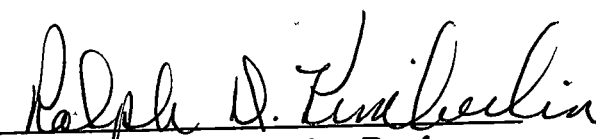


To the Graduate Council:

I am submitting herewith a thesis written by Richard Allen Burr entitled "Evaluation Of The Digital Flight Control System As Installed In The F-14A Tomcat For The All-Weather Aircraft Carrier Landing Mission." I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Aviation Systems.


Dr. Kimberlin, Major Professor

We have read this thesis
and recommend its acceptance:




Accepted by the Council:


Interim Vice Provost and
Dean of the Graduate School

EVALUATION OF THE DIGITAL FLIGHT CONTROL SYSTEM AS
INSTALLED
IN THE F-14A TOMCAT
FOR THE ALL-WEATHER AIRCRAFT CARRIER LANDING
MISSION

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

Richard Allen Burr
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ABSTRACT

The purpose of this test was to evaluate the Digital Flight Control System (DFCS), Operational Flight Program (OFP) 4.2.2 as installed in the F-14A Tomcat for the all-weather aircraft carrier landing mission. One ground test (1 hour) and 583 operational evaluation flights totaling 970 hours were conducted from the USS JOHN C STENNIS (CVN-74) during day and night all weather conditions in the northern Pacific ocean, Indian ocean, and Arabian Gulf. All test objectives were met.

The ten F-14A test airplanes were production aircraft assigned to, and maintained by, an operational F-14A squadron (VF-211). The F-14A Tomcat is a two-place, tandem cockpit, carrier-based supersonic strike fighter powered by two Pratt and Whitney TF-30-P-414A engines. Stability augmentation, autopilot, auxiliary control functions for spoilers, and automatic trim was provided by the DFCS.

The DFCS, as installed in the F-14A airplane for this test, was satisfactory for the all-weather carrier landing mission. There was no significant change in day landing grades, as assigned on 0 to 4 point scale by the landing signal officer team for each landing, or boarding rates as a result of the DFCS modification. However, night landing grades for aircraft with DFCS incorporated were moderately improved (+7.0%) over aircraft with the original analogue Automatic Flight Control System (AFCS). Bank angle control characteristics in the Power Approach (PA) configuration with the DFCS roll Stability Augmentation System (SAS) on were dramatically improved, however the severe pitch change characteristics during configuration changes will result in excessive pilot workload during instrument approaches. Overall, two deficiencies were identified that should be corrected as soon as practicable, and one deficiency was discovered that should be avoided in future designs.

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NOMENCLATURE

β	Sideslip
ψ	Pitch Angle
ϕ	Roll Angle
δ_a	Lateral Control Stick Displacement
δ_r	Rudder Displacement
δ_s	Longitudinal Control Stick Displacement
F_a	Lateral Control Stick Force
F_r	Rudder Force
F_s	Longitudinal Control Stick Force
n_z	Longitudinal Acceleration
T_{30}	Time for 30 degrees of roll
T_{360}	Time for 360 degrees of roll

ABBREVIATIONS

A/C	Aircraft
A/R	As Required
AFCS	Automatic Flight Control System
AIM	Air Intercept Missile
AOA	Angle of Attack
ARI	Automatic Rudder Interconnect
AUG	Augmentation
BIT	Built-in Test
BO+F	Break Out and Friction
CAI	Caution Advisory Indicator
CG	Center of Gravity
CNX	Cancelled
CR	Cruise Configuration
CRT	Combat Rated Thrust
DFCS	Digital Flight Control System
DRD	Dutch Roll Damping
DGR	Degrade
DT	Drop Tank
DTFO	Differential Tail Fadeout
FCS	Flight Control System
FPM	Feet Per Minute
FT	Feet
IBIT	Initiated Built-in Test
GBU	Guided Bomb Unit
HQR	Handling Qualities Rating
ILARTS	Integrated Launch and Recovery Television Surveillance System

ILS	Instrument Landing System
IMN	Indicated Mach Number
IN	Inch
KIAS	Knots Indicated Airspeed
LB	Pound
LGTR	Laser Guided Training Round
LSO	Landing Signal Officer
LSRI	Lateral Stick to Rudder Interconnect
LSXC	Low Speed Cross Control
MAC	Mean Aerodynamic Chord
MRT	Military Rated Thrust
MSL	Mean Sea Level
MTBF	Mean Time Between Failures
NATOPS	Naval Aviation Training and Operating Procedures
NM	Nautical Miles
NW	Needle Width
OPF	Operational Flight Program
PA	Power Approach
PA-ARI	Power Approach Automatic Rudder Interconnect
PA-NF	Power Approach – No Flaps
PIO	Pilot Induced Oscillations
PSI	Pounds Per Square Inch
ROC/D	Rate of Climb/Descent
RRC	Roll Rate Command
SAS	Stability Augmentation System
SEC	Second
SMS	Spiral Mode Stabilization
SR	Spin Recovery
TARPS	Tactical Airborne Reconnaissance Pod
TED	Trailing Edge Down
TEU	Trailing Edge Up
TLF	Thrust for Level Flight
UA-ARI	Up and Away Automatic Rudder Interconnect
V	Velocity
VCMS	Vehicle Control Management System
W_f	Fuel Weight
WLR	Work Load Rating
WRS	Wing Rock Suppression

CHAPTER 1 INTRODUCTION

1.1 BACKGROUND

The F-14A Tomcat, the Navy's premier carrier-based strike fighter aircraft, has been in operational service since the early 1970's. During this period, the Tomcat has experienced unacceptable mishap rates in flight due to lateral-directional coupled departures and subsequent spins, and in the landing approach phase due to excessive workload caused by unpredictable roll rates and weak directional stability.

To improve these undesirable characteristics, the Navy directed the upgrade of the Tomcat's stability augmentation system from the original analogue Automatic Flight Control System (AFCS) to a new digital flight control system (DFCS). Following the successful completion of the Naval Air Systems Command's directed developmental and operational testing, references 1 through 3, the ten F-14A Tomcats of the VF-211 FIGHTING CHECKMATES were upgraded during 1999.

