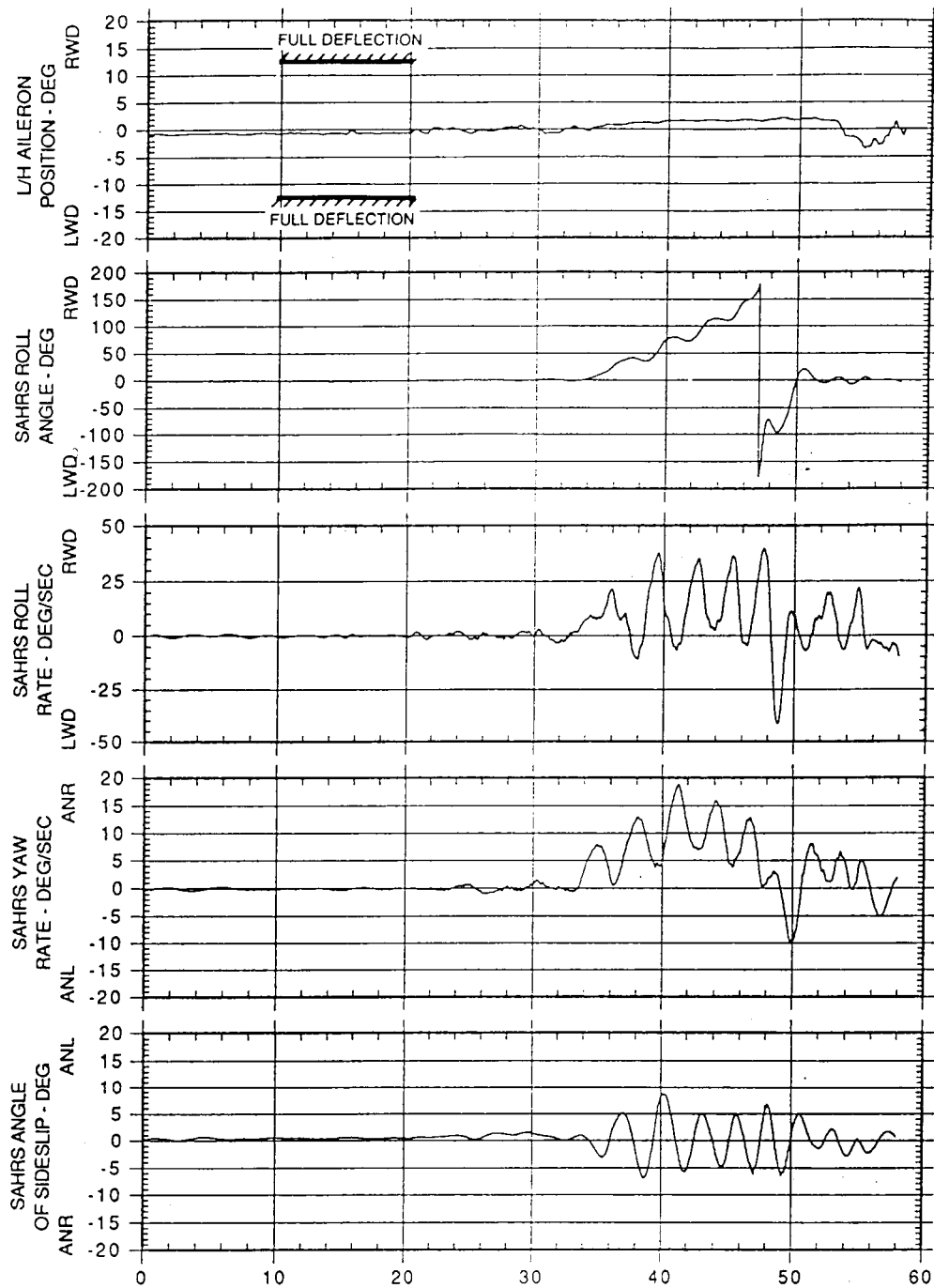


Figure 1 (Cont'd)

MODEL T-45A AIRPLANE
BuNo 163599



TIME - SEC

Figure 1 (Cont'd)

MODEL T-45A AIRPLANE
BuNo 163599

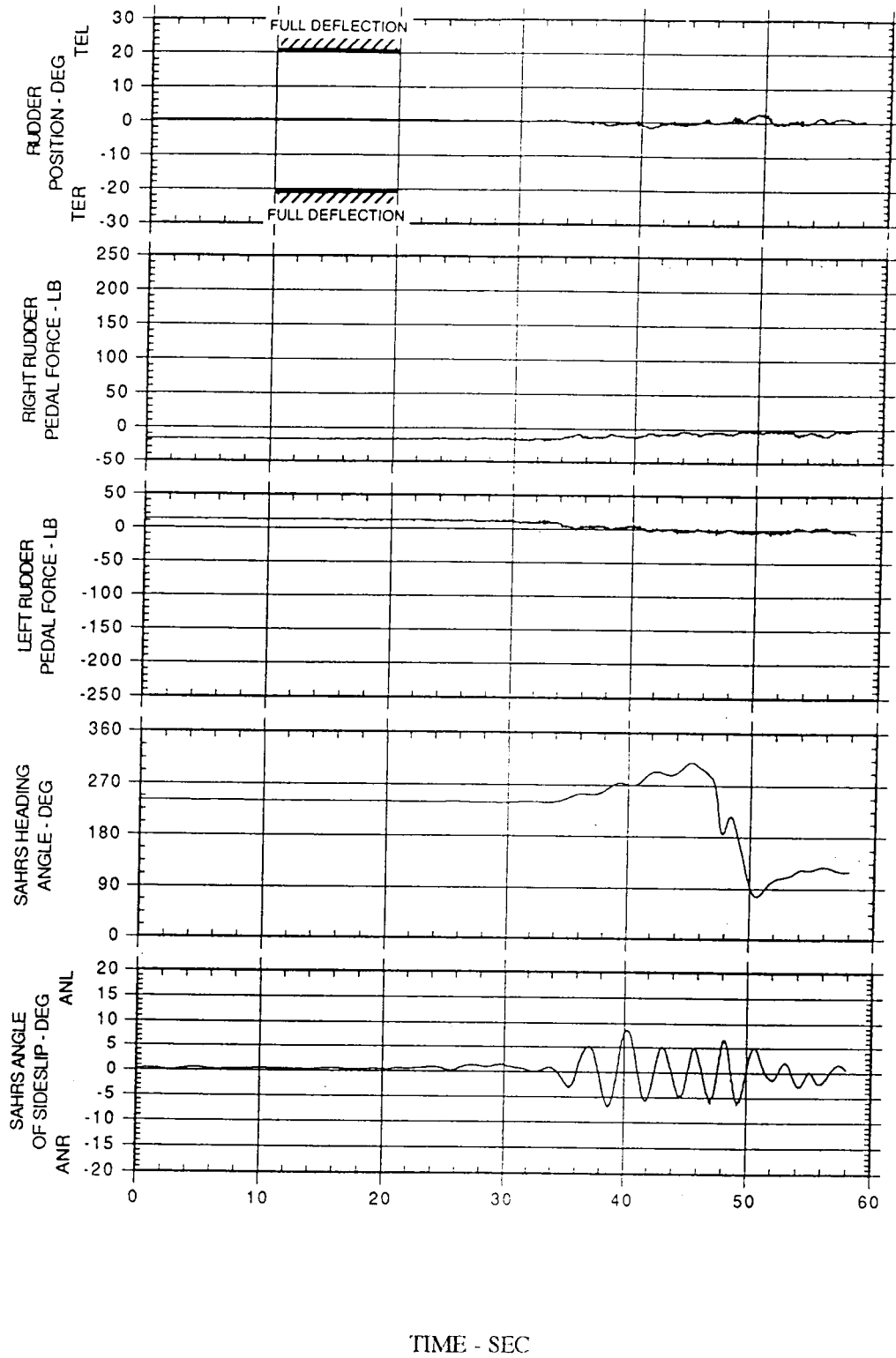


Figure 1 (Cont'd)

MODEL T-45A AIRPLANE
BuNo 163599

Control Aug: ALL
Gross Weight: 12,500 lb
Thrust: IDLE

Configuration: CR
CG: 18.8% MAC
Speed Brakes: Retracted
Loading: Clean

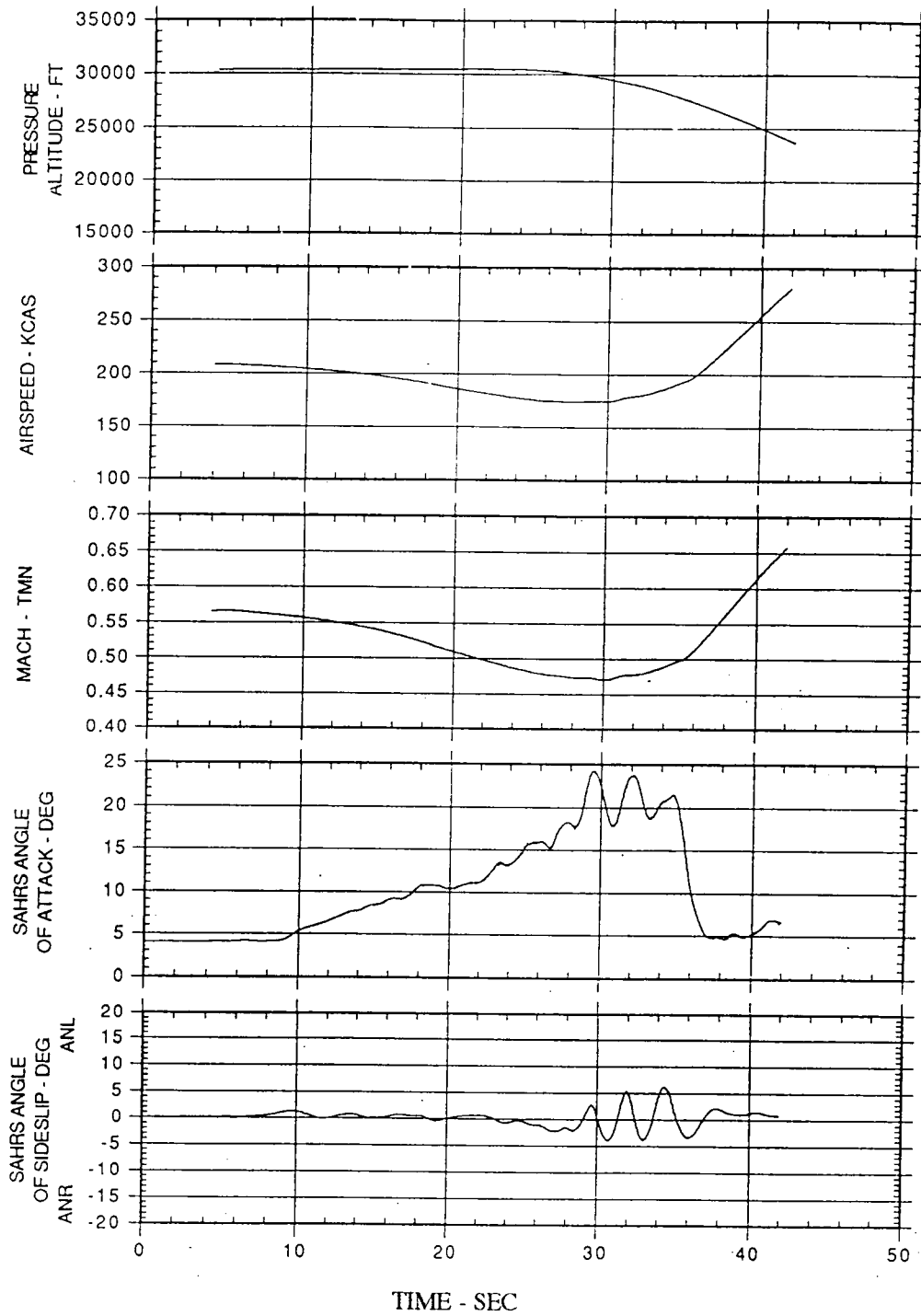


Figure 2
0.5 MACH WIND UP TURN TO FULL BACK STICK

MODEL T-45A AIRPLANE
BuNo 163599

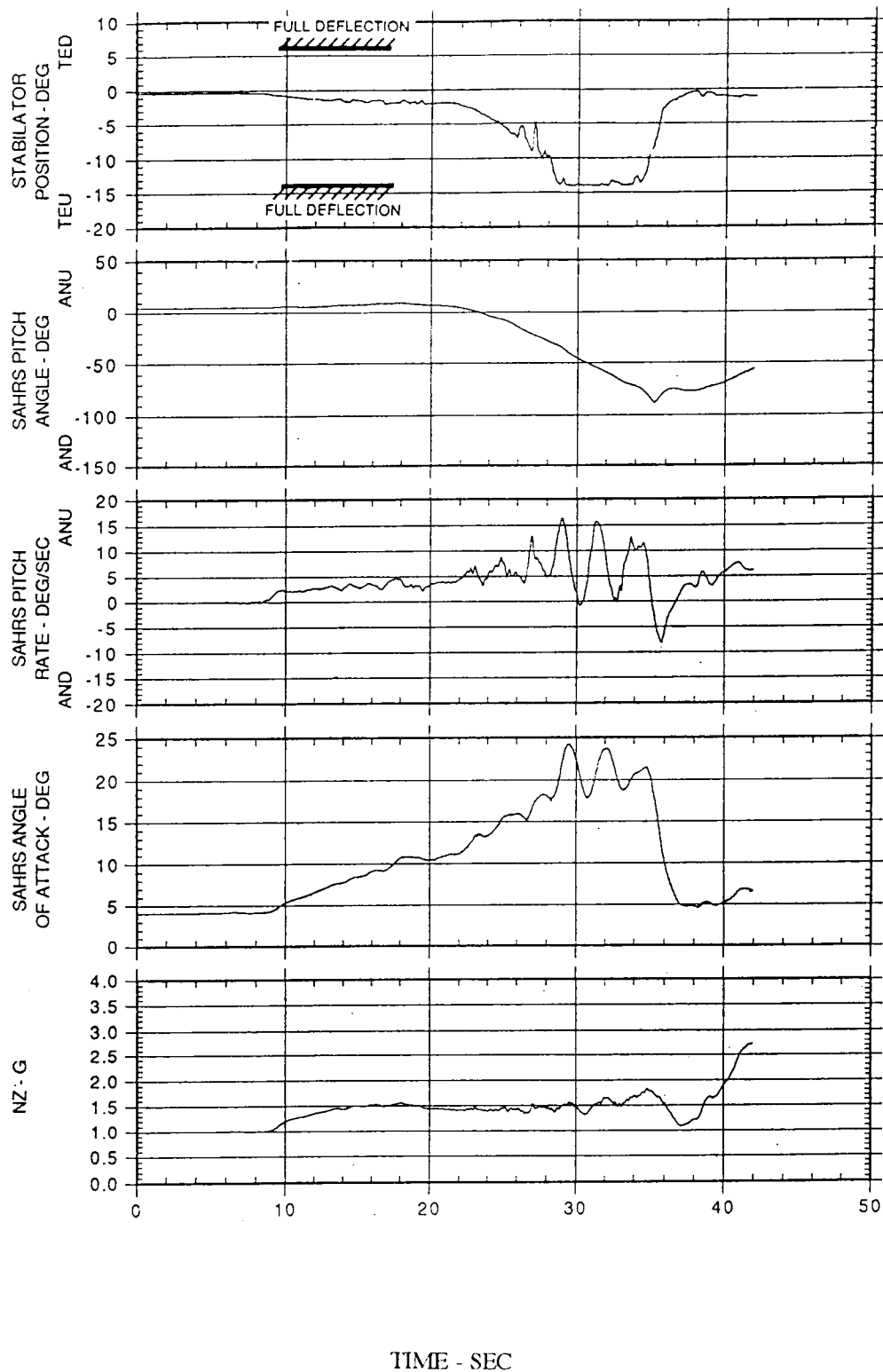


Figure 2 (Cont'd)

MODEL T-45A AIRPLANE
BuNo 163599

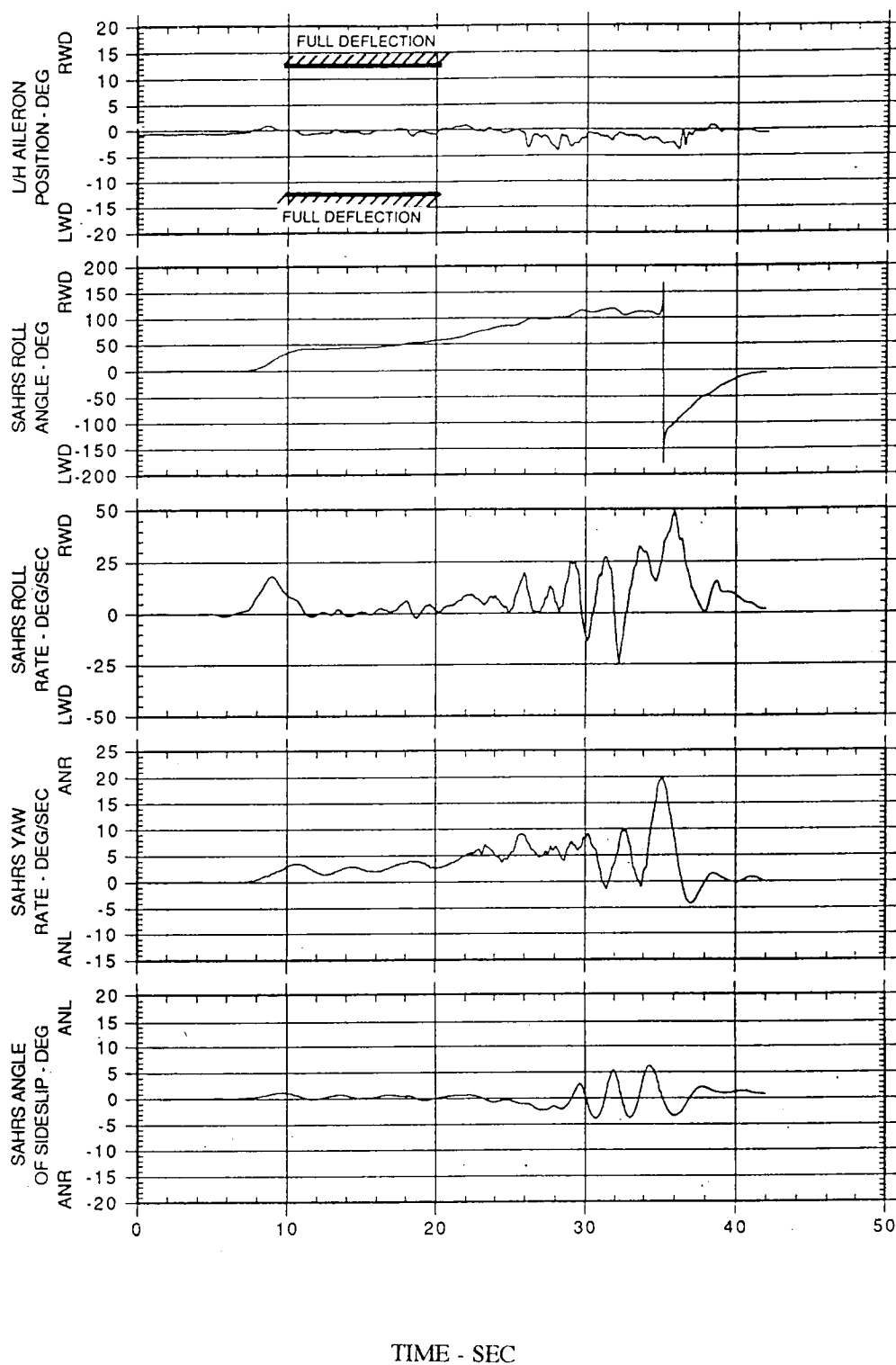


Figure 2 (Cont'd)