1.2 PURPOSE

The purpose of this test was to qualitatively evaluate the flying qualities and operational suitability of the F-14A Tomcat aircraft with the digital flight control system (DFCS) for the precision landing approach and carrier landing mission during an operational deployment with operational pilots in actual mission scenarios.

1.3 DESCRIPTION OF TEST AIRCRAFT

The F-14A Tomcat was a two-place, tandem cockpit, carrier-based supersonic strike fighter aircraft, with variable swept wings and tricycle landing gear. The aircraft was equipped with an all-movable horizontal tail, dual rudders, and wing spoilers. All

primary flight controls were irreversible and powered by two independent 3000 psi hydraulic systems connected to the control stick and rudder pedals through push-pull rods as well as bell crank and cable assemblies. Stability augmentation, autopilot, auxiliary control functions for spoilers, control authority, and automatic trim was provided by the Digital Flight Control System (DFCS) version 4.2.2. The control systems' mechanical linkages provided artificial feel. A more detailed description of the F-14A flight control system is presented in the Flight Control Description of the F-14A Tomcat, appendix A.

The aircraft was powered by two Pratt and Whitney TF-30-P-414A, 16-stage axial-flow afterburner equipped, turbofan engines. Sea-level standard day static thrust for an installed engine was approximately 10,875 lb at military rated thrust (MRT) and 17,000 lb at full afterburner combat rated thrust (CRT). A more detailed description of the F-14A airplane is presented in the F-14A Naval Air Training and Operational Manual (NATOPS), reference 4. The test airplanes, Bureau Numbers (side numbers) 159428 (100), 162696 (101), 161607 (102), 161288 (103), 158618 (104), 162603 (105), 158628 (110), 161295 (111), 158637 (112), and 161622 (114) were production aircraft assigned to and maintained by an operational F-14A squadron (VF-211).

1.4 DESCRIPTION OF TEST SYSTEMS

The Digital Flight Control System (DFCS) was designed to replace the F-14's original analogue Automatic Flight Control System (AFCS). The DFCS retained all the functions of the AFCS, including a stability augmentation system, an autopilot, and auxiliary control functions for the spoilers, control authority, and automatic trim. In addition, DFCS provided functions to enhance high AOA and Power Approach flight characteristics. DFCS version 4.2.2, as tested, included an Up and Away Automatic

Rudder Interconnect (UA-ARI) to provide enhanced departure resistance, spin recovery and high angle of attack flying qualities with the landing gear retracted. DFCS also provided a Power Approach Automatic Rudder Interconnect (PA-ARI) to enhance landing approach flying qualities with the landing gear extended.

DFCS hardware and software included existing aircraft sensors, interfaces, series servoactuators, and actuator authorities with the addition of a rudder pedal position transducer, pitch/roll voter monitor, and an angle of attack/Mach redundancy management algorithm. The autopilot and automatic carrier landing functions of the AFCS were replicated in the DFCS in digital format. The DFCS consisted of three computers, one for each axis (pitch, roll and yaw), that replaced the three AFCS computers. Each computer had two distinct and independent processors called channels (one "A" and one "B" channel for each axis) All channels shared data through cross channel data links.

1.5 SCOPE OF TESTS

The Power Approach flying qualities and operational suitability of the F-14A Tomcat with the DFCS system were qualitatively evaluated during one ground test (1 hour) and 649 scheduled operational evaluation flights, of which 583 were completed totaling 970 hours. The evaluation was conducted aboard the USS JOHN C STENNIS (CVN-74) during day and night all weather conditions. Sea state varied between sea state one (calm) and four (rough). Landing approaches were evaluated with vertical deck motion of up to ± 15 ft. Outside air temperature varied between 20° to 100 ° F. Visibility during approaches varied from $\frac{1}{4}$ NM in blowing snow to greater than 7 NM. Test airplane configurations are presented in table 1-1.

Table 1-1. F-14A DFCS TEST CONFIGURATIONS

CONFIGURATION	LANDING GEAR	FLAPS	SPEEDBRAKES
Power Approach (PA)	Down	Full Down	Out
Power Approach-No Flaps (PA-NF)	Down	Up	Out
Cruise (CR)	Up	Up	In

Table 1-2. F-14A FLIGHT TEST ENVELOPE

Parameter	Test Limit	NATOPS Limit
Altitude (ft MSL)	Surface to 25K	Surface to 50K
Airspeed (KIAS)	0 to 450	0 to 680
Mach (IMN)	0 to 0.6	0 to 1.88
AOA (units)	5 to 25	No Limit
Normal Accel (n_z)	+0.5 to +1.8 (PA) +0.0 to +6.0 (CR)	0 to +2.0 (PA) -2.0 to +6.5 (CR)
Center of Gravity (% MAC)	8.0 to 24	6.3 to 27

The flights were conducted within the limits of F-14A NATOPS manual, reference 4, and test envelope presented in table 1-2. The test loadings were per the F-14A approved standard conventional loads for the fighter, strike, and reconnaissance missions found in the F-14A Air to Ground Tactical Manual, reference 5. Test loadings are presented in figures B-1 and B-2 and a detailed test and test conditions matrix is presented in tables B-1 through B-3, appendix B. The F-14 aircraft with DFCS installed was evaluated against the specifications listed in tables B-4 to B-7, appendix B. The Vehicle Control Management System (VCMS) was evaluated under Operational State I, II, III flying quality requirements delineated in table D-1, appendix D.

1.6 METHOD OF TESTS

The evaluation was conducted as delineated in the tests and test conditions matrix, appendix B, and the Detailed Method of Test, appendix C. Tests that were addressed in the "USNTPS Fixed Wing Stability and Control Theory and Flight Test Techniques Manual" reference 6 were conducted using the procedures therein. Two of the thirteen evaluation pilots were trained test pilots, and these pilots conducted the flying qualities portion of the evaluation, tables B-1 and B-2. All evaluation pilots were trained in the use of the Cooper Harper Rating Scale, figure D-1, as described in "The Use of Pilot Rating in the Evaluation of Aircraft Handling Qualities," NASA TN D-5153, reference 7 and the Bedford Workload Scale, figure D-2. Handling Qualities Ratings (HQRs) and Workload Rating Levels (WRLs) were assigned by all pilots immediately following landing during the first 100 landings. Pilot Induced Oscillation levels (PIO) were assigned according to the PIO Rating Scale, figure D-3. Deficiencies were assigned in accordance with the Naval Test Wing Atlantic Report Writing Guide, FTEG-TID-94-1-RWG, reference 8, as described in figure D-4. Flight phases with associated flying quality levels and handling quality regions were defined in the Joint Service Specification Guide, JSSG-2008 VCMS, reference 9. All test aircraft were fleet configured F-14A Tomcats with no special instrumentation.

All flight test data were recorded on knee board cards, the aircraft standard 8mm video recorder for Heads Up Display video, and the aircraft carrier's Integrated Launch and Recovery Television Surveillance System (ILARTS). ILARTS camera installation, which was embedded into the landing area centerline, was located slightly beyond the intended aircraft touchdown point. Additional information on ILARTS is available in the U.S. Navy Landing Signal Officer Reference Manual, reference 10.

1.7 CHRONOLOGY

The evaluation was planned and conducted as listed below in table 1-3.

Table 1-3. CHRONOLOGY

EVENT	START DATE	COMPLETE DATE
Test Planning	01 Dec 99	31 Dec 99
Flight Testing	07 Jan 00	17 Mar 00
Data Reduction	01 Mar 00	30 Jun 00

CHAPTER 2 RESULTS AND EVALUATION

2.1 LANDING PERFORMANCE

2.1.1 GENERAL

Glideslope and lineup control (during 453 day and 269 night landings on board the USS JOHN C STENNIS (CVN-74) conducted by 13 pilots) were quantitatively evaluated by the Carrier Airwing NINE (CVW-9) Landing Signal Officer (LSO) team. The LSO team, which monitored each landing, quantitatively evaluated each landing using a 0 to 4 point scale (4 being the best) and qualitatively evaluated by providing comments on glideslope, power, and lineup deviations. Weather varied from 200 ft overcast in blowing snow to sky clear with visibility unrestricted. Temperatures varied from 20°F to 110 ° F. Deck conditions varied from steady to ± 15 ft. More information on grading criteria may be found in the US Navy Landing Signal Officer NATOPS, reference 10. Qualitative comments for all approaches are provided in the CVW-9 Automatic Performance Assessment and Readiness Training System data base, reference 11.

2.1.2 DAY LANDING GRADES

Day landing grades were evaluated quantitatively and qualitatively according to the landing signal officers assigned grades and comments for each landing. The overall average DFCS-equipped F-14 day landing grade was 3.28. Glideslope deviations were noted during every day approach, however lineup deviations were noted during 24% of the day approaches. Approaches with lineup deviations had an average grade of 3.15 while approaches with no noted lineup deviations had an average grade of 3.32. A summary of landing grades is provided in table 2-1 and depicted in figure 2-1.

Table 2-1. LANDING PERFORMANCE SUMMARY

	# APPR.	% WITH LINE UP DEV	% WITH MULT. LINE UP DEV	% OFF-CENTE R LNDS	AVE GRADE WITH LINE UP DEV	AVE GRADE WITH NO LINE UP DEV	TOTAL AVE GRADE	97-98 VF-211 AVE GRADE	% CHANGE
DAY	453	24.3%	14.8%	0.7%	3.15	3.32	3.28	3.32	-1.2%
NIGHT	269	23.8%	16.0%	0.7%	3.06	3.33	3.23	3.02	+7.0%

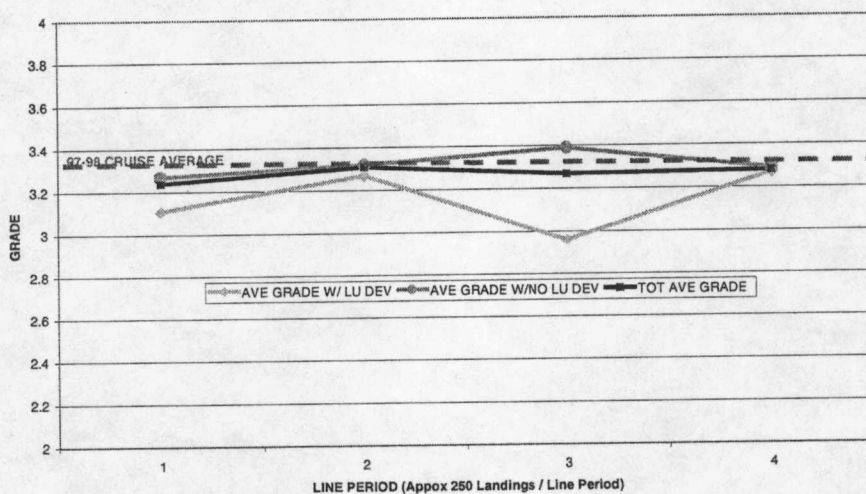


Figure 2-1. DAY LANDING GRADES

Additional information is listed in table E-1, appendix E. During the previous VF-211 deployment with AFCS-equipped aircraft, which was conducted during the same time of year, at the same locations with pilot's having a similar range of experience, the average day landing grade was 3.32. Although a slight decrease in day landing grades occurred with DFCS aircraft (-1.2%), the day landing grades for aircraft with DFCS incorporated are satisfactory for the all-weather aircraft carrier landing mission.

2.1.3 NIGHT LANDING GRADES

Night landing grades were evaluated quantitatively and qualitatively according to the landing signal officers assigned grades and comments for each landing. The overall average DFCS-equipped F-14 night landing grade was 3.23. Glideslope deviations were noted during every day approach and lineup deviations were noted during 24% of the night approaches. Approaches with lineup deviations had an average grade of 3.06 while approaches with no noted lineup deviations had an average grade of 3.33. A summary of night landing grades is provided in table 2-1 and depicted in figure 2-2. Additional information is presented in table E-2, appendix E. During the previous VF-211 deployment with AFCS-equipped aircraft the average night landing grade was 3.02. Nights landing grades for aircraft with DFCS incorporated were moderately improved (+7.0%) over AFCS aircraft and are satisfactory for the all-weather aircraft carrier landing mission.