MODEL T-45A AIRPLANE
BuNo 163599

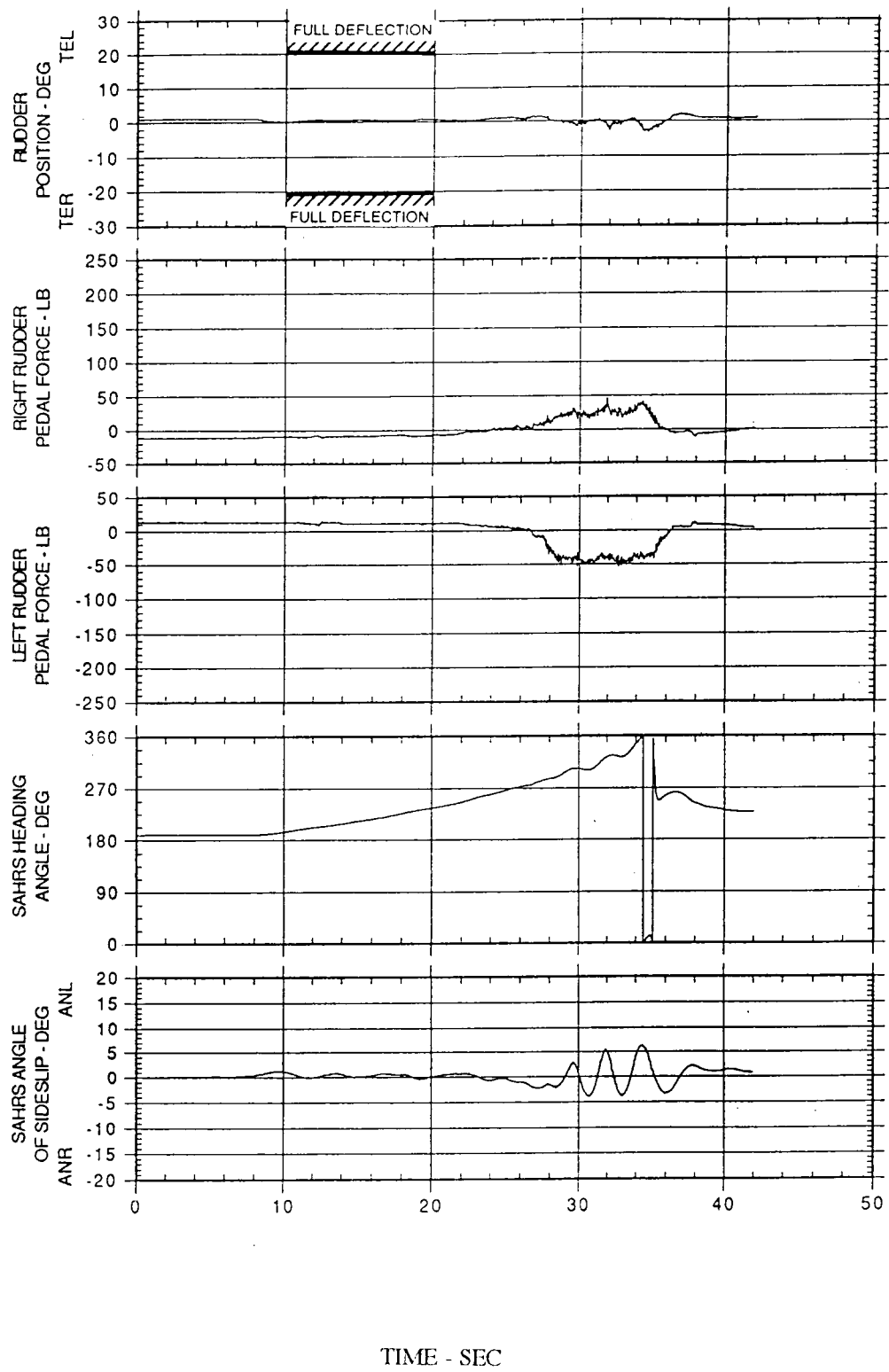


Figure 2 (Cont'd)

MODEL T-45A AIRPLANE
BuNo 163599

Control Aug: ALL
Gross Weight: 12,950 lb
RPM: 93%

Configuration: CR
CG: 17.9% MAC
Speed Brakes: Retracted
Loading: Clean

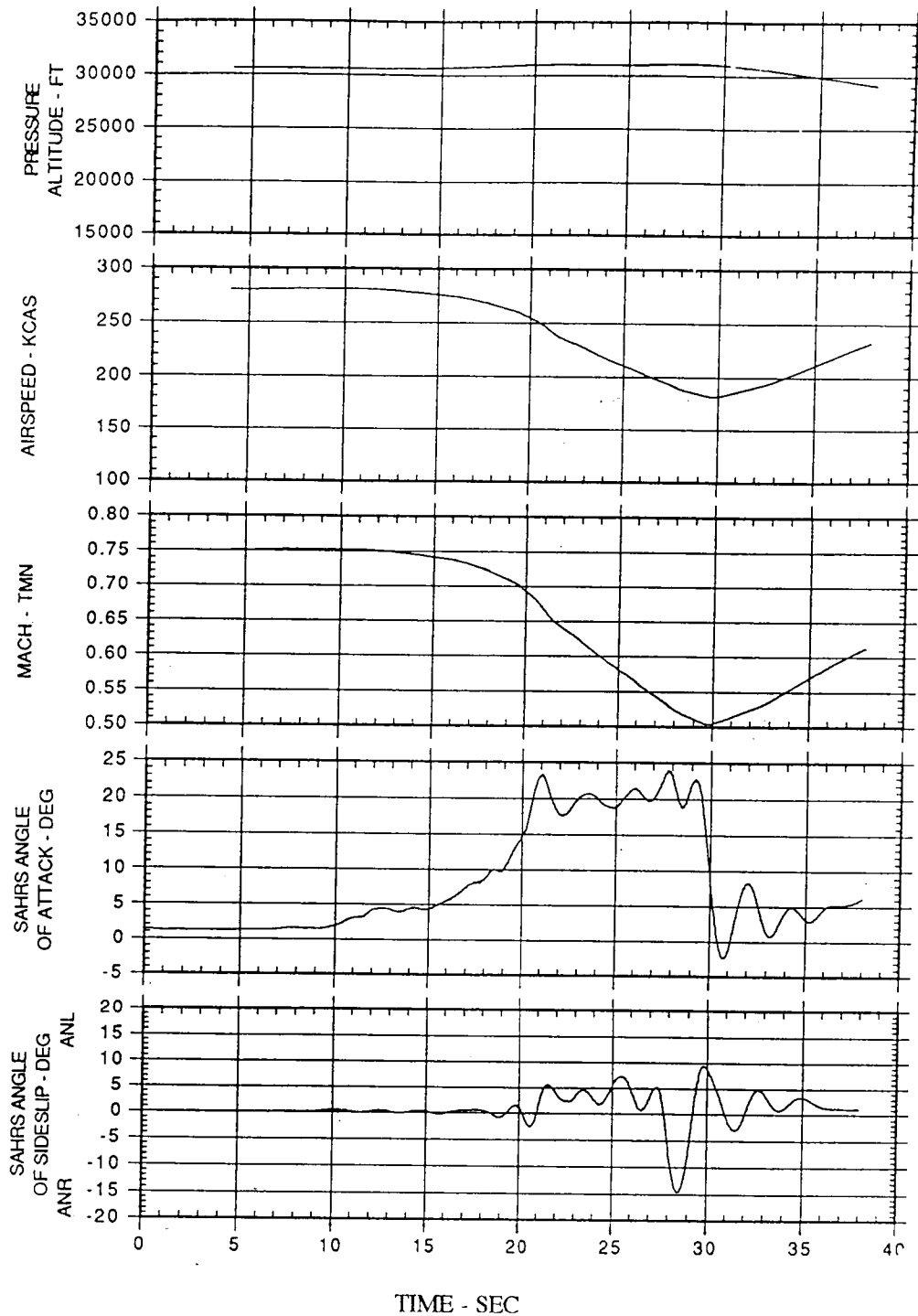


Figure 3
0.7 MACH 180 DEG PEDAL ROLL AT FULL BACK STICK

MODEL T-45A AIRPLANE
BuNo 163599

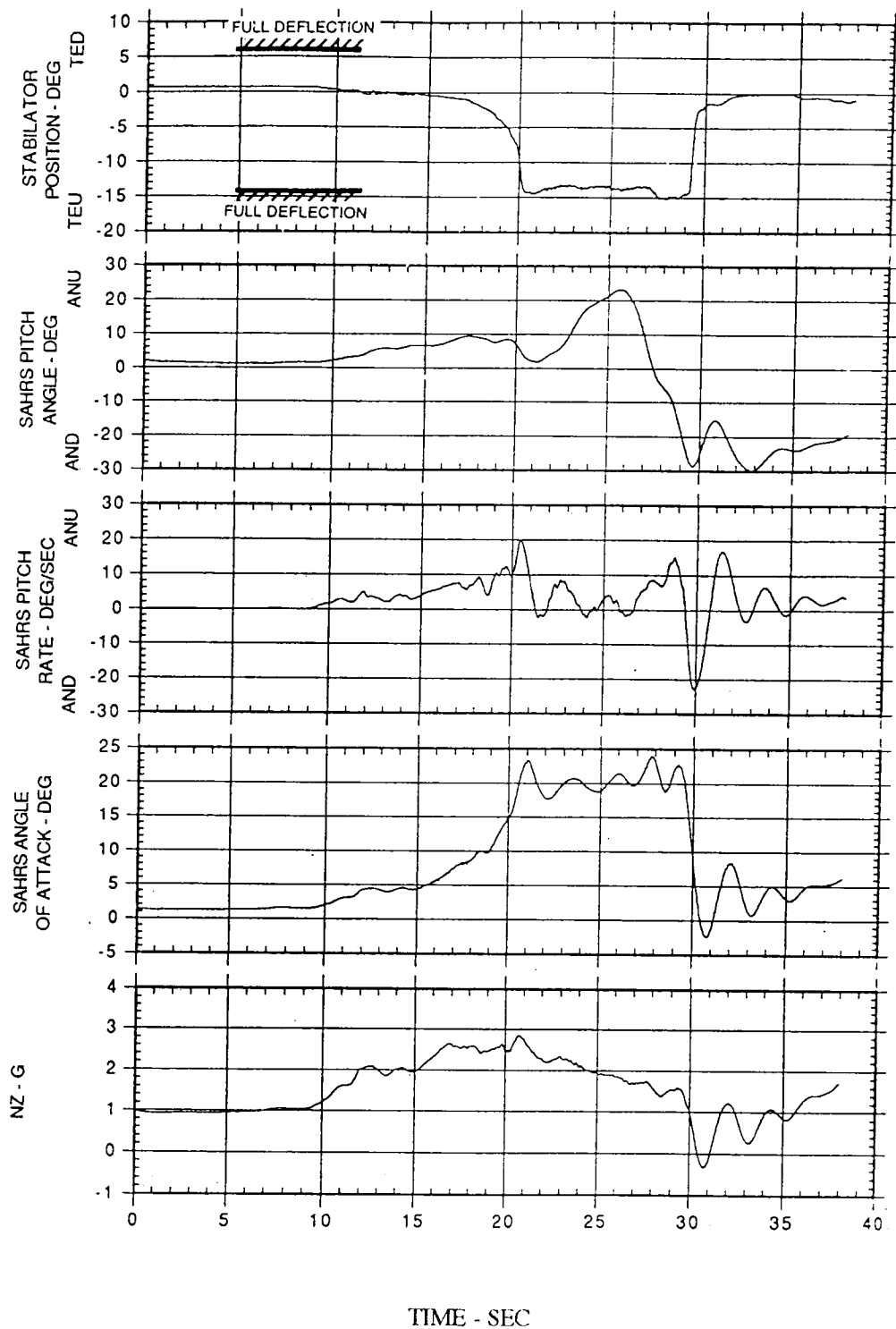


Figure 3 (Cont'd)

MODEL T-45A AIRPLANE
BuNo 163599

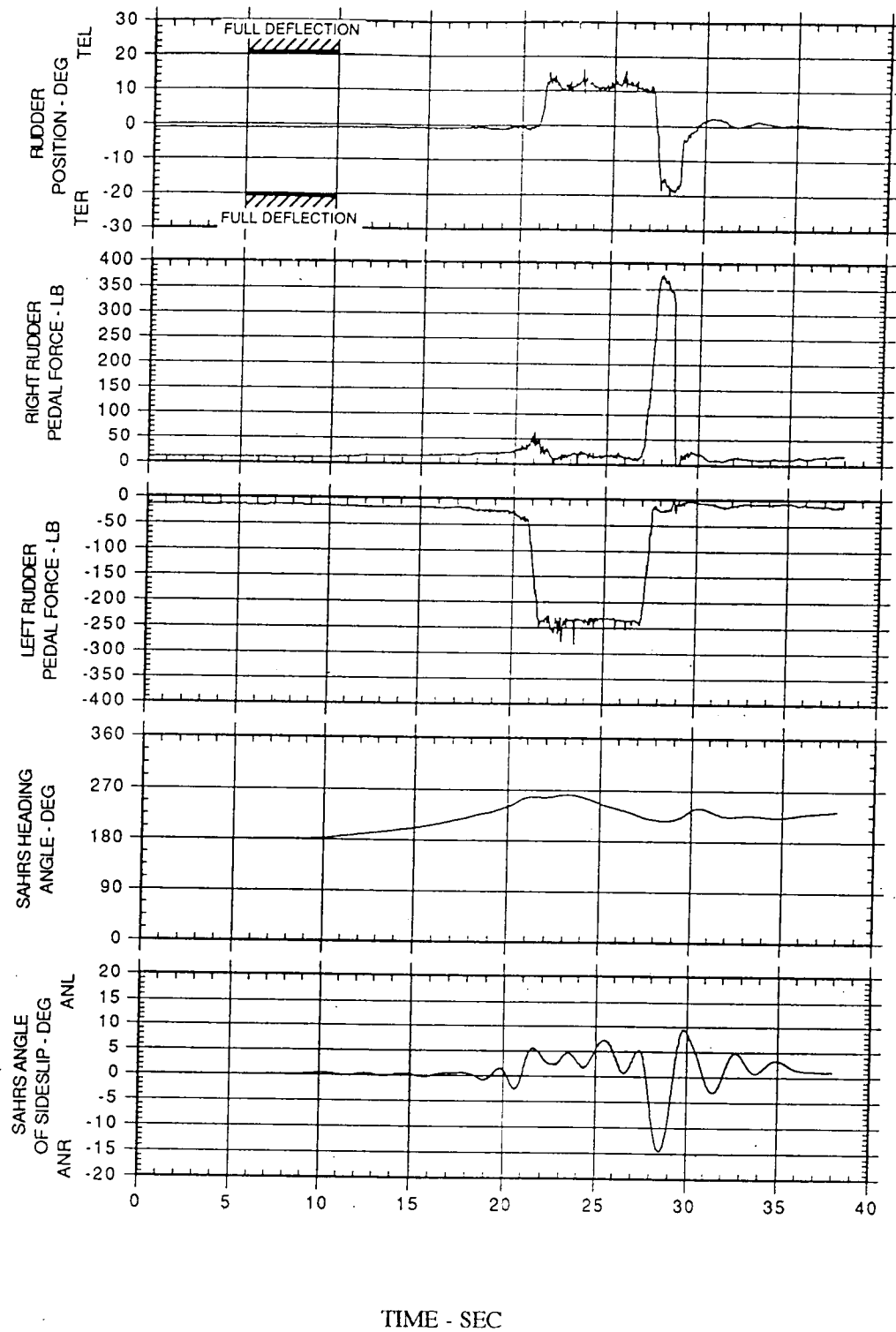


Figure 3 (Cont'd)

MODEL T-45A AIRPLANE
BuNo 163599

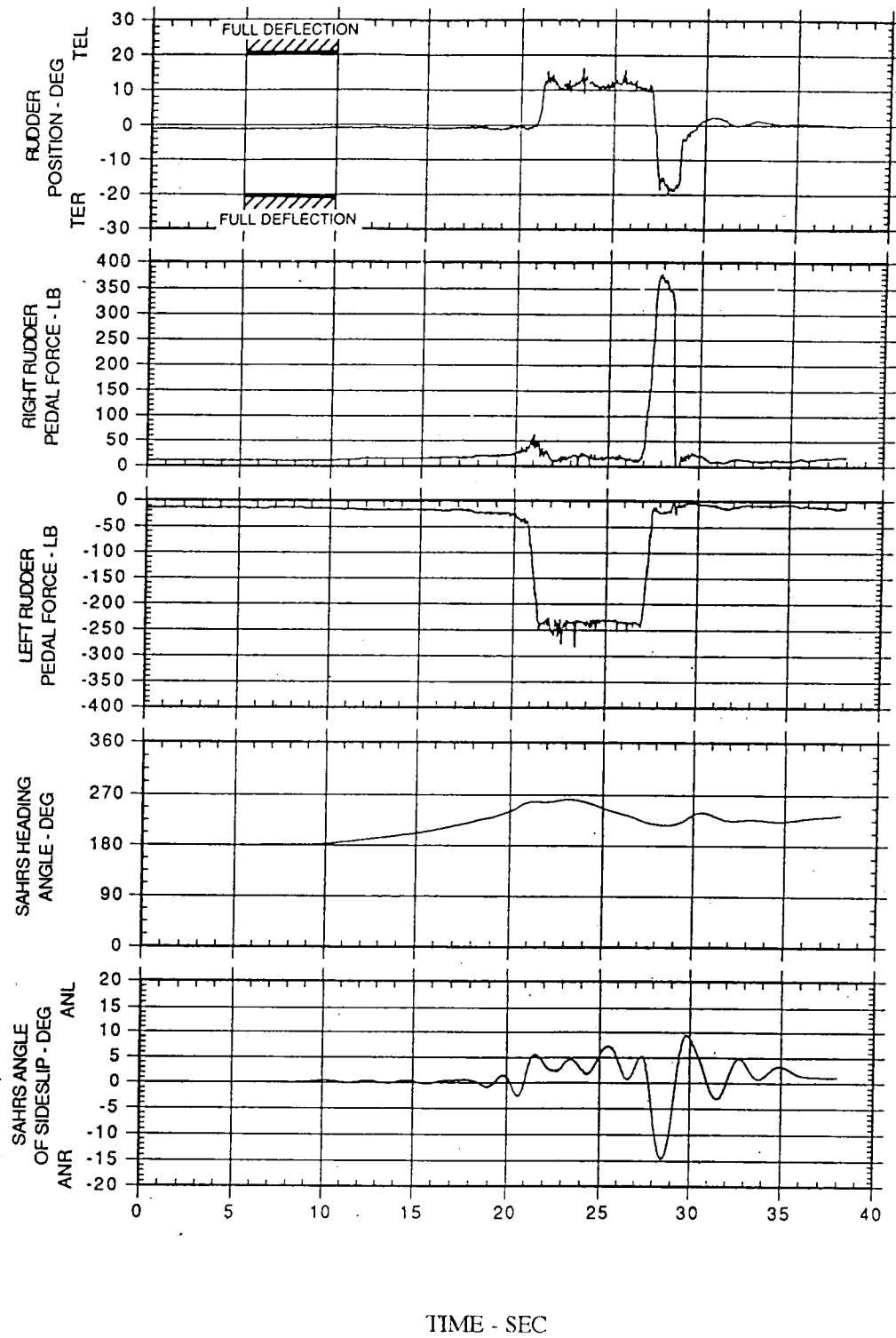


Figure 3 (Cont'd)