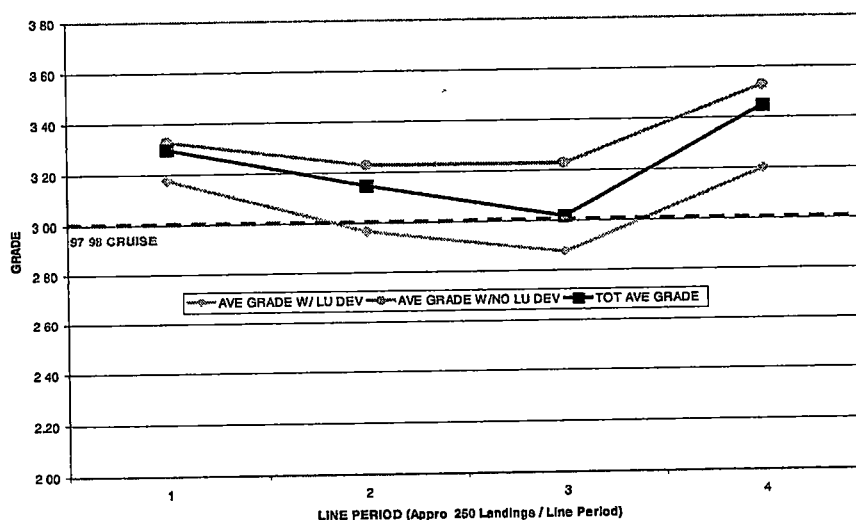


Figure 2-2. NIGHT LANDING GRADES

2.1.4 DAY BOARDING RATE

Day boarding rate for DFCS-equipped F-14 aircraft was qualitatively evaluated and compared with the boarding rate performance of AFCS aircraft. The overall average DFCS-equipped F-14 day boarding rate presented in table 2-2 was 95.6%. Approaches that resulted in a foul deck waveoffs (i.e. arresting gear not ready / aircraft still in the landing area) were not counted as an approach. During the previous VF-211 deployment with AFCS-equipped aircraft the average day boarding rate was 96.4%. Although DFCS-equipped F-14 aircraft had a slightly lower day boarding rate (-0.8%) than AFCS aircraft, the DFCS as installed on the F-14 aircraft is satisfactory for the all-weather aircraft carrier landing mission. Additional information is presented in table E-1, appendix E. Boarding rate was defined as the total number of approaches minus the number of bolters (landing beyond the arresting gear) and technique waveoffs divided by the total number of approaches

$$\text{Boarding Rate} = \frac{\text{Total \# Approaches} - (\text{Bolters} + \text{Waveoffs})}{\text{Total \# Approaches}}$$

Table 2-2. BOARDING RATE SUMMARY

	% WITH LINE UP DEV	BOARDING RATE WITH LINE UP DEV	BOARDING RATE WITH NO LINE UP DEV	OVERALL BOARDING RATE	97-98 VF-211 AVE BOARDING RATE	% CHANGE
DAY	24.3%	94%	96.2%	95.6%	96.4%	-0.8%
NIGHT	23.8%	80%	82.4%	81.8%	82.6%	-0.8%

2.1.5 NIGHT BOARDING RATE

Night boarding rate for DFCS-equipped F-14 aircraft was qualitatively evaluated and compared with the boarding rate performance of AFCS aircraft. The overall average DFCS-equipped F-14 night boarding rate as presented in table 2-2 was 81.8%. Approaches that resulted in a foul deck waveoffs (i.e. arresting gear not ready/aircraft still in the landing area) were not counted as an approach. During the previous VF-211 deployment with AFCS-equipped aircraft the average night boarding rate was 82.6%. Although DFCS-equipped F-14 aircraft had a slightly lower night boarding rate (-0.8%) than AFCS aircraft, the DFCS as installed on the F-14 aircraft is satisfactory for the all-weather aircraft carrier landing mission. Additional information is presented in table E-2, appendix E.

2.2 AIRCRAFT CHARACTERISTICS

2.2.1 GENERAL

Longitudinal and lateral directional flying qualities were stringently evaluated during Naval Air Systems Command directed Developmental Testing as detailed in references 1 and 2. These flying qualities were qualitatively verified during this evaluation during 453 day visual approaches, 269 night Instrument Landing System (ILS) approaches in the power approach configuration, and 3 day ILS approaches in the power approach-no flap configuration to the aircraft carrier, as depicted in the detailed method of test (appendix C). Weather varied from clear air visibility unlimited to <200' ceiling / <1nm visibility with varied wind conditions..

2.2.2 LONGITUDINAL FLYING CHARACTERISTICS

2.2.2.1 Configuration Changes

Longitudinal flying characteristics during configuration changes between the cruise and power approach configurations and from power approach to cruise were evaluated during 40 instrument approaches and waveoffs with the pitch SAS on. Lowering the landing gear at 250 KIAS resulted in an immediate and relatively large pitch down tendency ($-1^\circ/\text{sec}$) resulting in altitude deviations of up to 100ft. Subsequent flap extension at 225 KIAS initially caused the nose to pitch down to -10° and then as the flaps extended beyond 15° down, the pitching moment reversed and caused the aircraft to rapidly start climbing ($+1000\text{fpm}$) resulting in unintended climbs of up to 200ft. During a wave off, while attempting to set $+10^\circ$ nose up, raising the landing gear followed immediately by retracting the flaps, resulted in an extremely large nose pitch up moment. If a large, precisely timed forward stick (3in) input was not simultaneously made to counter the pitch up moment, the aircraft pitch attitude increased up to 20° nose up. Maintaining level flight ± 100 ft during configuration changes from the cruise configuration to power approach, and pitch attitude $\pm 2^\circ$ during a configuration change from power approach to cruise, was very difficult and required large, rapid and well timed longitudinal stick inputs while constantly monitoring aircraft altitude/attitude to avoid unsafe deviations (HQR-5). The severe pitch change characteristics during configuration changes will result in excessive pilot workload during instrument approaches and should be corrected as soon as practicable. Consideration should be given to increasing the gain of the pitch rate feedback into the pitch stability

augmentation system with the landing gear not up and locked to reduce the amount of uncommanded pitch changes during configuration changes.

2.2.2.2 Angle of Attack Control

Angle of attack control was evaluated in the power approach configuration from the surface to 1200 ft from 135kt to 150kt, during an ILS straight-in approach and in the visual landing pattern. During a straight-in approach to landing, the aircraft rarely deviated by greater than ± 1 unit α when trimmed on speed for a 15 unit α approach. However, during typical landing pattern maneuvers (turns, lineup/glideslope corrections), angle of attack deviations of up to ± 2 unit α frequently occurred. Controlling angle of attack ± 2 unit α in the power approach configuration during mild maneuvering was relatively difficult, requiring frequent monitoring of AOA indicator followed by an occasional (every 5-8 sec) small (2-3 lb) longitudinal stick inputs precisely coordinated with small ($\pm 1/2$ in) throttle adjustments (HQR-5). The difficult angle of attack control characteristics in the power approach configuration should be corrected as soon as practicable. Consideration should be given to increasing the pitch SAS control authority and/or increasing the gain on the angle of attack feedback in the power approach configuration

2.2.3 LATERAL DIRECTIONAL FLYING QUALITIES

2.2.3.1 Roll Angle Control in the Power Approach Configuration

Roll angle control with DFCS was evaluated quantitatively and qualitatively against for ability to precisely capture and maintain a desired angle of bank in the power approach configuration. In the power approach configuration, the aircraft demonstrated

a predictable roll rate for small to moderate lateral stick deflections (18°/in) (paragraph 3.4.3) allowing bank angle to be captured within one degree by neutralizing the lateral stick input 1-2° prior to the desired bank angle. The small, but discernable, lateral control system breakout and friction forces allowed the pilot to rapidly and positively neutralize the lateral stick input (paragraph 3.4.2) with no undesirable oscillations noted during roll-in or roll out (PIO-1). Once a desired bank angle was established, assuming the lateral controls were correctly trimmed, the aircraft maintained the precise angle of bank ($\pm 1^\circ$) with the lateral stick released in the neutral position. Precise bank angle control ($\pm 1^\circ$) in the power approach configuration was easy, requiring only one lateral stick input to initiate the roll followed by a timely neutralization of the lateral controls once the bank angle was achieved (HQR-2). The predictable and simple bank angle control characteristics in the power approach configuration with DFCS roll SAS on will dramatically reduce the pilot's workload during night instrument approaches, providing additional time to monitor other critical items such as airspeed and altitude. The dramatically improved bank angle control characteristics in the power approach configuration with DFCS Roll SAS on are an enhancing characteristic and should be incorporated into future designs.

2.2.3.2 Precision Course Control in the Power Approach Configuration

Precision course control was evaluated during night ILS approaches in the power approach and power approach-no flaps configurations. While capturing centerline during an ILS approach in either configuration, the aircraft responded relatively quickly (18°/sec per inch of lateral stick) (paragraph 3.4.3) and predictably to lateral stick only roll commands, resulting in only small undershoots or overshoots (< 2 needle widths

(nw)) of the desired course. The coordinated rudder provided by the automatic rudder interconnect (ARI) virtually eliminated all dutch roll when rolling out, making heading capture easy. Once centerline was captured, the roll rate feedback provided by the Roll SAS maintained the wings relatively level ($\pm 2^\circ$) resulting in occasional small course deviations (< 2 nw). Precision course control (± 2 nw) during ILS approaches was relatively easy, requiring minimal attention and only a few small (< 1 in) uncoordinated lateral stick inputs every 20-30 sec (HQR-3). The precision course control characteristics in the power approach and power approach-no flap configurations are satisfactory for the carrier ILS approach mission.

2.2.3.3 Bank Angle Capture With Aft Wing Sweep

Bank angle capture was evaluated with Roll SAS on and off in the cruise configuration during numerous day visual pattern entry "break turn" maneuvers, as described in the detailed method of test, appendix C. Break turn entries were conducted in both clear and reduced visibility (< 2 nm) meteorological conditions. With Roll SAS off, which was required to reduce roll control authority with AFCS since AFCS did not provide differential tail fadeout to reduce roll-generated torque, bank angle capture varied $\pm 20^\circ$, resulting in several $\pm 200'$ climbs/descents while attempting the level turn to downwind. During all of the 4-6g break turns with Roll SAS on however, roll rates were slightly quicker (up to $180^\circ/\text{sec}$) (paragraph 3.4.4) and significantly more predictable. Utilizing up to full stick uncoordinated rolls, bank angle was repeatedly captured within 10° on all attempts, resulting in minimal altitude deviations ($\pm 50'$) during the subsequent level high-g decelerating 180° break turn to downwind heading. Capturing bank angle with the Roll SAS on with the wings swept 68° was relatively easy,

requiring the pilot to simply neutralize the lateral stick input 10-15° prior to the desired bank angle (HQR-3). The predictable bank angle capture characteristics of the DFCS-equipped aircraft with Roll SAS on will minimize F-14 altitude deviations while in the level break turn to the landing pattern downwind, particularly with poorly defined horizon conditions. The bank angle capture characteristics of the DFCS aircraft in the cruise configuration were satisfactory for the day carrier landing mission.

2.2.4 COCKPIT EVALUATION

2.2.4.1 DFCS Control Box Fault Display

The DFCS fault display, located on the DFCS Control Box on the pilot's left side control panel as shown in figure 2-3, was evaluated for accessibility during pre-flight and post-flight checks. The fault display was an amber colored digital display, which provided a three or four digit alphanumeric code to signify system status on-deck only. The fault display was slightly obscured by the throttles when at idle, which required the pilot to look directly at the display (90-100° left and 45° down) while frequently having to shade it from direct sunlight during the day. The fault display also provided no intensity control, resulting in the display being too bright during night operations and too dim during daylight operations. Checking the status codes on the obscured and non-adjustably lit fault display during the day will force the pilot to divert complete attention inside the cockpit, delaying other critical pre-flight and post-flight checks and increasing the required on deck time (WLR-4). The obscured and non-adjustably lit fault display should be avoided in future designs. Consideration should be given to modifying the DFCS control box location and lighting to allow the pilot to easily determine the DFCS status.