MODEL T-45A AIRPLANE
BuNo 163599

Control Aug: ALL
Gross Weight: 12,600 lb
Thrust: IDLE

Configuration: CR
CG: 18.6% MAC
Speed Brakes: Retracted
Loading: Clean

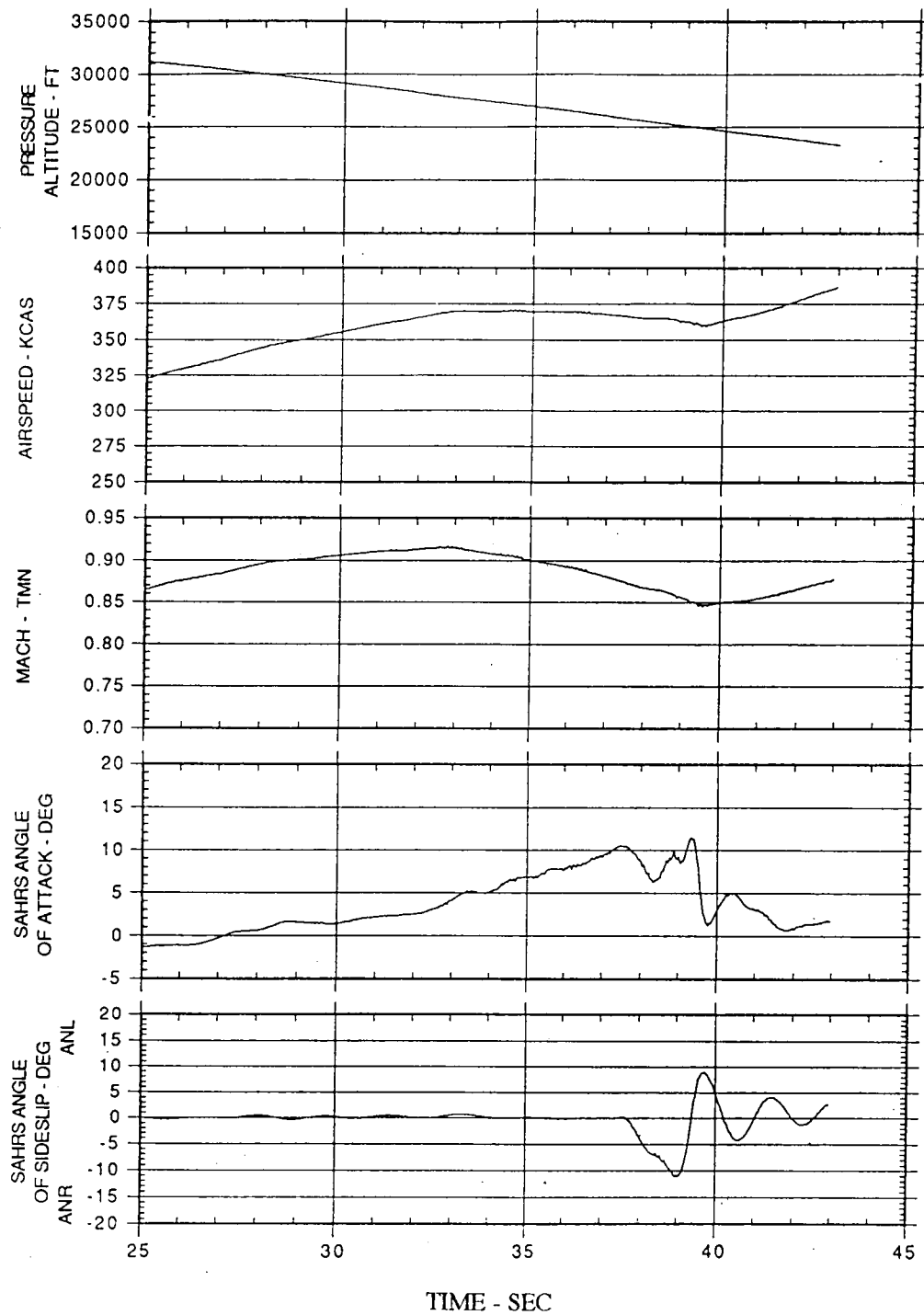


Figure 4
0.9 MACH FULL LATERAL STICK 180 DEG ROLL

MODEL T-45A AIRPLANE
BuNo 163599

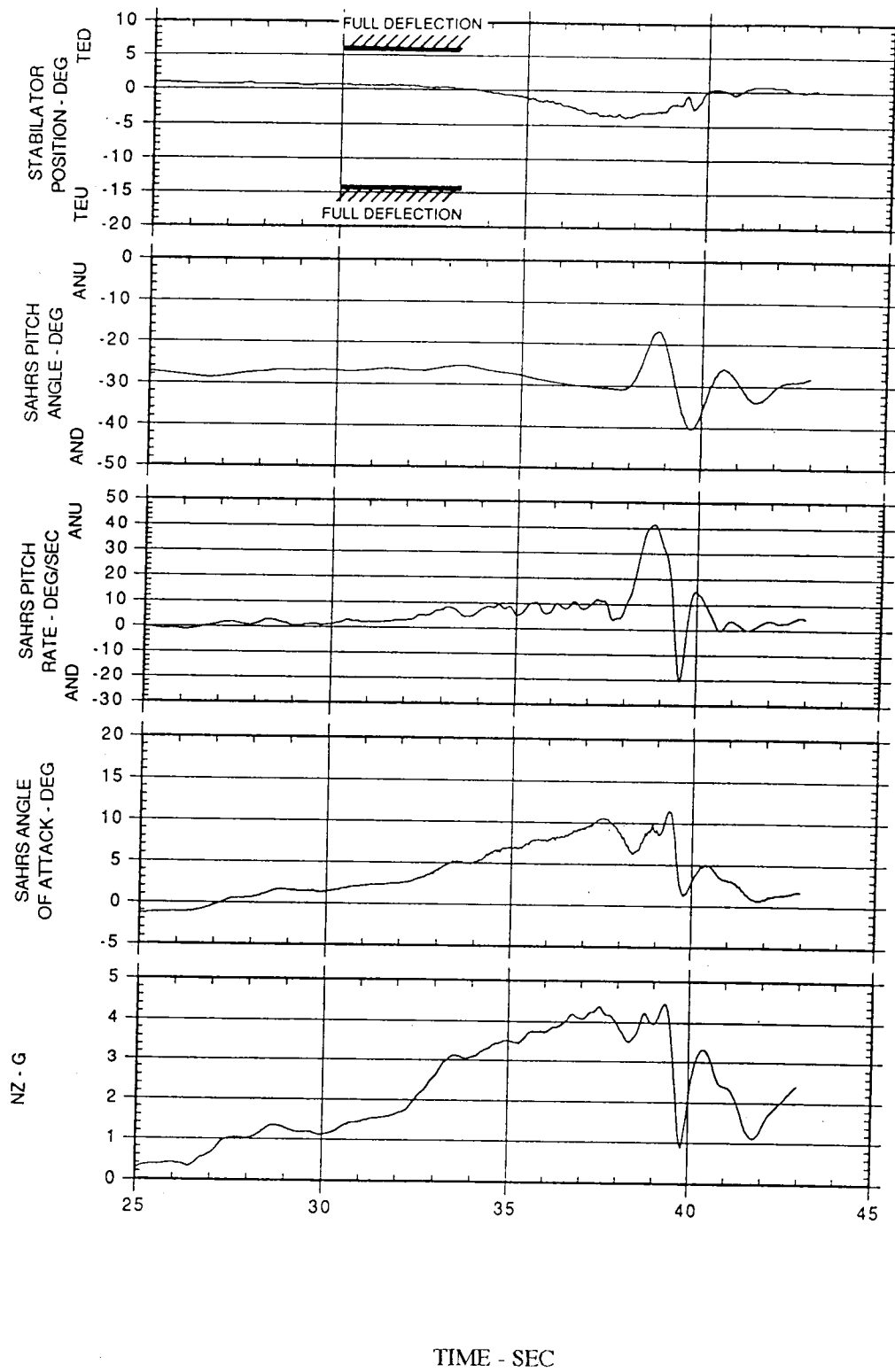


Figure 4 (Cont'd)

MODEL T-45A AIRPLANE
BuNo 163599

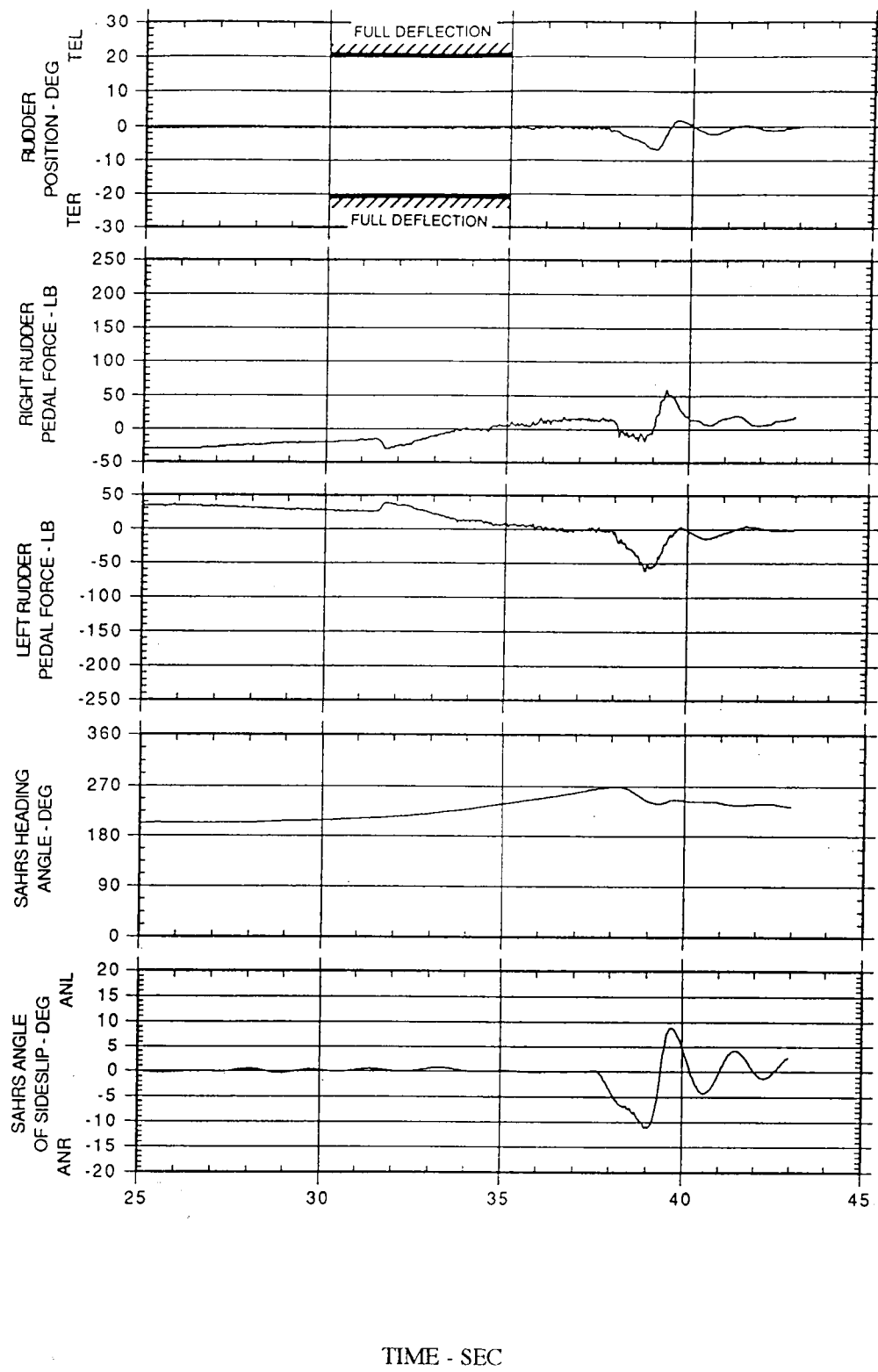


Figure 4 (Cont'd)

MODEL T-45A AIRPLANE
BuNo 163599

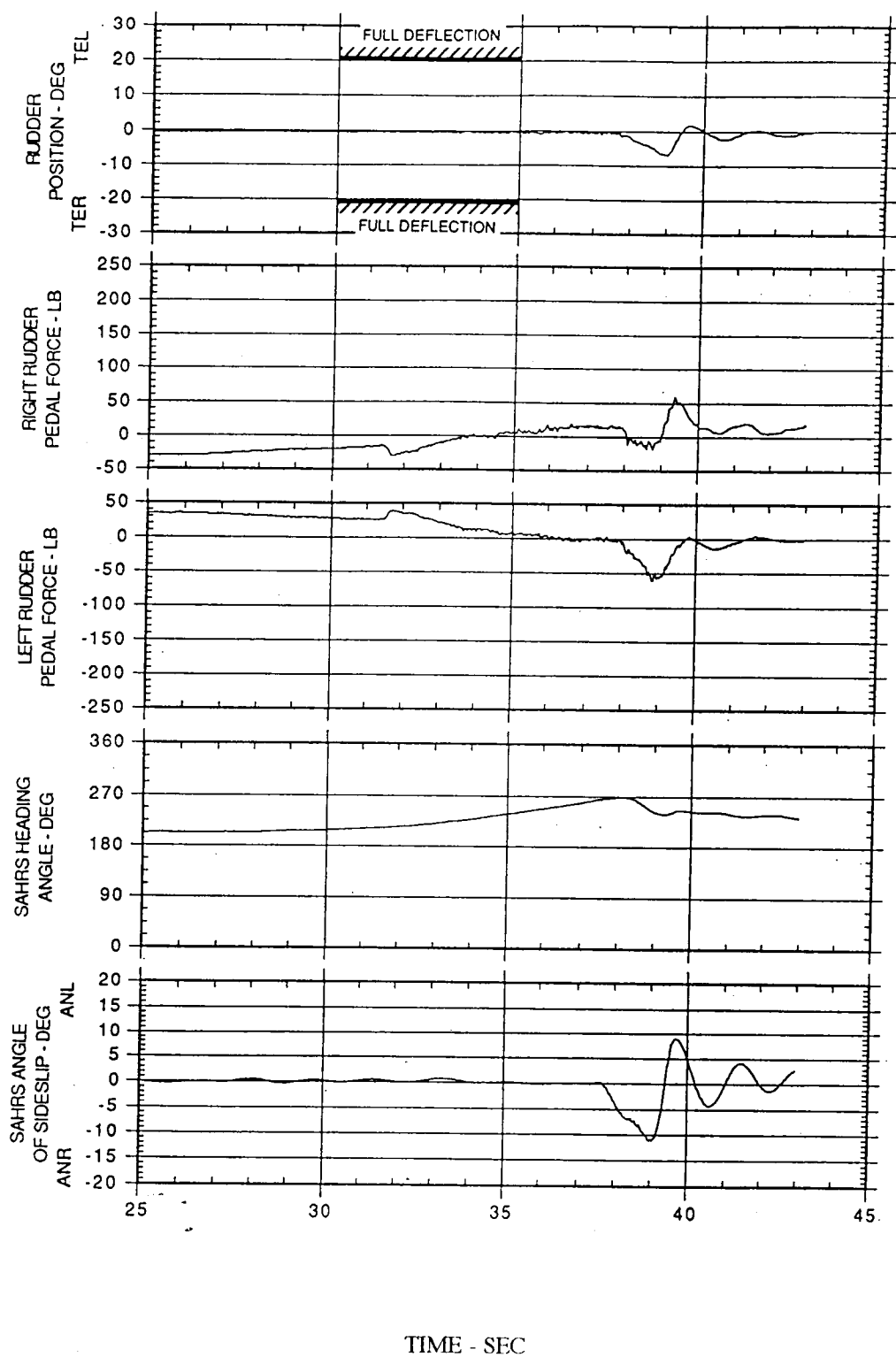


Figure 4 (Cont'd)

MODEL T-45A AIRPLANE
BuNo 163599

Control Aug: ALL
Gross Weight: 12,950 lb
RPM: 92%

Configuration: CR
CG: 17.9% MAC
Speed Brakes: Retracted
Loading: Clean

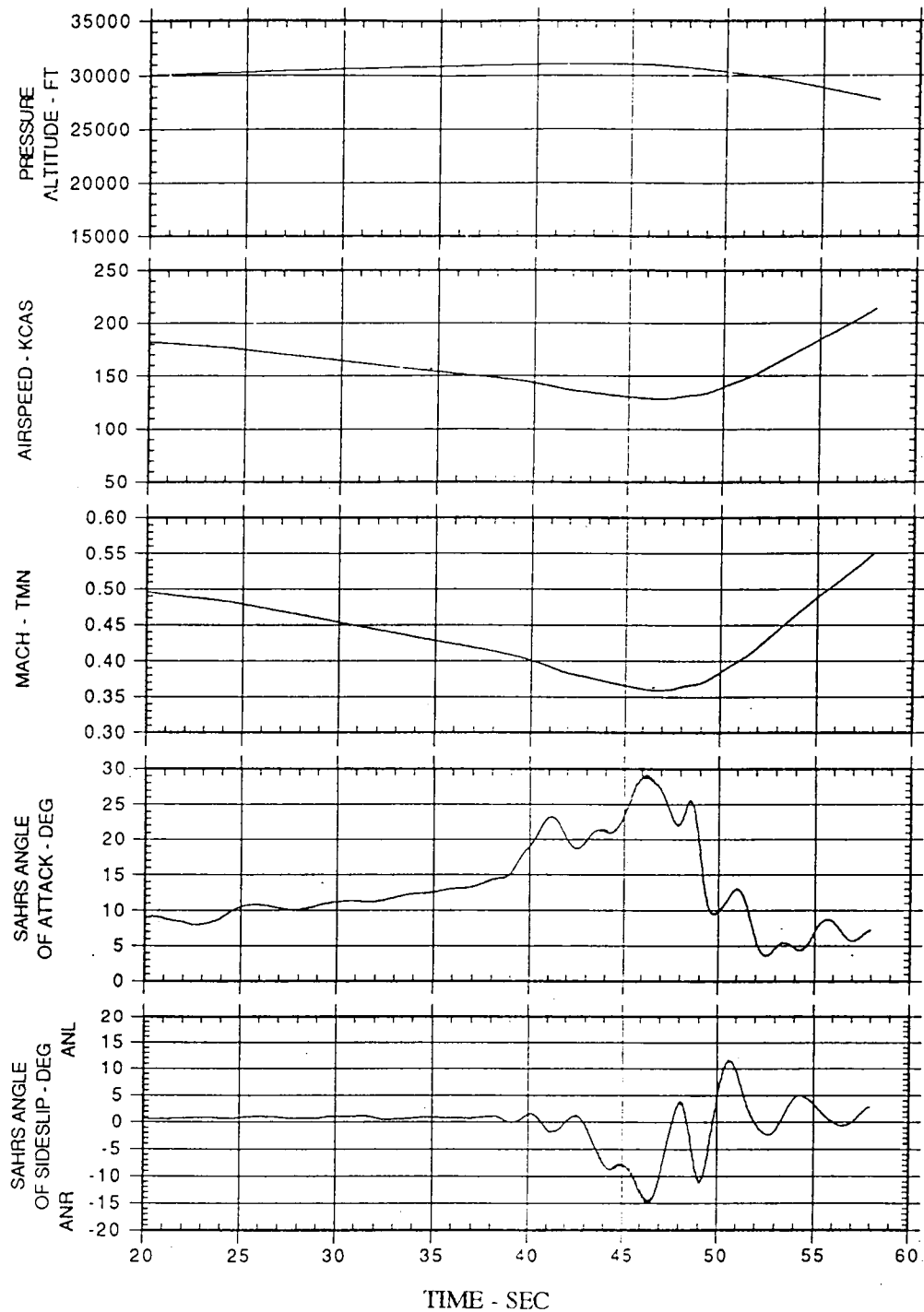


Figure 5
0.4 MACH FULL COORDINATED 360 DEG ROLL AT FULL BACK STICK

MODEL T-45A AIRPLANE
BuNo 163599

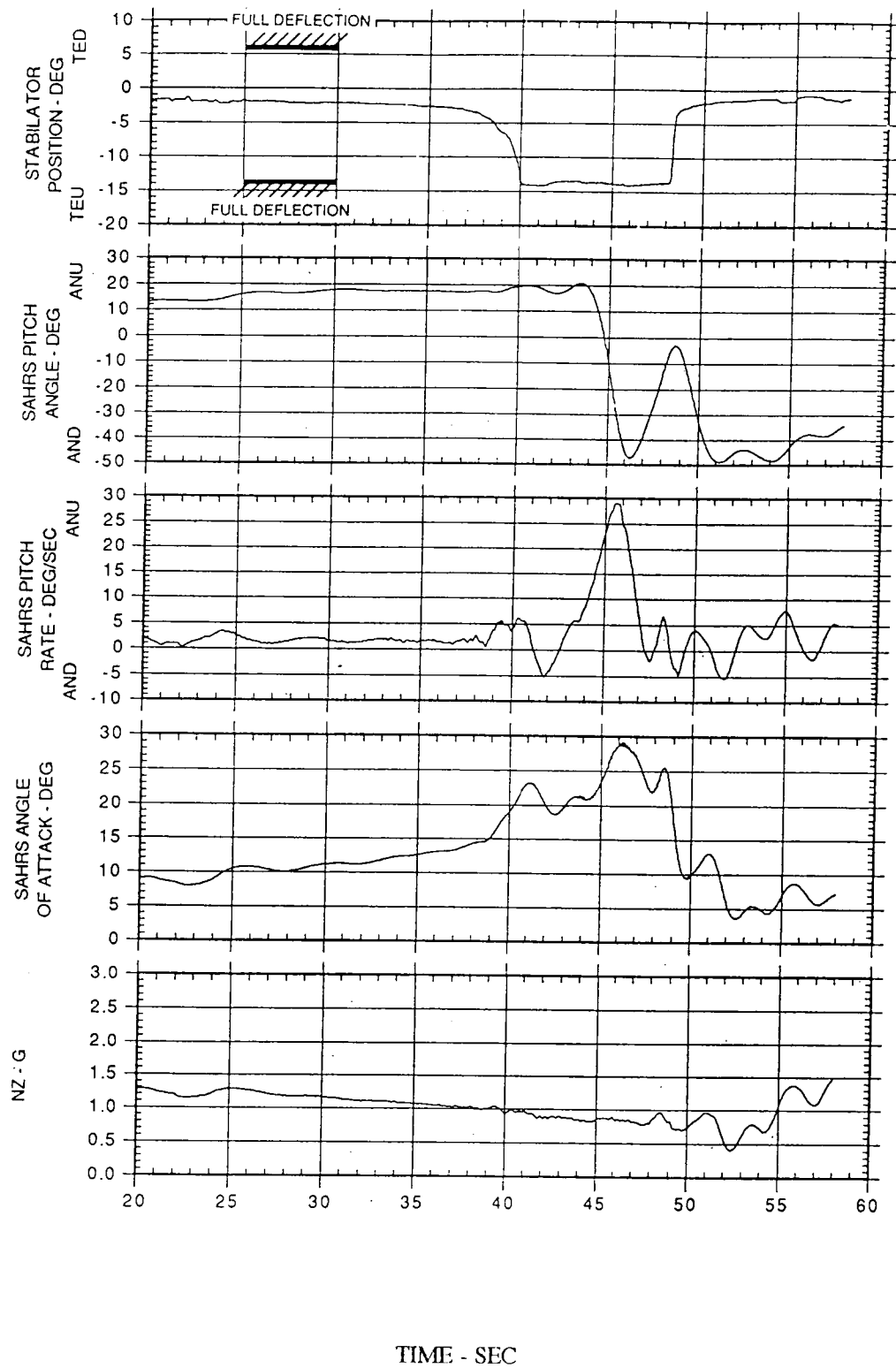


Figure 5(Cont'd)

MODEL T-45A AIRPLANE
BuNo 163599

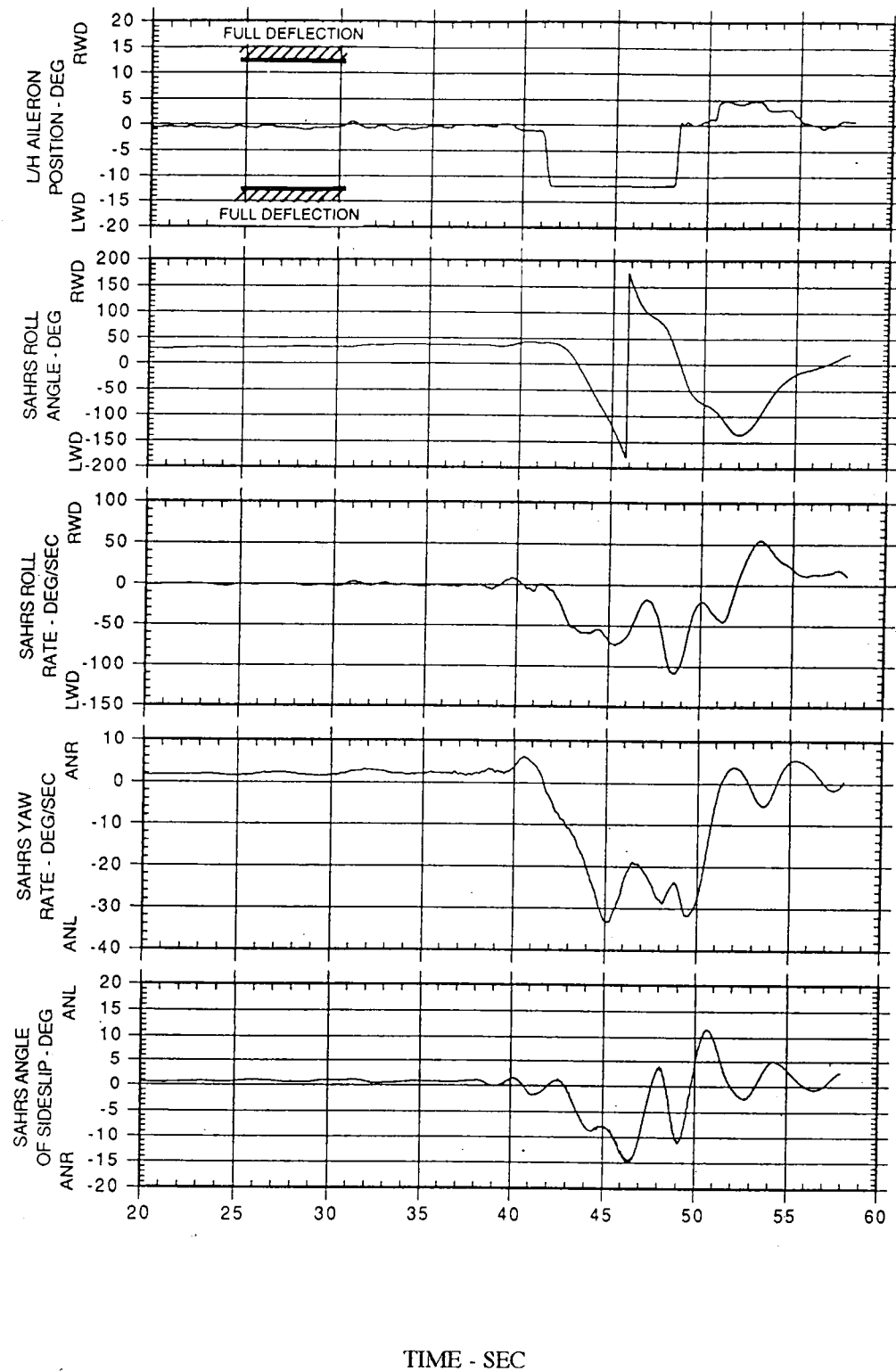


Figure 5(Cont'd)

MODEL T-45A AIRPLANE
BuNo 163599

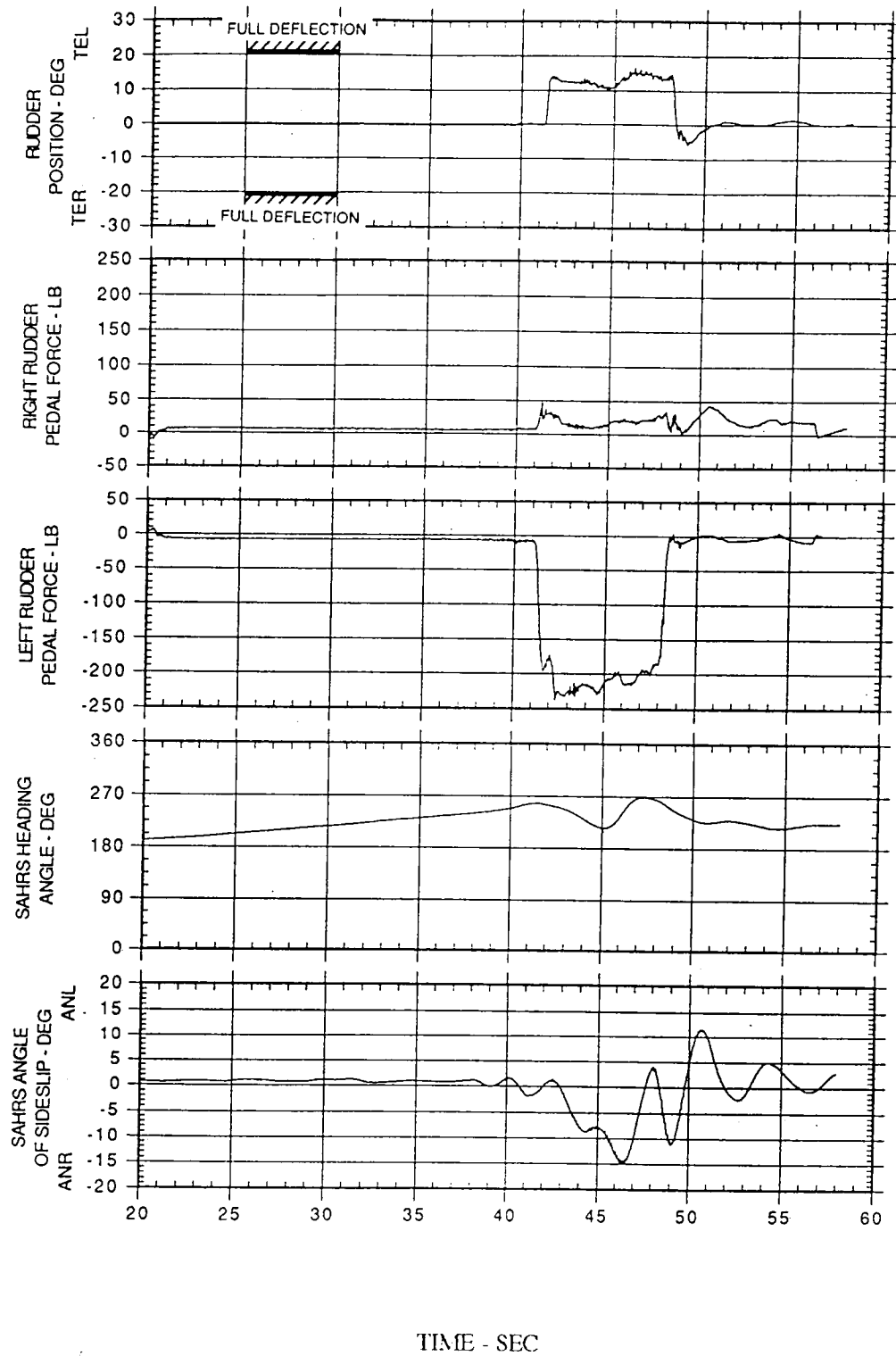


Figure 5 (Cont'd)

MODEL T-45A AIRPLANE
BuNo 163599

Control Aug: ALL
Gross Weight: 12,200 lb
Thrust: IDLE

Configuration: CR
CG: 17.7% MAC
Speed Brakes: Retracted
Loading: Clean

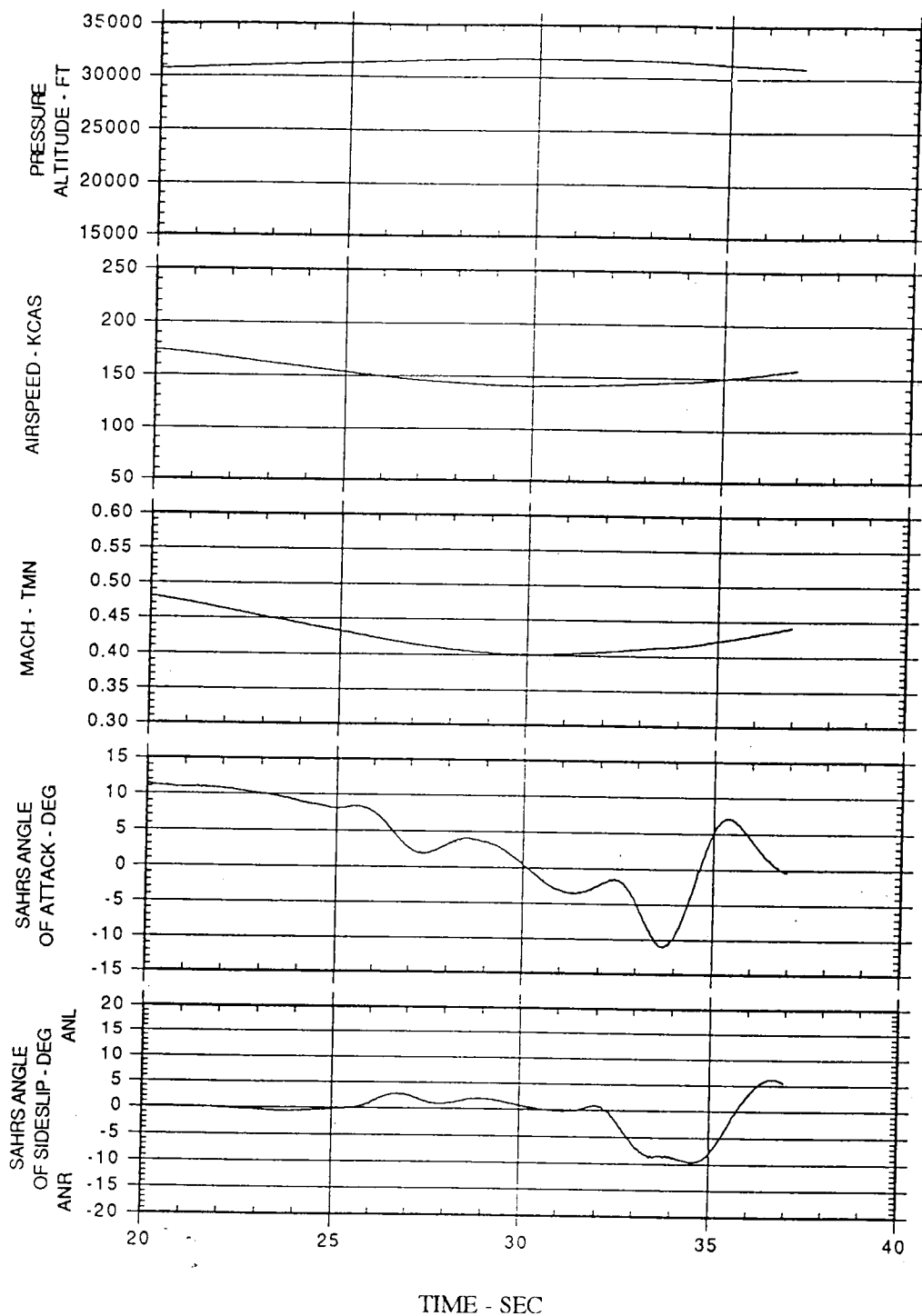
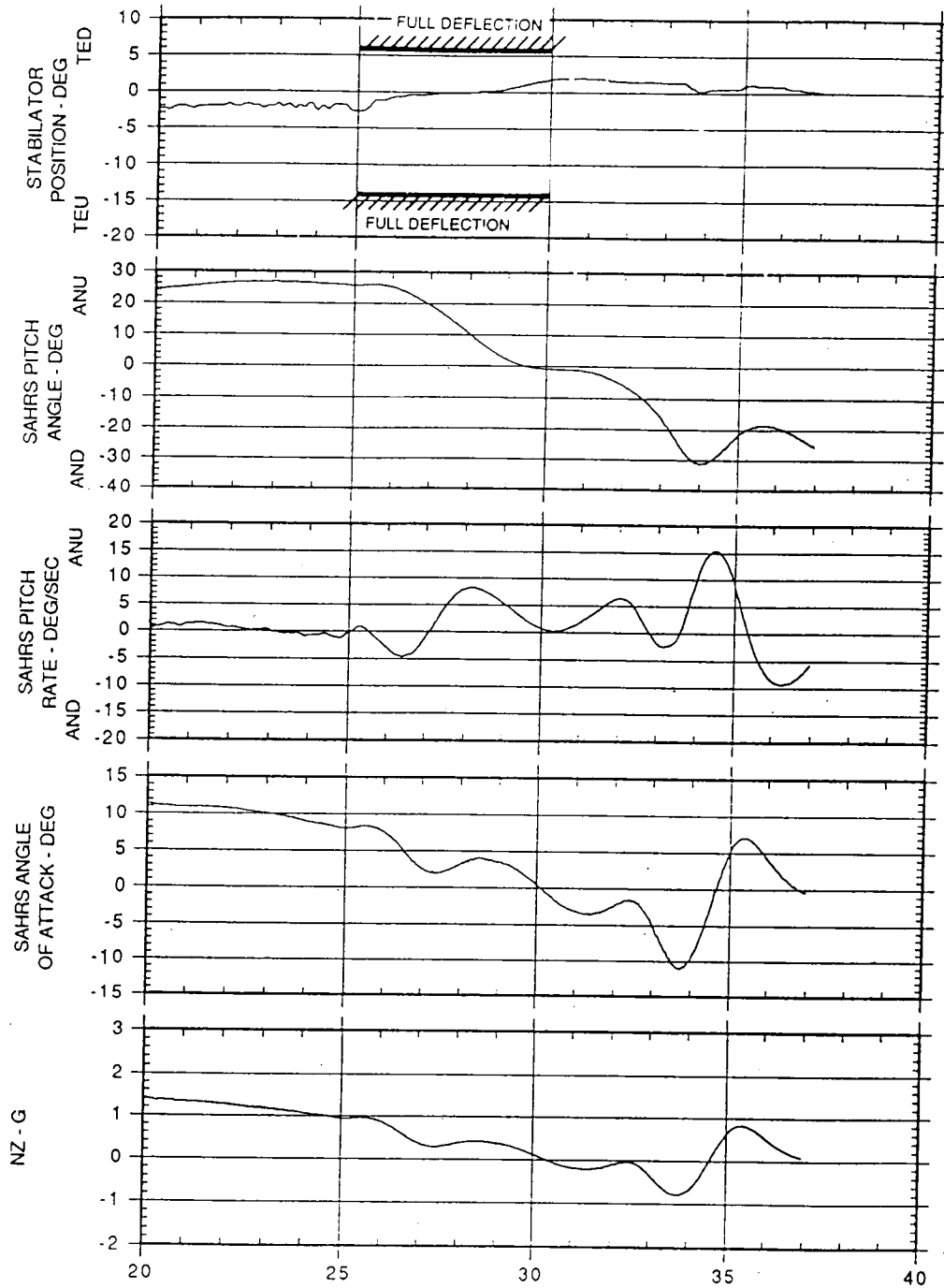