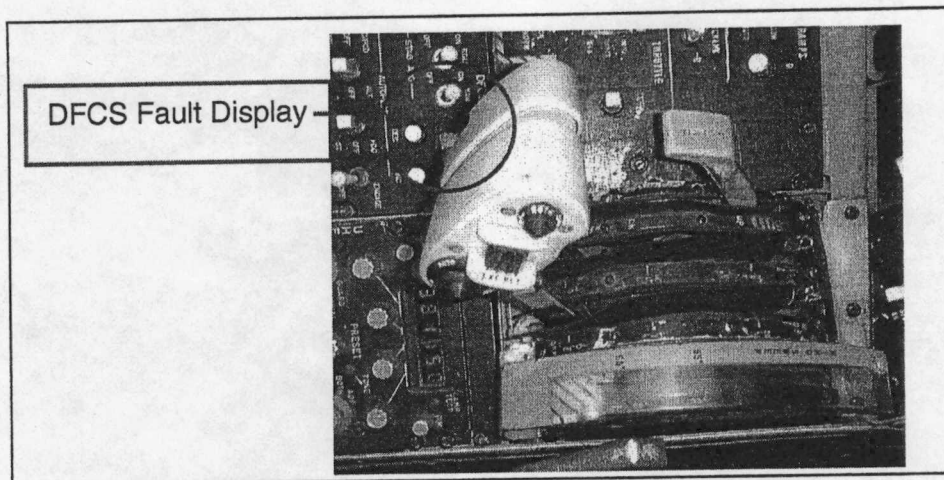


Figure 2-3. DFCS FAULT DISPLAY

2.3 DFCS SUITABILITY

2.3.1 DFCS RELIABILITY

DFCS system reliability was evaluated during 639 carrier-based and 10 land-based scheduled flights, totaling 970 flight hours. Reliability was operationally evaluated by analyzing the cancellation rate of flights due to DFCS system faults and the Mean Time between Failures (MTBF) in terms of average flights hours per documented system fault. A total of 7 out of 649 scheduled flights were cancelled for DFCS-related maintenance reasons (1.1%). In addition to the 7 DFCS-related maintenance cancelled flights, 49 flights were cancelled for other maintenance reasons, making the DFCS faults responsible for 12.5% of the total maintenance flight cancellations. A total of 28 DFCS faults were documented during the 970 hours flown on the 10 test aircraft, resulting in a MTBF of 34.6 flight hours per fault. Of the 28 faults, 13 were "down faults," meaning that the fault degraded the system enough to negatively impact flight safety and was required to be corrected prior to the aircraft flying again. The other 15 faults were "up faults" which degraded the system to a lesser extent and did not require correction prior to the next flight. A summary of DFCS reliability is provided in table 2-3. Extensive historical

Table 2-3. DFCS RELIABILITY

TOT FLTS FLOWN ¹	TOTAL FLT HOURS	TOTAL MAINT CNX FLTS ¹	TOT DFCS CNX FLTS	% OF MAINT CNX DUE TO DFCS	# OF DOWN FAULTS ²	# OF UP FAULTS ³	MTBF (HRS/ FAULT) ⁴	OVERALL DFCS CNX RATE
583	970	56	7	12.5%	13	15	34.6	1.1%

Note: 1. Maintenance cancelled flights only include scheduled flights that were cancelled prior to takeoff due to a maintenance discrepancy being detected post-engine start.
2. Down faults are defined as system faults which are safety of flight items that must be fixed prior to the aircraft flying again.
3. Up faults are defined as system faults, which degrade system performance, but are not considered as safety of flight items.
4. Mean Time Between Failures (MTBF). Defined as the average number of flight hours completed between system faults, which includes both Up and Down faults.

data on AFCS reliability was not available, however the limited AFCS data available indicated that DFCS reliability significantly improved by at least a factor of two over AFCS reliability. Additional information is presented in table E-3, appendix E. The DFCS reliability was satisfactory for the all-weather aircraft carrier approach mission.

2.3.2 DFCS MAINTAINABILITY

DFCS system maintainability was evaluated during 573 carrier-based and 10 land-based flights, totaling 970 flight hours. Maintainability was operationally evaluated by analyzing the man-hours and actual days required to correct detected DFCS faults. Faults were categorized as "up" faults, which did not affect safety of flight, and "down" faults, which affected safety of flight and required correction prior to the aircraft flying again. The 15 reported up faults required an average of 2.6 man-hours each to correct and the corrective maintenance action was completed in an average of 9.2 days. The 13 reported down faults required a slightly higher 3.9 man-hours per fault to correct, however, the faults were corrected much quicker in an average of only 1.0 days. The primary reason for the significantly reduced number of days to correct down faults was that there was a higher maintenance priority placed on fixing down gripes since the

Table 2-4. DFCS MAINTAINABILITY

# OF DOWN FAULTS	AVE MAINT MAN HOURS/ DOWN FAULT	AVE DAYS TO REPAIR DOWN FAULTS	# OF UP FAULTS ⁹	AVE MAINT MAN HOURS/ UP FAULT	AVE DAYS TO REPAIR UP FAULTS	OVERALL AVE MAINT MAN HOURS/ FAULT	OVERALL AVE DAYS TO REPAIR DFCS FAULTS
13	3.9	1.0	15	2.6	9.2	3.5	5.4

aircraft could not fly until the fault was corrected. A summary of DFCS maintainability is provided in table 2-4. Extensive historical data on AFCS maintainability was not available, however the limited AFCS data available indicated that DFCS maintainability was at least as good as AFCS maintainability. Additional information is presented in table E-4, appendix E. In general, DFCS maintainability was satisfactory for the all-weather aircraft carrier landing mission.

CHAPTER 3 SUPPORTING DATA

3.1 GENERAL

3.1.1 ACCURACY OF DATA

Longitudinal and lateral-directional characteristics were stringently evaluated during Naval Air System Command directed Developmental Testing as detailed in references 1 and 2, prior to fleet release. The following data were collected to provide a rough verification of these characteristics with DFCS installed in a fleet aircraft. The test aircraft were operationally representative in all ways and no special instrumentation was installed. All of the following data were obtained through hand-held measurements or estimates.

3.2 MECHANICAL CHARACTERISTICS

Mechanical characteristics were measured airborne in the cruise configuration at 15,000 ft at 300 KIAS and in the power approach configuration at 2,000 ft at 145 KIAS with the longitudinal, lateral, and directional trim set and visually checked in the neutral position.