Figure 6
0.7 MACH CROSS CONTROL

MODEL T-45A AIRPLANE
BuNo 163599



TIME - SEC

Figure 6 (Cont'd)

MODEL T-45A AIRPLANE
BuNo 163599

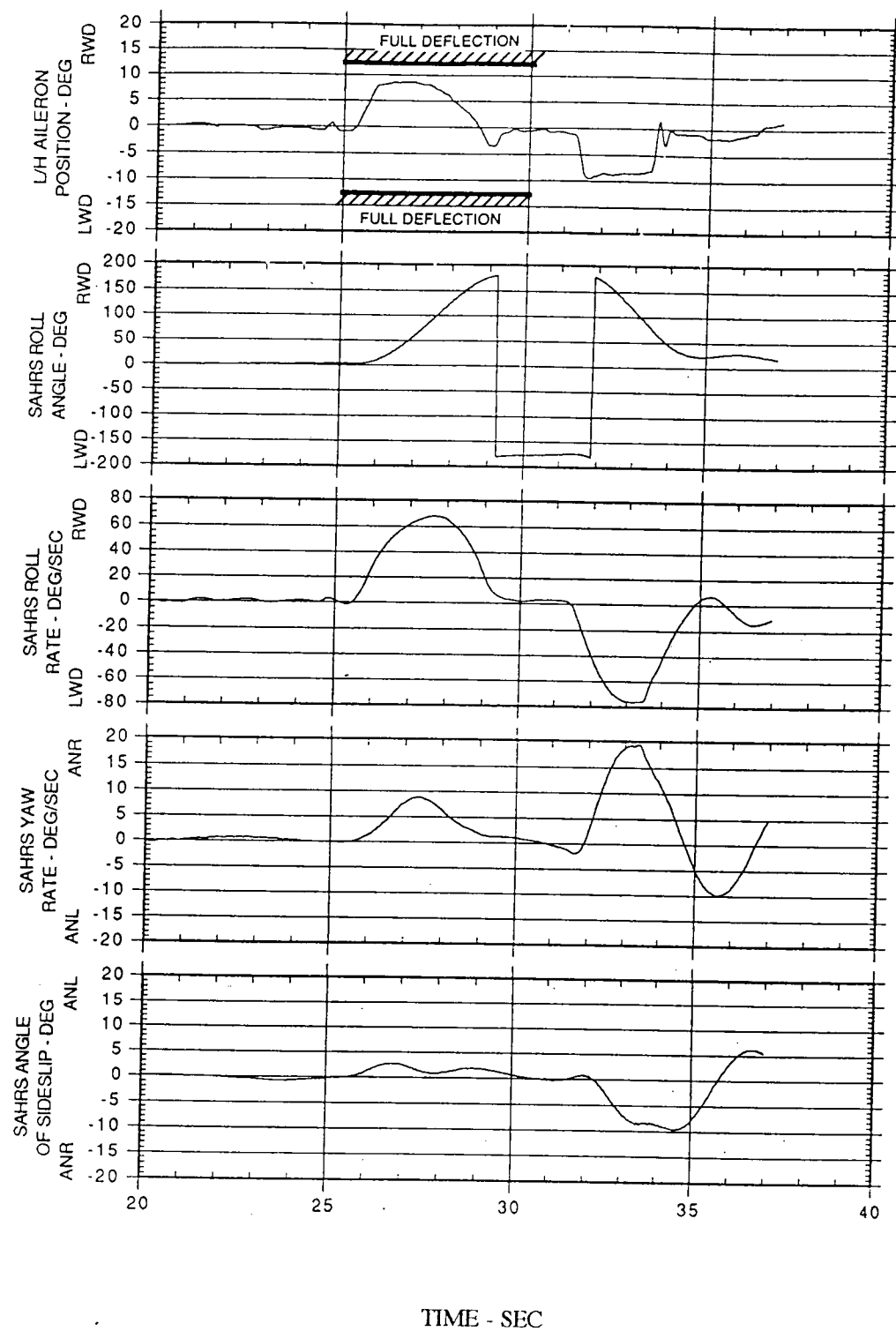


Figure 6 (Cont'd)

MODEL T-45A AIRPLANE
BuNo 163599

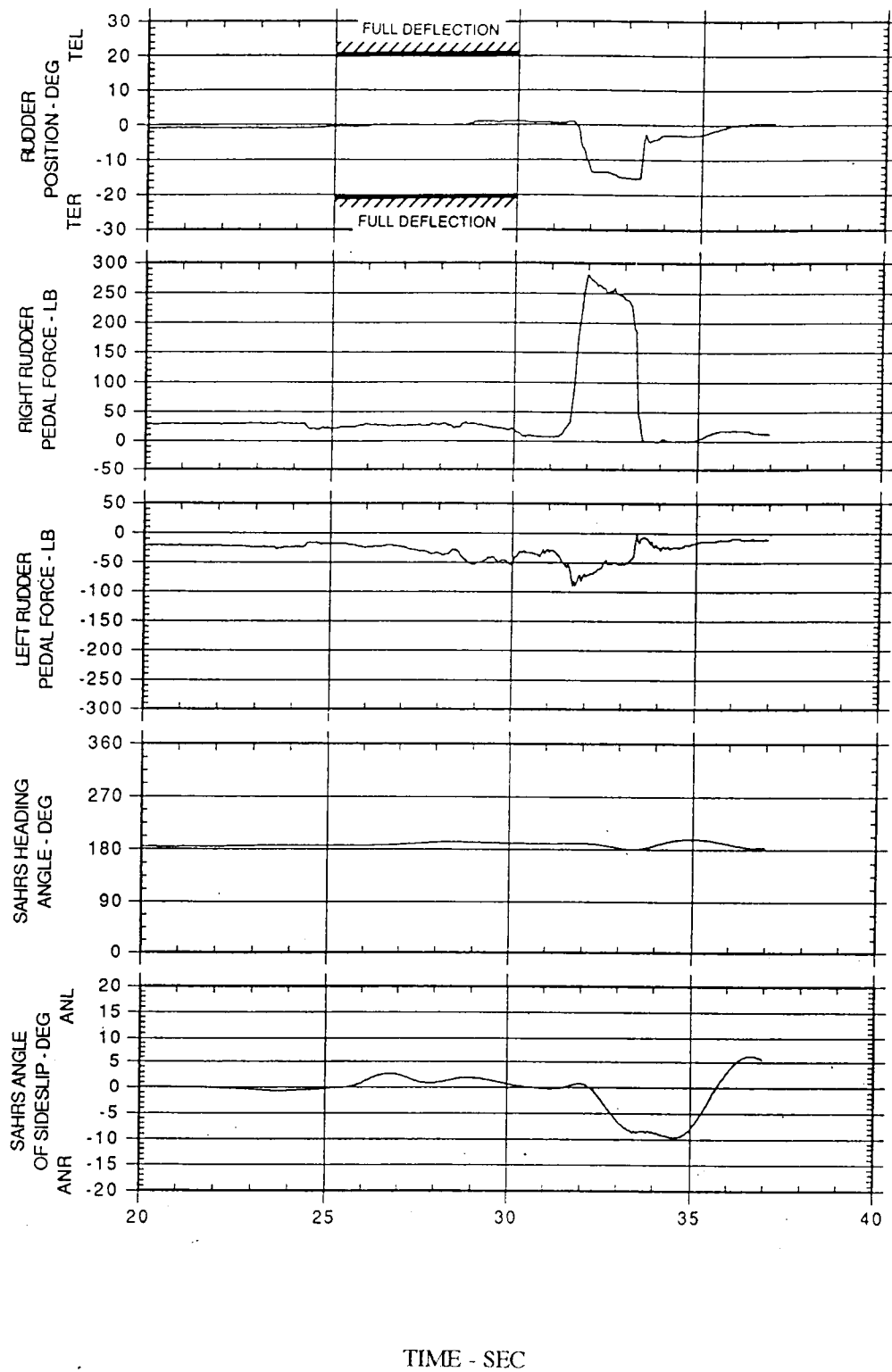


Figure 6 (Cont'd)

MODEL T-45A AIRPLANE
BuNo 163599

Control Aug: SBI
Gross Weight: 12,900 lb
Thrust: IDLE

Configuration: CR
CG: 18.4% MAC
Speed Brakes: Extended
Loading: Clean

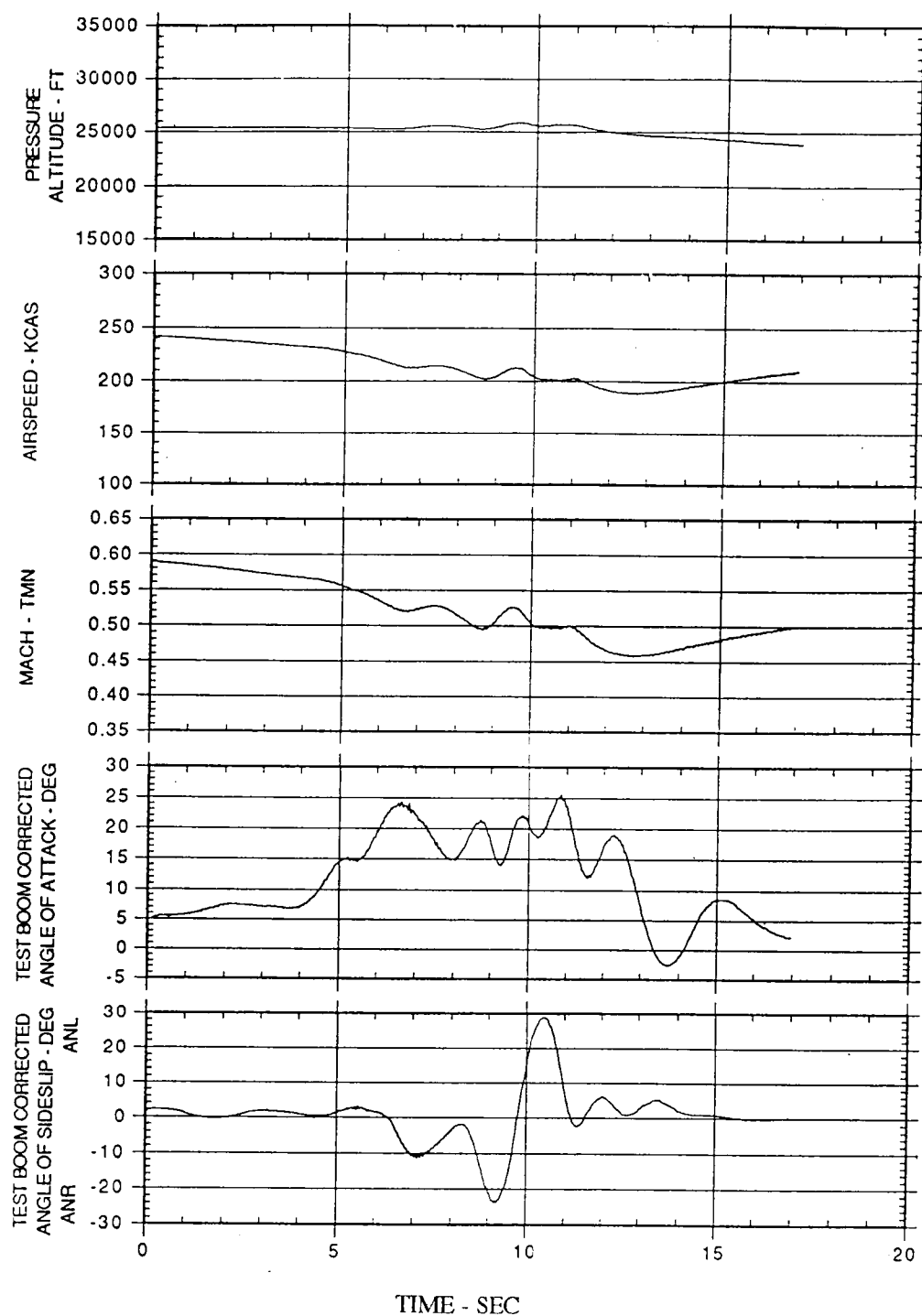
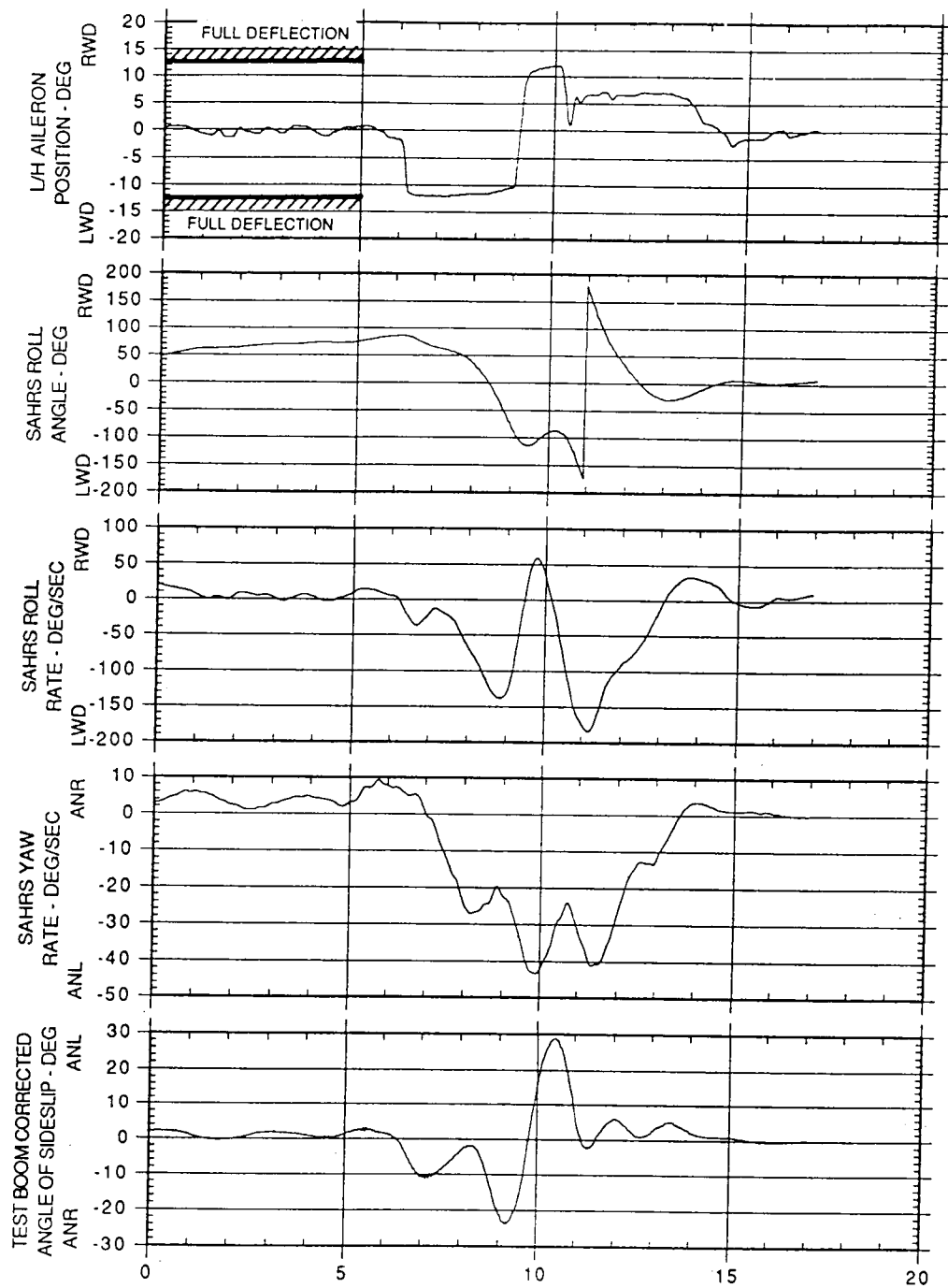


Figure 7
LATERAL STICK OUT-OF-CONTROL FLIGHT TRAINING MANEUVER

MODEL T-45A AIRPLANE
BuNo 163599



TIME - SEC

Figure 7 (Cont'd)

MODEL T-45A AIRPLANE
BuNo 163599

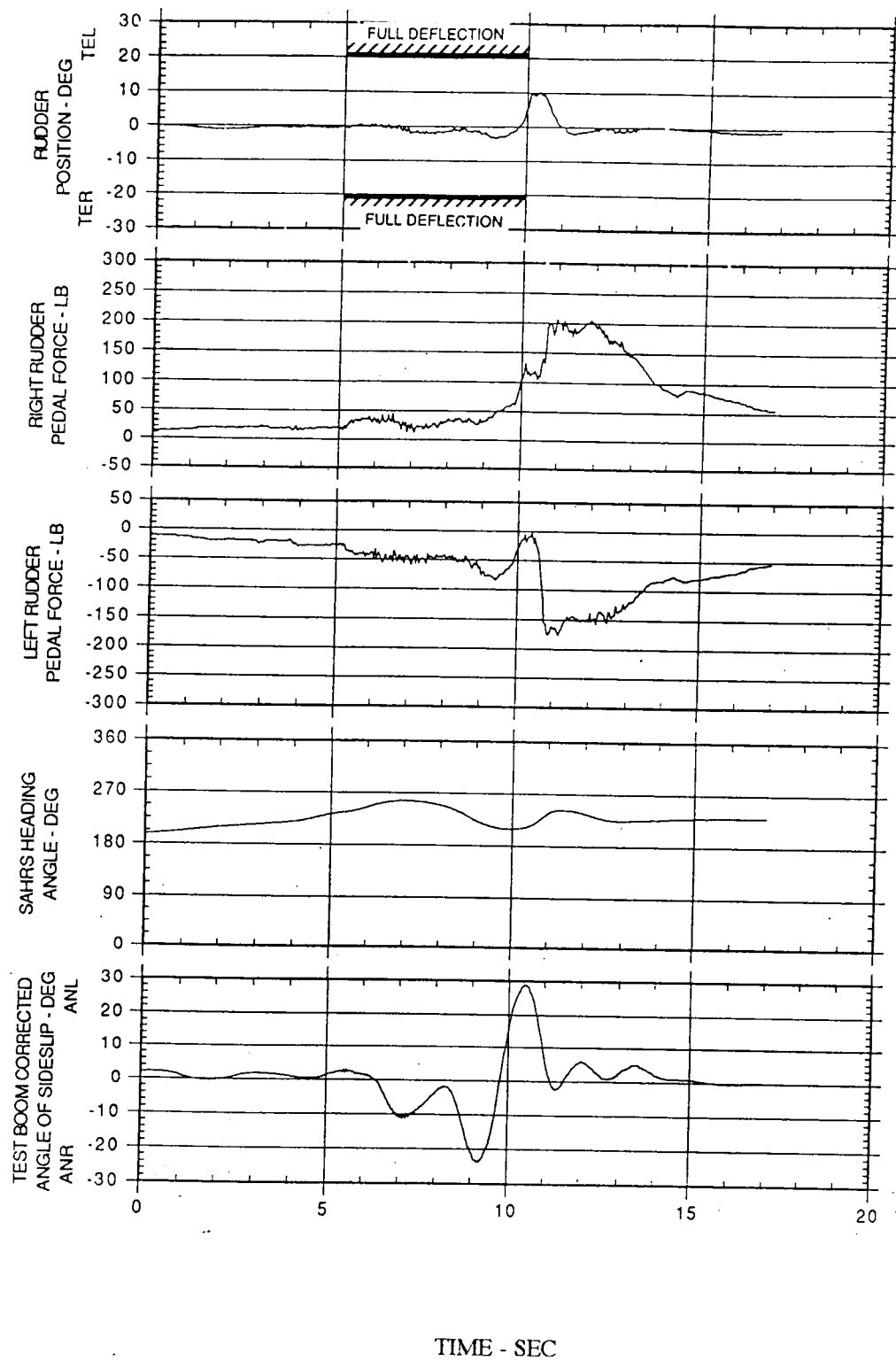


Figure 7 (Cont'd)

MODEL T-45A AIRPLANE
BuNo 163599

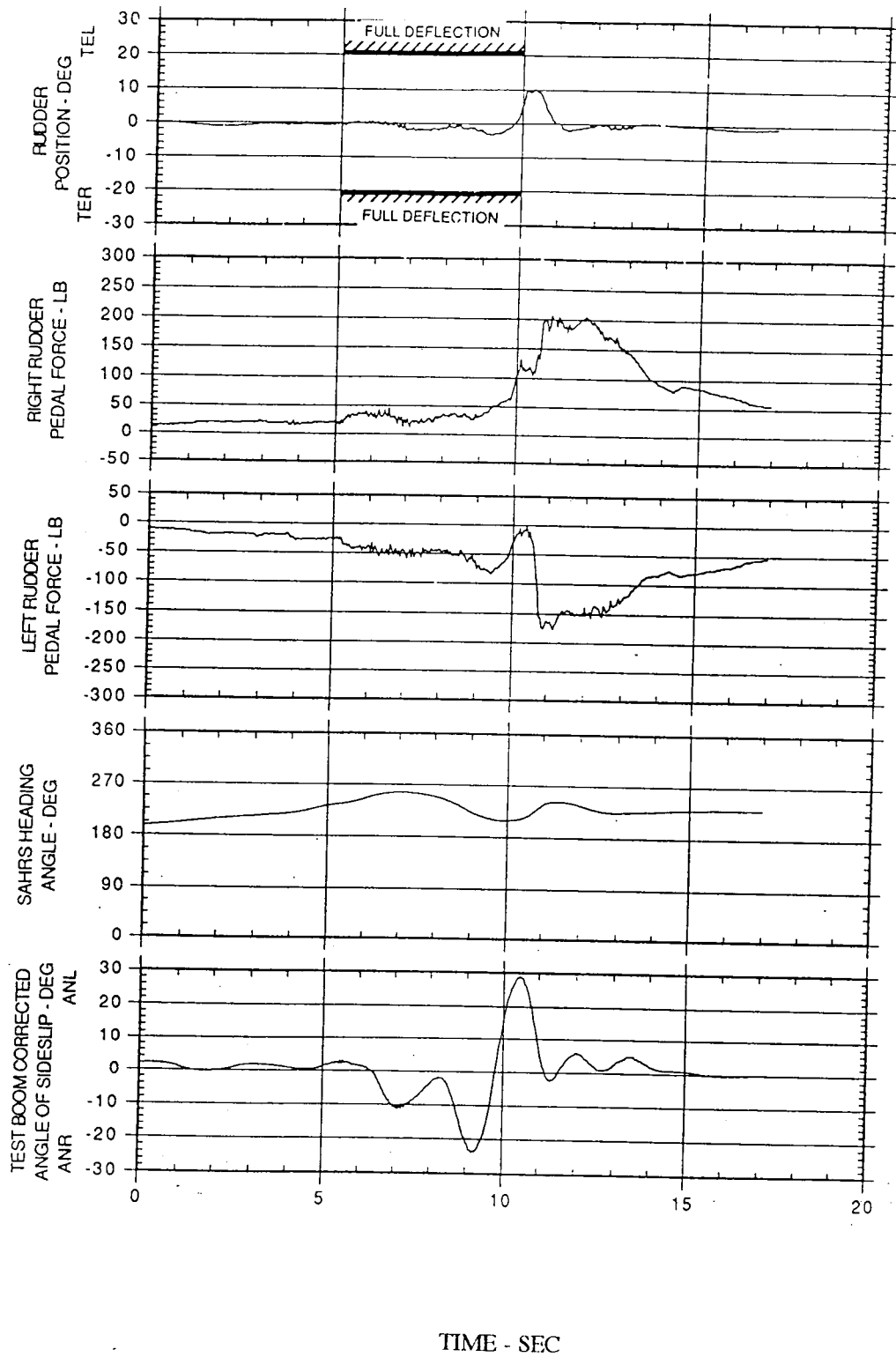


Figure 7 (Cont'd)

MODEL T-45A AIRPLANE
BuNo 163599

Control Aug: SBI
Gross Weight: 12,550 lb
Thrust: IDLE

Configuration: CR
CG: 18.9% MAC
Speed Brakes: Retracted
Loading: Clean

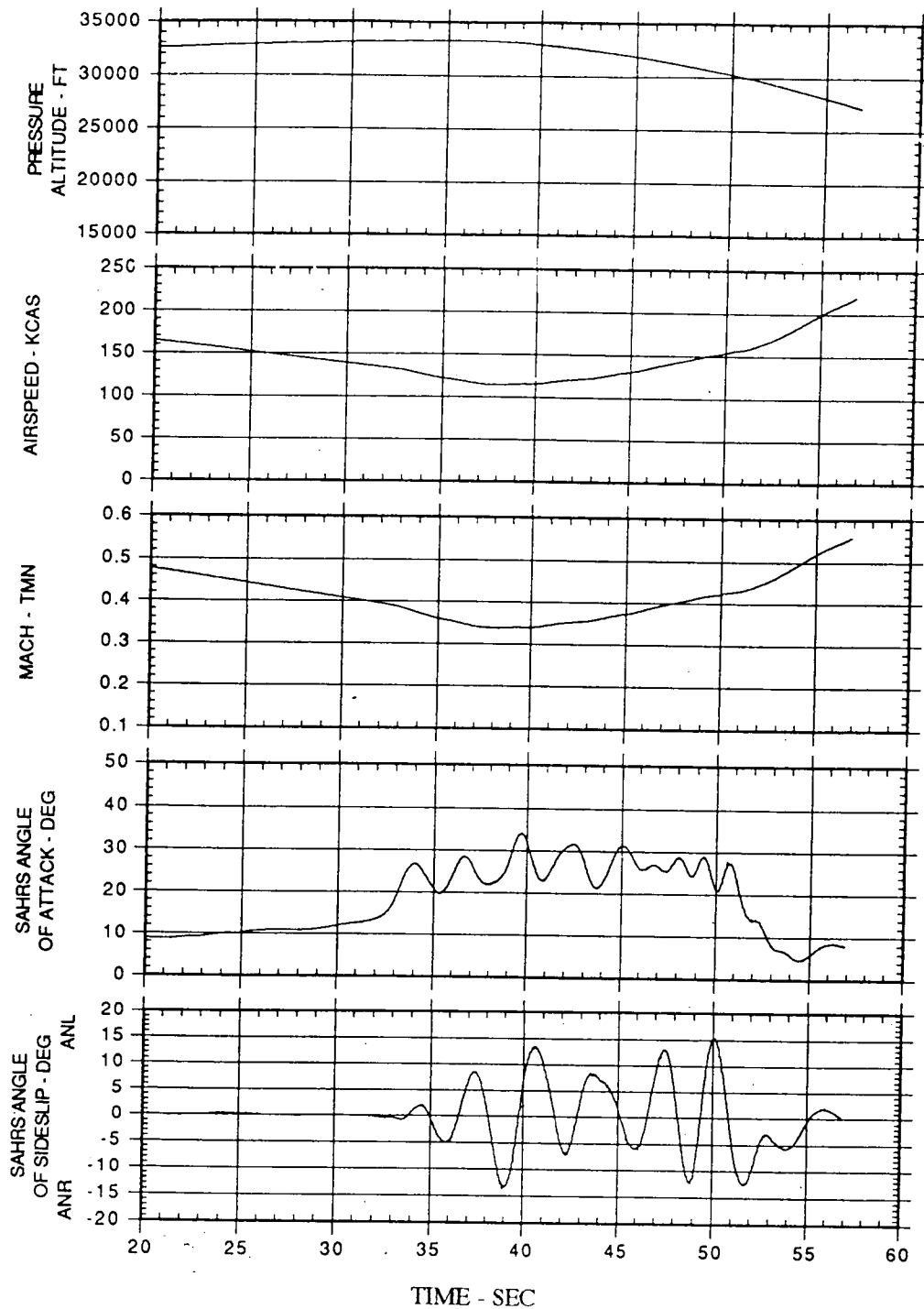


Figure 8
HAWK MODE SPIN

MODEL T-45A AIRPLANE
BuNo 163599

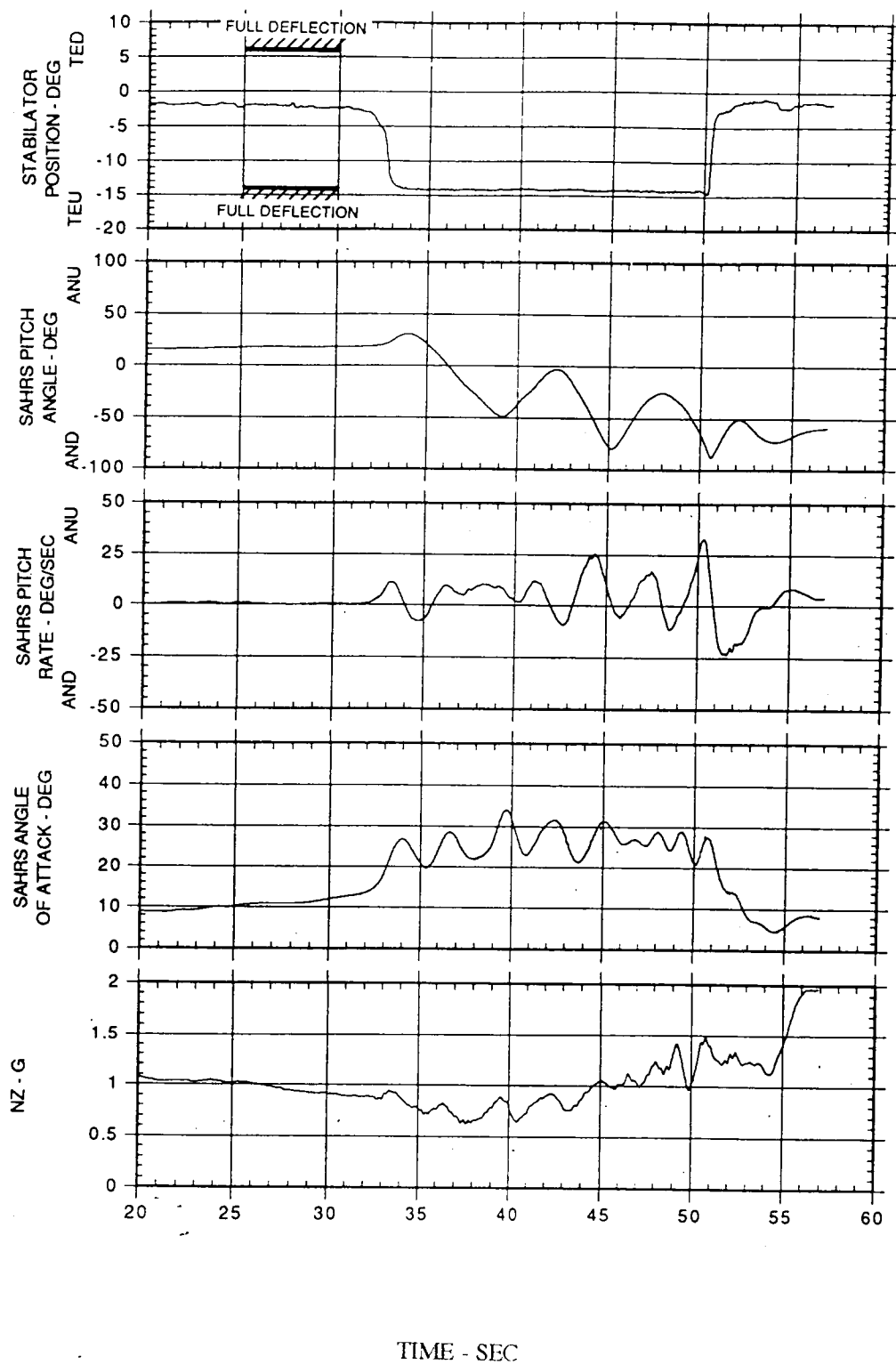


Figure 8 (Cont'd)

MODEL T-45A AIRPLANE
BuNo 163599

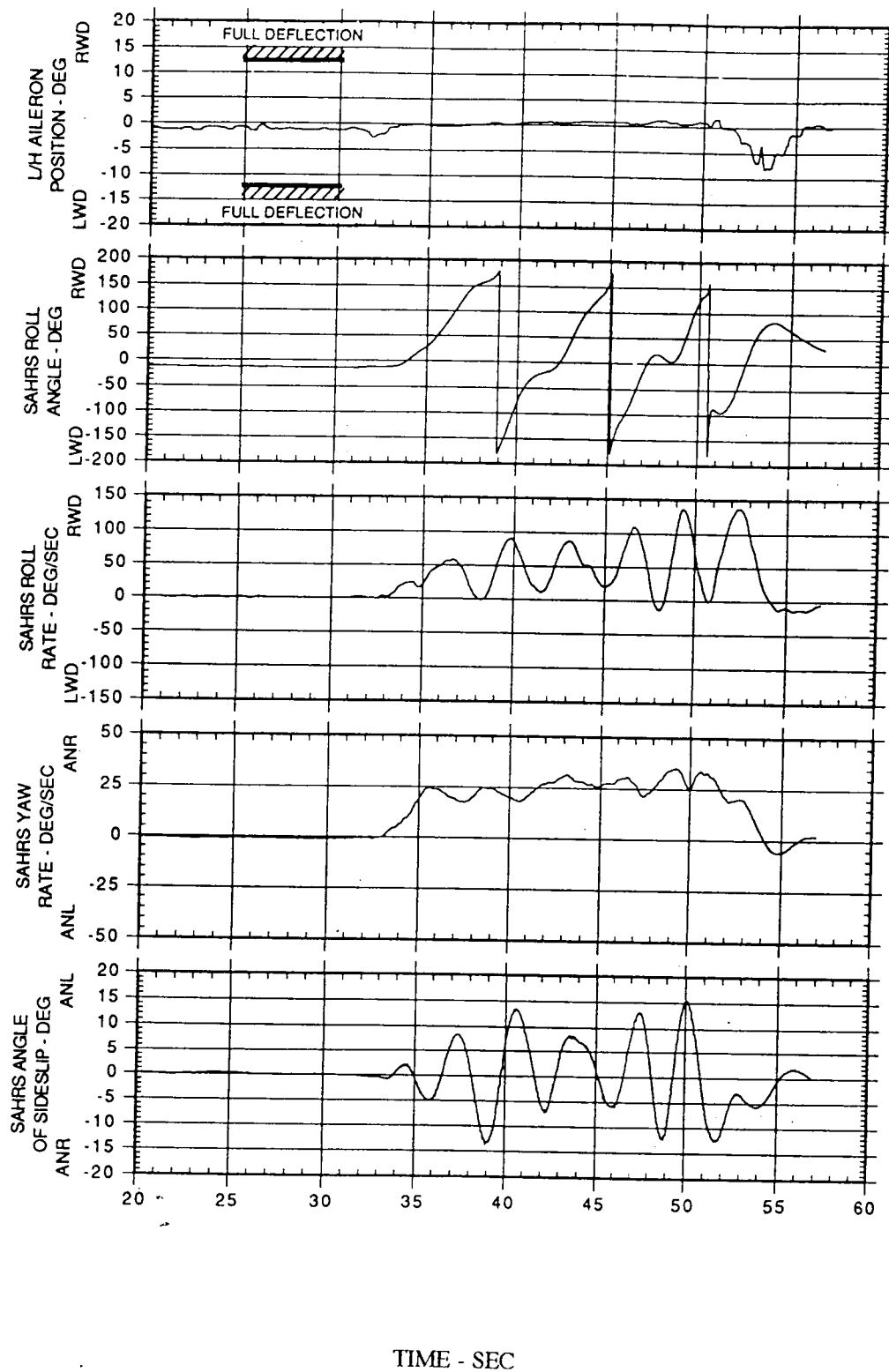


Figure 8 (Cont'd)