3.2.1 LONGITUDINAL CONTROL SYSTEM

The longitudinal control stick, which operated the horizontal stabilizers through an irreversible hydraulic system, moved 4 in forward and 5.5 in aft, and provided artificial feel to the pilot. The pitch command gradient was smooth and predictable in all

Table 3-1. LONGITUDINAL MECHANICAL CHARACTERISTICS

Config	Breakout + Friction (lb)		BO+F Specification (lb) ⁽¹⁾		Average Friction (lb)		Free play (in)	Oscillations	Centering
	Pull	Push	Min	Max	Pull	Push			
CR / PA	1	1	½	3	1/2	1/2	±1/4	None	Absolute

Note: (1) Specification paragraph 4.1.12.1

configurations without any objectionable non-linearity. Breakout force was light but appeared sufficient to prevent inadvertent control deflections and was not objectionable. The longitudinal stick demonstrated minimal freeplay (1/4 in) and stick centering appeared to be absolute. Following small longitudinal stick raps, no oscillations were observed before the stick centered. Full longitudinal stick inputs were not obstructed by any part of the pilot's body. The longitudinal mechanical characteristics met the requirements of the Specification and are summarized in table 3-1.

3.2.2 LATERAL CONTROL SYSTEM

The lateral control stick, which operated the horizontal stabilizers and spoilers through an irreversible hydraulic system, moved ± 3.5 in left and right, and provided artificial feel to the pilot. The roll command gradient was smooth and predictable in all configurations without any objectionable non-linearity. Breakout force was relatively light, however, was sufficient to prevent inadvertent lateral control deflections. The lateral stick demonstrated minimal freeplay (1/8 in) and stick centering appeared to be absolute. Following small lateral stick raps, two small oscillations were observed before the stick centered. Full lateral stick inputs were not obstructed by any part of the pilot's body. The lateral mechanical characteristics met the requirements of the Specification and are summarized in table 3-2.

Table 3-2. LATERAL MECHANICAL CHARACTERISTICS

Control Axis	Breakout + Friction (lb)		BO+F Specification ⁽¹⁾ (lb)		Average Friction (lb)		Freeplay (in)	Oscillations	Centering (in)
	Right	Left	Min	Max	Right	Left			
Lateral	½	½	½	1	N/A	N/A	±1/8	2	Absolute

Note: (1) Specification paragraph 4.5.9.4

3.2.3 DIRECTIONAL CONTROL SYSTEM

The rudder pedals, which operated the rudders through an irreversible hydraulic system, moved ± 3 in fore/aft, and provided artificial feel to the pilot. The directional command gradient was smooth and predictable in all configurations without any objectionable non-linearity. Breakout force was sufficient to prevent inadvertent directional control deflections. The rudder pedals demonstrated minimal freeplay (1/8 in) and centering appeared to be absolute. Following small pedal raps, two small oscillations were observed before the pedals centered. Full rudder pedal inputs were not restricted by any part of the aircraft or due to the design seat position. The directional mechanical characteristics met the requirements of the Specification and are summarized in table 3-3.

Table 3-3. DIRECTIONAL MECHANICAL CHARACTERISTICS

Control Axis	BO+F (Estimated) (lb)		BO+F Spec ⁽¹⁾ (lb)		Average Friction (lb)		Freeplay (in)	Oscillations	Centering (in)
	Right	Left	Min	Max	Right	Left			
Directional	5	5	1	7	N/A	N/A	1/8	2	Absolute

Note: (1) Specification paragraph 4.6.7.11

3.3 LONGITUDINAL CHARACTERISTICS

3.3.1 NON-MANEUVERING STATIC STABILITY

Apparent non-maneuvering static stability, as indicated by the variation of longitudinal stick force with airspeed, was evaluated in the cruise configuration at 15,000 ft MSL and 300 KIAS and in the power approach configuration at 2,000 ft MSL at 143 KIAS (15 units α). The aircraft exhibited apparent positive non-maneuvering static stability in both configurations, as indicated by increasing longitudinal stick force with deviations from trimmed airspeed. The non-maneuvering static stability characteristics met the requirements of the Specification.

3.3.2 MANEUVERING STATIC STABILITY

Apparent maneuvering static stability, as indicated by the variation of longitudinal stick force with normal acceleration was qualitatively evaluated using steady turns in the cruise configuration at 15,000 ft MSL at 400 KIAS from 0.0 to +6.0 g; and in the power approach configuration at 2,000 ft MSL at 142 KIAS (15 units α). The aircraft exhibited apparent positive maneuvering stability in both configurations, as indicated by increasing longitudinal stick force with increasing load factor. The maneuvering static stability characteristics met the requirements of the Specification.

3.3.3 PHUGOID

Phugoid response characteristics, as indicated by airspeed variation with time, were evaluated following a deviation from trim airspeed in the power approach configuration at 2,000 ft MSL at 144 KIAS. The aircraft demonstrated positive static

stability with slight damping ($\zeta=0.1$) and a period of 63 sec. The phugoid response characteristics met the requirements of the Specification.

3.3.4 SHORT PERIOD

Short period response characteristics, as indicated by normal load factor (N_z) variation with time, were evaluated following a pitch doublet in the cruise configuration at 15,000 ft MSL at 300 KIAS and in the power approach configuration at 2,000 ft MSL at 144 KIAS. In both configurations, the DFCS pitch axis command and feedback gains effectively damped the short period to provide a deadbeat response. The short period characteristics met the requirements of the Specification.

3.3.5 CONFIGURATION CHANGES

Configuration change characteristics, as indicated by longitudinal control forces required during landing gear, flap, and speed brake transition, were evaluated while maintaining level flight at 5,000 ft MSL from 300 KIAS to 150 KIAS and during all takeoffs and landings. The DFCS provided no improvement over AFCS in correcting for pitch trim changes resulting from configuration changes. Changing configurations from CR to PA required a large 15lb aft stick input as the flaps transitioned from 0-25° down, followed by an equally large forward stick input as the flaps continued to full down to maintain the desired pitch attitude and/or altitude. Raising the flaps required a large 10-15lb forward stick input as flaps programmed up. Extending the speed brakes required a 5-7 lb aft stick input to compensate for a pitch down tendency, and an equal but opposite input when retracting to speed brakes. The landing gear transition required 10 lb aft stick input to maintain the desired pitch attitude and/or altitude. The longitudinal forces required during configuration changes met the requirements of the Specification.