MODEL T-45A AIRPLANE
BuNo 163599

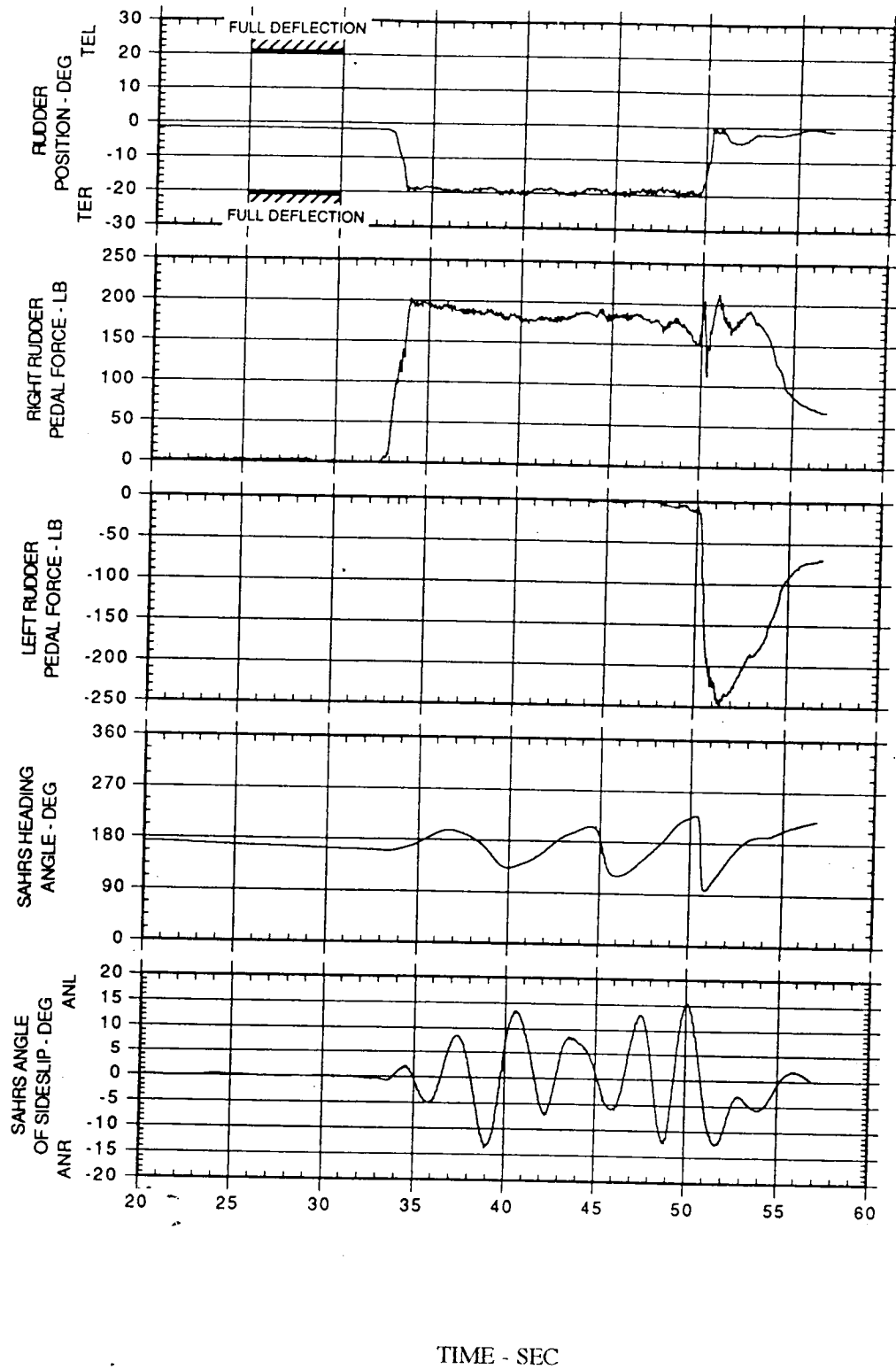


Figure 8 (Cont'd)

MODEL T-45A AIRPLANE
BuNo 163599

Control Aug: SBI (Failed during maneuver)
Gross Weight: 12,100 lb
Thrust: IDLE

Configuration: CR
CG: 17.9% MAC
Speed Brakes: Retracted
Loading: Clean

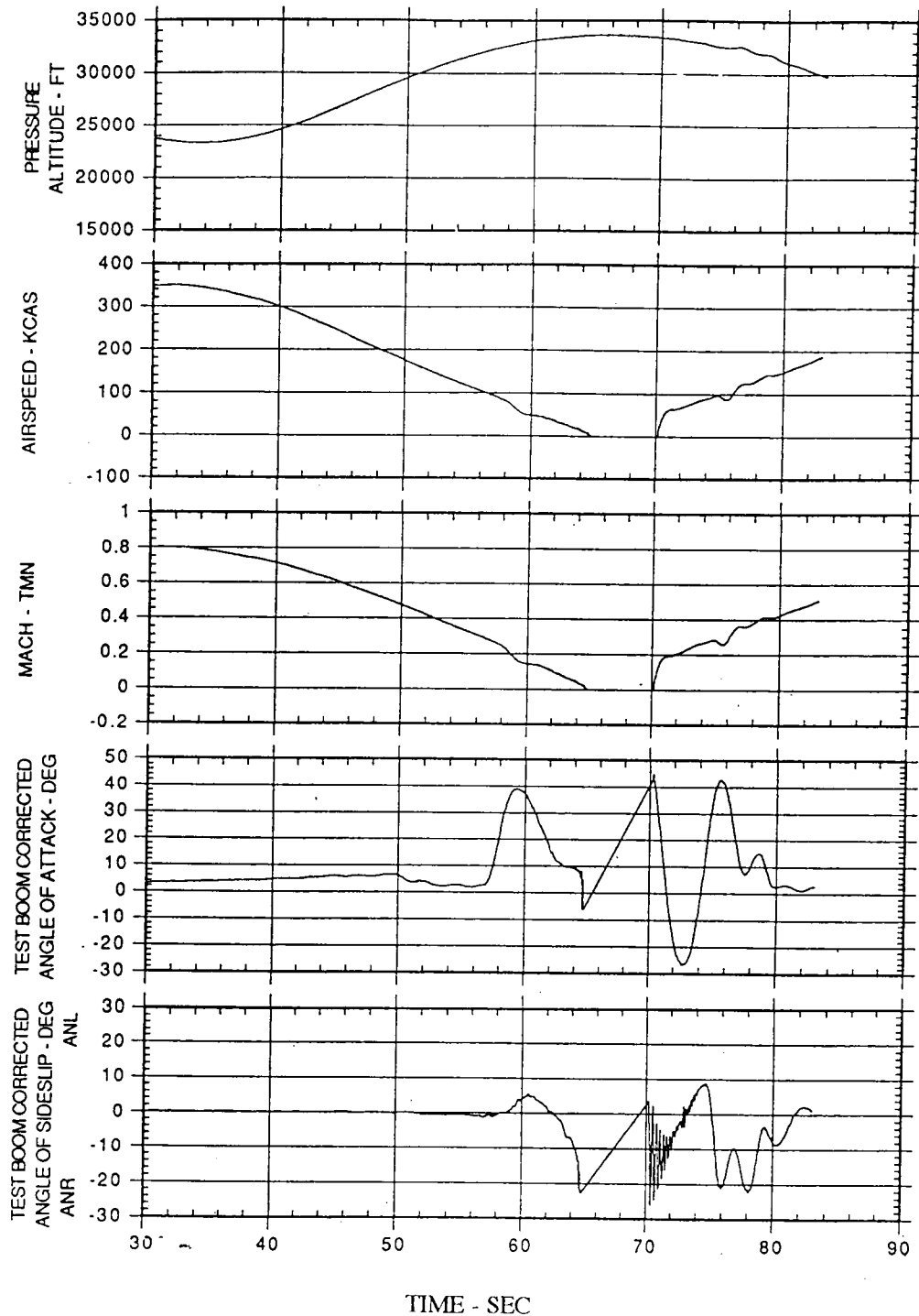


Figure 9
TYPICAL VERTICAL MANEUVER WITHIN 10 DEG OF VERTICAL

MODEL T-45A AIRPLANE
BuNo 163599

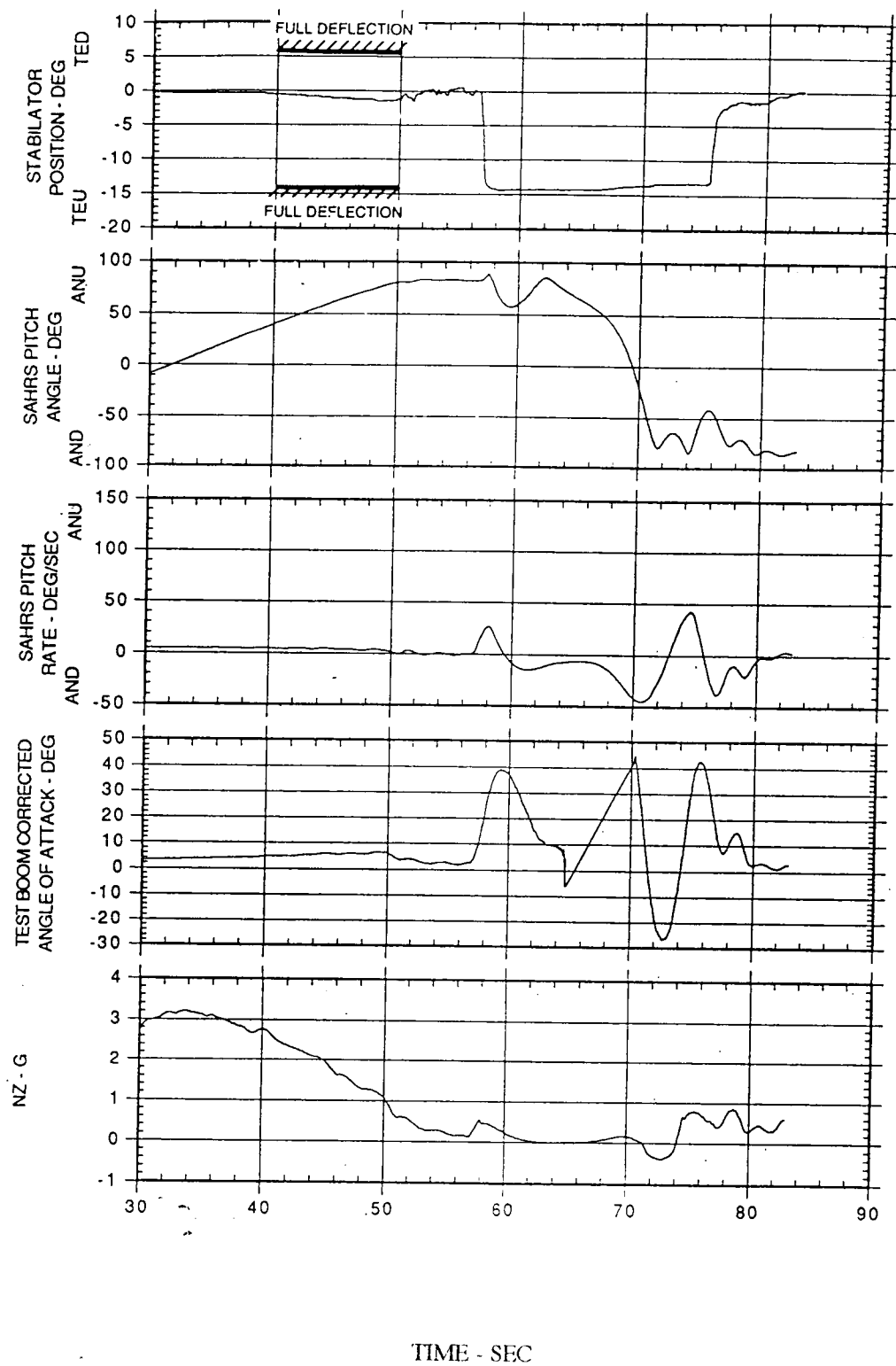


Figure 9 (Cont'd)

MODEL T-45A AIRPLANE
BuNo 163599

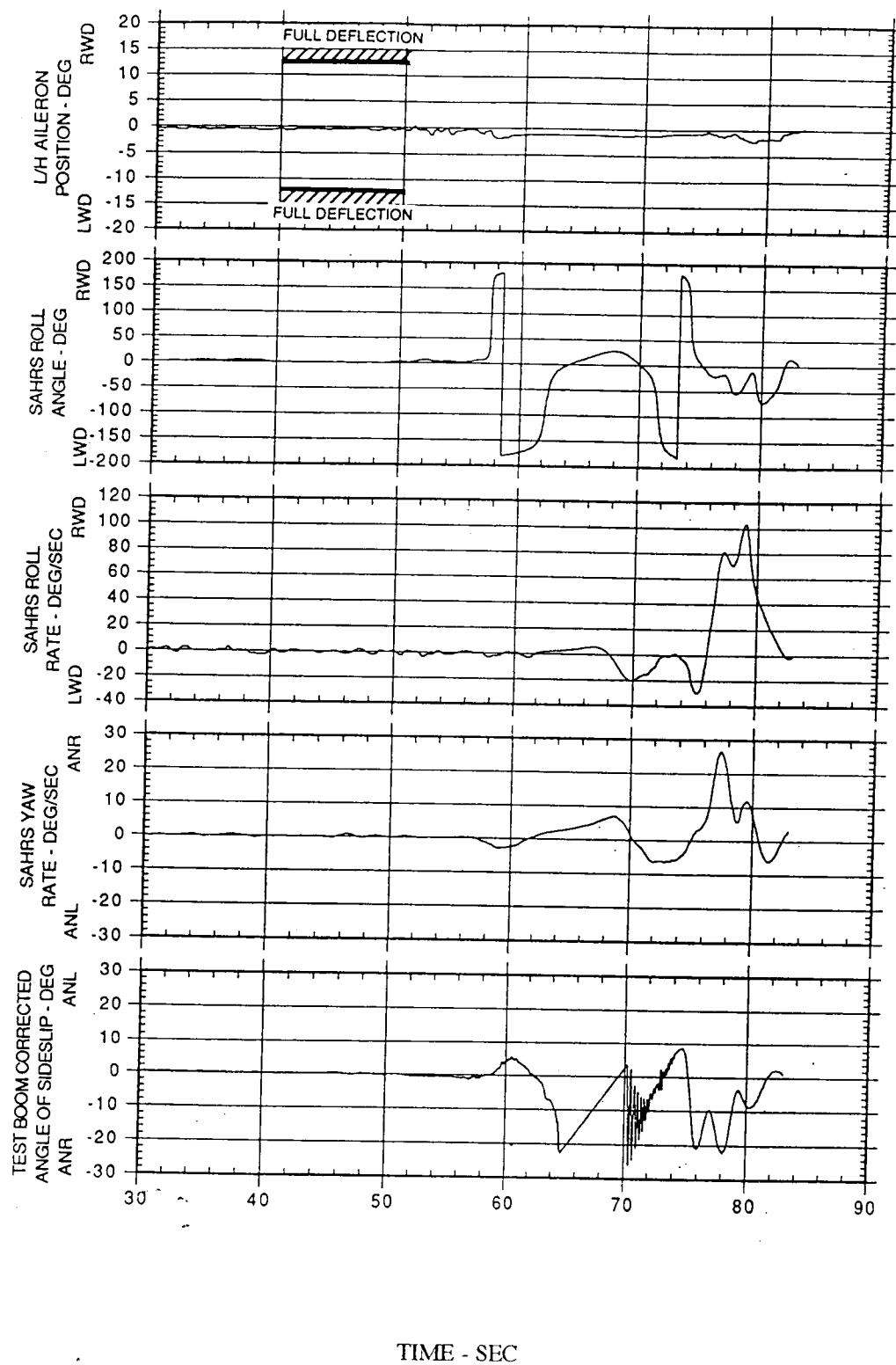


Figure 9 (Cont'd)

MODEL T-45A AIRPLANE
BuNo 163599

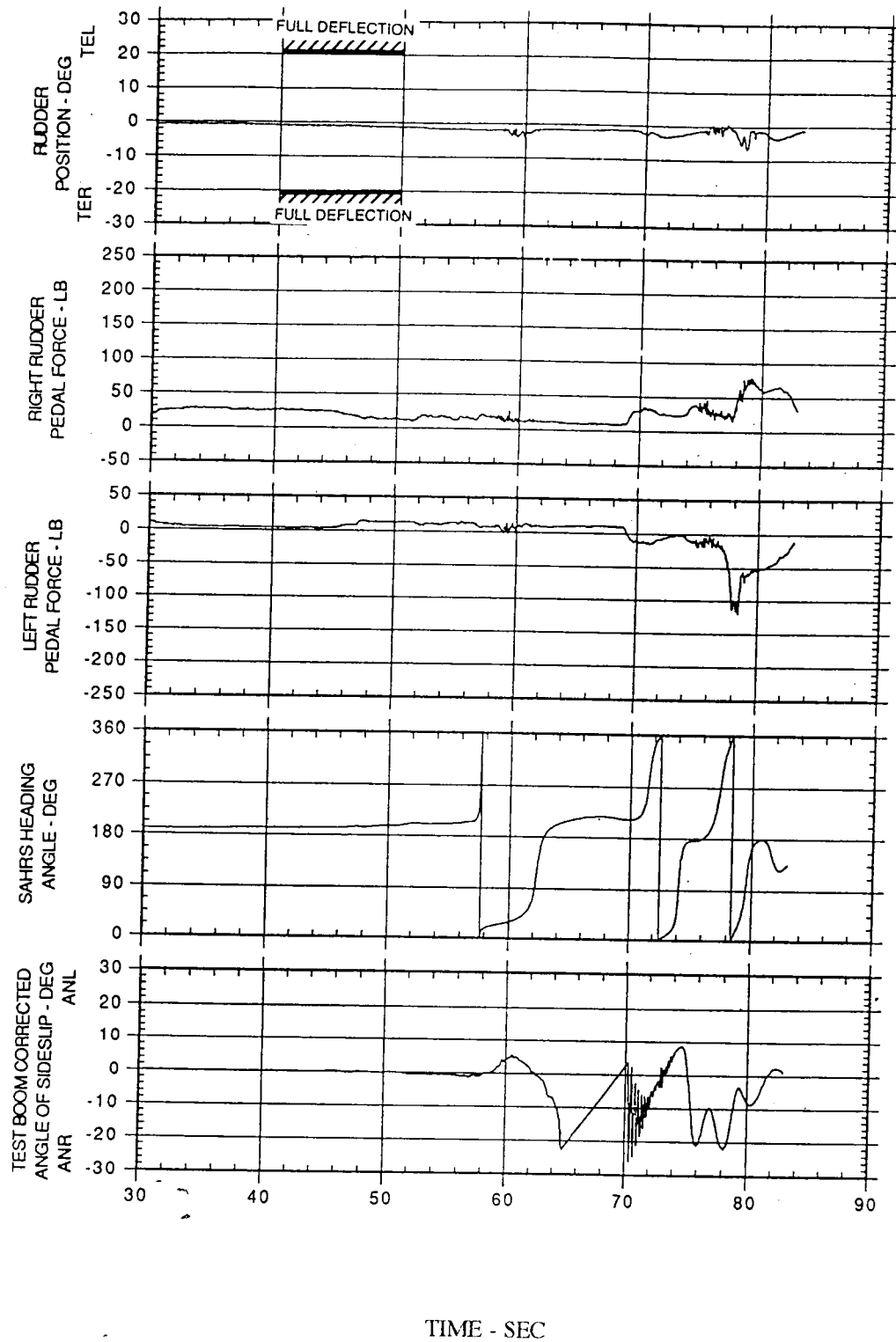


Figure 9 (Cont'd)

MODEL T-45A AIRPLANE
BuNo 163599

Control Aug: ALL
Gross Weight: 11,900 lb
Thrust: IDLE

Configuration: CR
CG: 17.4% MAC
Speed Brakes: Retracted
Loading: Clean

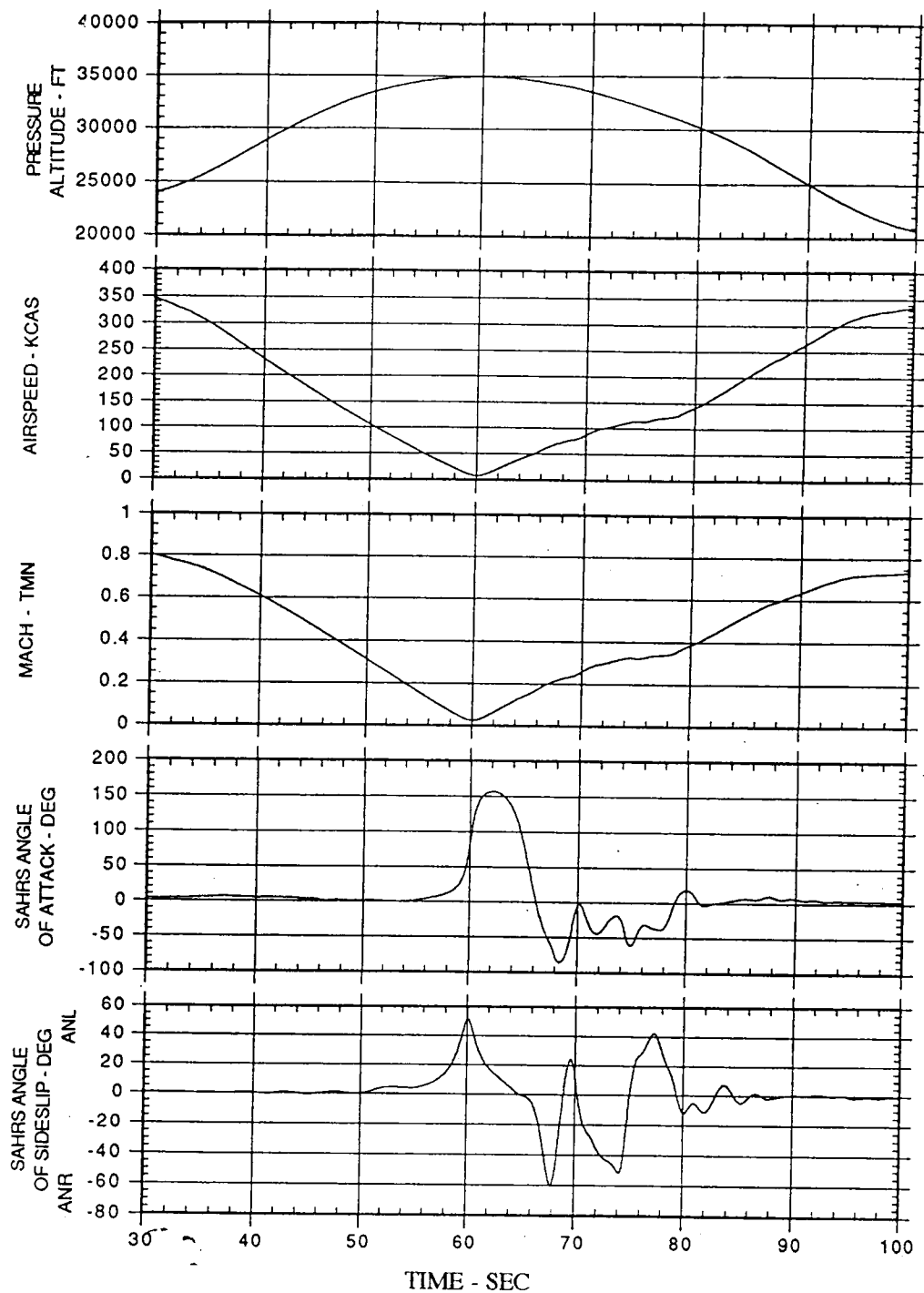


Figure 10
INCIPIENT INVERTED SPIN FROM VERTICAL MANEUVER

MODEL T-45A AIRPLANE
BuNo 163599

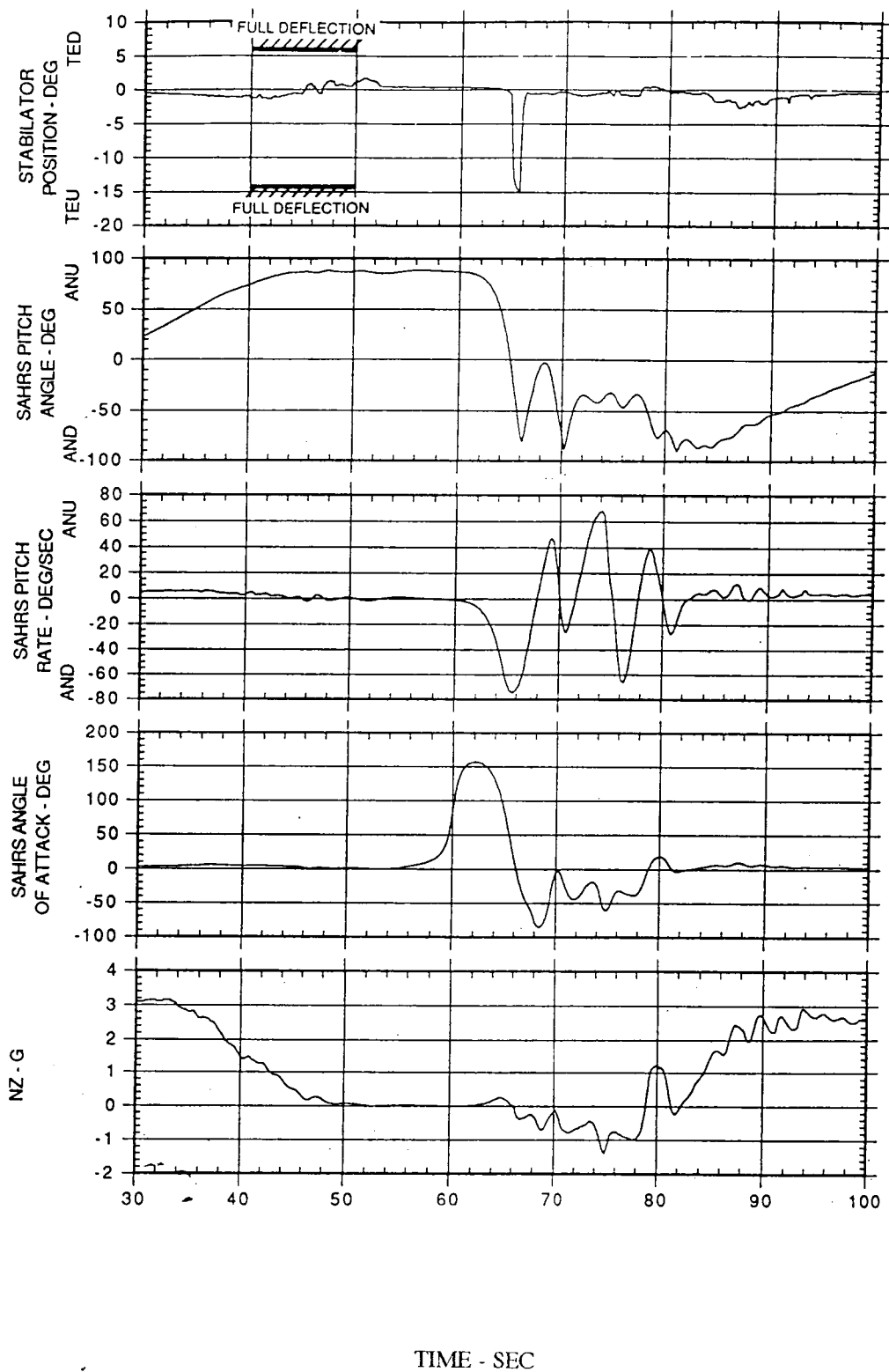


Figure 10 (Cont'd)

MODEL T-45A AIRPLANE
BuNo 163599

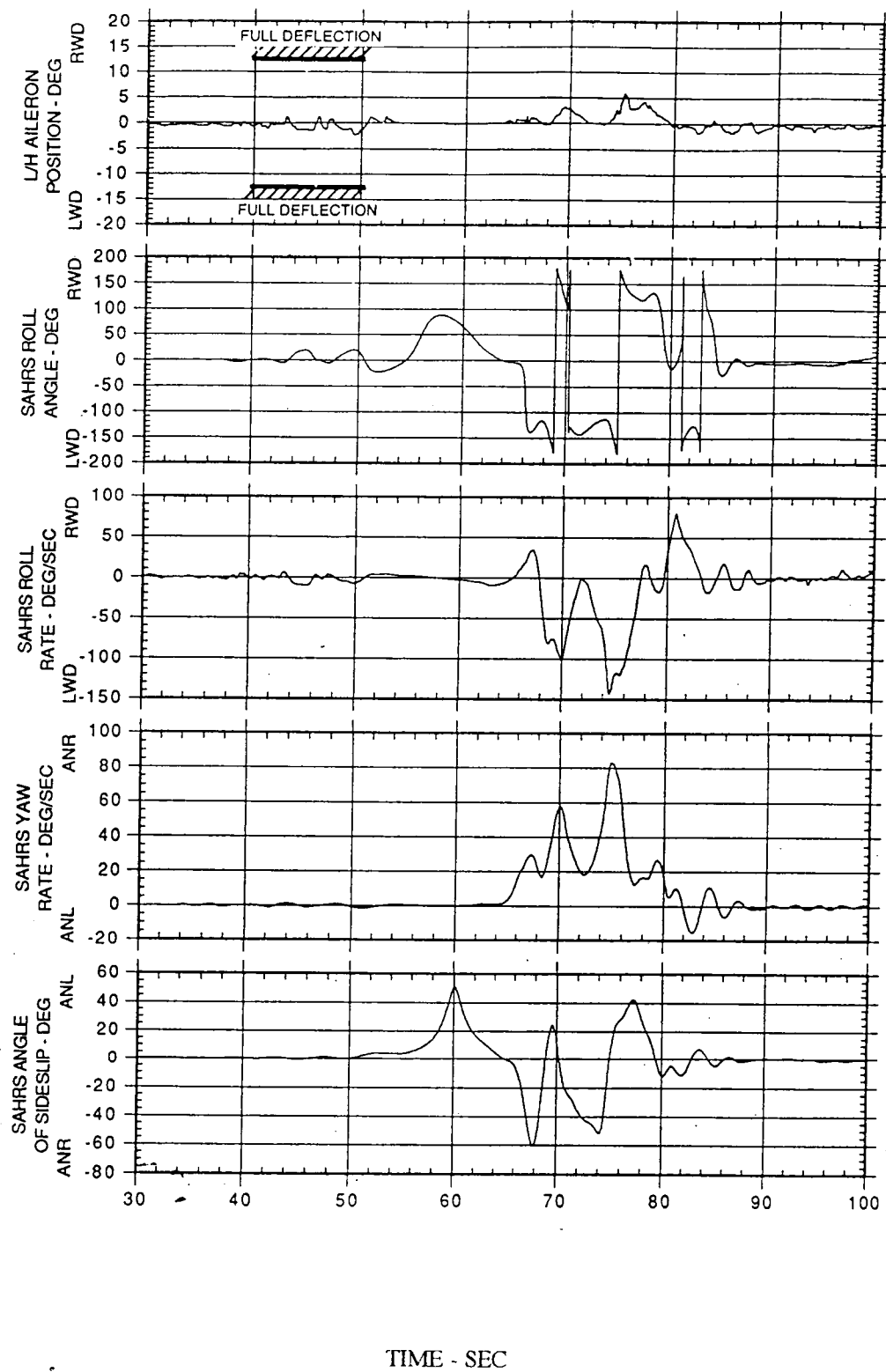


Figure 10 (Cont'd)

MODEL T-45A AIRPLANE
BuNo 163599

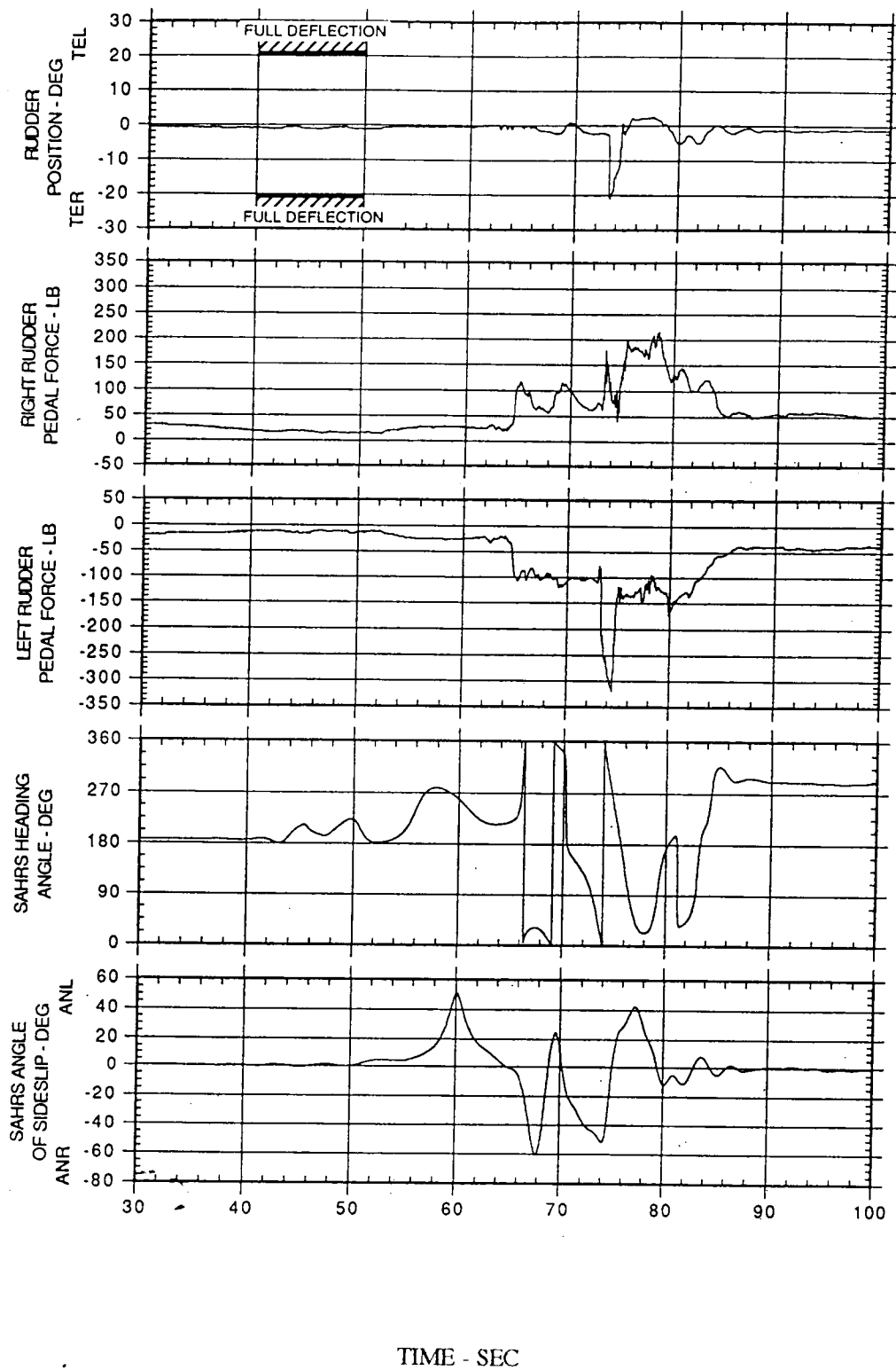


Figure 10 (Cont'd)

VITA

VITA

Joseph Maximillian Rogers was born in Los Angeles, California on December 1, 1964. He lived in Puerto Rico from the age of 5 up to the age of 15. He attended catholic schools from Kindergarten through twelfth grade and graduated from Bishop Moore High School in Orlando, Florida in June, 1982. The following August he entered The University of Michigan's Engineering program with a Naval Reserve Officer Training Corps (NROTC) scholarship. In May, 1986 he received a degree of Bachelor of Science in Mechanical Engineering. He entered the United States Navy and served on active duty from May, 1986 through July, 1994 as a Naval Aviator. During his career in the Navy, he flew the mighty A-6E Intruder airplane while attached to Attack Squadron Thirty-Five detached to the USS Theodore Roosevelt (CVN-71) initially, and then to USS Saratoga (CV-60). While serving as part of the Saratoga airwing, he flew in over 30 combat missions in direct support of Operation Desert Storm. From his days as a front line attack pilot, he flew to Patuxent River Maryland to become a member of the elite corps of Navy Test Pilots. This started with his training at the United States Naval Test Pilot School (USNTPS). While at Patuxent River he served as a test pilot and project officer, flying not only the A-6, but also the new T-45 trainer airplane. The T-45 program was a Full Scale Development (FSD) flight test program that saw it's culmination and introduction into the fleet as a result of his testing. Following his tour of duty at Patuxent River, he separated from the active duty Navy and joined the Reserves as a Lieutenant in the Ready Reserves.

He currently calls Houston, Texas his home and is involved with the Manned Space Flight Program at the Johnson Space Center with the National Aeronautics and Space Administration (NASA). With him are the joys of his life: his wife Amy, daughter Melanie, son Spencer, and his golf clubs.