3.3.6 TRIM SYSTEM CHARACTERISTICS

Trim system characteristics were evaluated in the cruise configuration at 300 KIAS at 15,000 ft and in the power approach configuration at 140 KIAS at 1,200 ft. Location of the longitudinal trim controls was standard and their operational sense was normal. Trim rate and sensitivity was sufficient in both configurations. The trim system characteristics met the requirements of the Specification.

3.4 LATERAL-DIRECTIONAL CHARACTERISTICS

3.4.1 SPIRAL STABILITY

Spiral stability, as indicated by the time required for bank angle to double or half with controls free, was evaluated in the cruise configuration at 15,000 ft at 300 KIAS and in the power approach configuration at 140 KIAS at 2,000 ft. Lateral stick inputs were used to establish a 20° angle of bank and timing began when the lateral controls were neutralized. In both configurations, the spiral mode was apparently neutral, with no angle of bank change noted for 30 sec following release. Spiral stability characteristics were satisfactory during all phases of flight within the test envelope. The spiral stability characteristics met the requirements of the Specification.

3.4.2 ROLL MODE

The roll mode time constant, as estimated by one third of the time for a steady roll rate to decay to zero following neutralization of the lateral controls was evaluated in the cruise configuration at 15,000 ft at 300 KIAS and in the power approach configuration at 2,000 ft at 140 KIAS. The roll mode time constant in both configurations was virtually unmeasurable using a hand-held stopwatch, with the roll rate stopping in

less than 1 sec, and is estimated to be less than 0.3 sec. Although stringent quantitative testing was beyond the scope of this test, the roll mode time constant appears that it should meet or exceed the requirements of the Specification.

3.4.3 ROLL CONTROL SENSITIVITY

Roll control sensitivity, as indicated by the variation of roll rate with lateral stick displacement, was measured in the power approach configuration at 138 KIAS at 1,200 ft. Roll control sensitivity was measured for left rolls only, however, no differences were noted during qualitative build-up. In the power approach configuration, roll rate was a linear function of lateral stick displacement. The measured variation of roll rate with lateral stick displacement was 18°/sec for a 1 in lateral input and 60 °/sec with a full (3 5 in) lateral input. There was no objectionable non-linearity in roll response over the range of airspeeds encountered during testing. The roll control sensitivity characteristics, as defined by the Specification as the bank angle change during the first second of roll following a lateral step input, could not be accurately measured using hand-held methods, however, data indicates that the roll control sensitivity should meet the requirements of the Specification.

3.4.4 ROLL PERFORMANCE

Roll performance, as indicated by the average roll rate achieved using full lateral controls, was evaluated in the cruise configuration at 15,000 ft at 300 KIAS and in the power approach configuration at 2,000 ft at 138 KIAS. Roll rate was calculated using a 360° roll in the cruise configuration and a 30° roll in the power approach configuration. Rolls were initiated from wings level and zero initial roll rate. Following an aileron only

input, there was no measurable apparent adverse yaw. The roll performance characteristics met the requirements of the Specification as summarized in table 3-4.

3.4.5 DUTCH ROLL

The Dutch roll mode, as indicated by sideslip variation with time, was evaluated with DFCS yaw SAS on following rudder doublet inputs in the cruise configuration at 15,000 ft MSL at 300 KIAS and in the power approach configuration at 140 KIAS at 2,000 ft MSL. The Dutch roll mode was effectively damped in both configurations, demonstrating a deadbeat response with no apparent sideslip overshoots. The Dutch roll characteristics met the requirements of the Specification.

3.4.6 DIRECTIONAL STABILITY

Directional stability characteristics, as indicated by the variation of sideslip with rudder pedal force, were evaluated during steady heading sideslips in the power approach configuration at 15 units α (140 KIAS) at 2,000 ft. Steady heading sideslips were qualitatively performed in both directions, and measured using full left rudder deflection. Steady heading sideslip results of the shown below in table 3-5. The aircraft demonstrated positive apparent directional static stability, as indicated by increasing

Table 3-4. ROLL PERFORMANCE

Configuration / Load	Airspeed (KIAS)	Stick Deflection / Degrees of Roll	Time to Roll (sec)	Roll Rate (deg/sec)
CR / T1	300	FULL / 360	2.0	180
PA / T1	138	FULL / 30	0.5	60

Table 3-5. STEADY HEADING SIDESLIP

δ_{rudder}	F_{rudder}	F_{aileron}	ϕ (AOB)	β (Sideslip) ⁽¹⁾	ROC/D	$F_{\text{longitudinal}}$
Full Left	100 lb	5 lb Right	5° Right	10°	0 fpm	+5 lb FWD

Note: 1. Sideslip estimated by comparing aircraft heading with GPS computed course on a zero wind day.

rudder deflections required to generate increased sideslip angles. The rudder pedal forces required to generate sideslip (~10 lb/deg) were not objectionable. The limiting control factor during steady heading sideslips was rudder authority. Approaching full rudder deflections no force lightening was noted.

3.4.7 TRIM SYSTEM CHARACTERISTICS

Lateral and directional trim system characteristics were evaluated in the cruise configuration from 190 KIAS to 400 KIAS at 1,200 ft to 20,000 ft, and in the power approach configuration and PA-NF from 135 KIAS to 190 KIAS at 600 ft to 1,200 ft. Location of the lateral trim controls was standard and their operational sense was normal. Lateral trim rate and sensitivity were sufficient in both configurations for the range of airspeeds and altitudes tested. The directional trim control was located on the pilot's left console, positioned outboard of the throttle quadrant, requiring the pilot to look approximately 90° left and 45° down to locate the directional trim control knob (WLR-4). Directional trim rate and sensitivity were sufficient in both configurations for the range of airspeeds and altitudes tested. The trim system characteristics met the requirements of the Specification.

CHAPTER 4 CONCLUSIONS

4.1 GENERAL

- The Digital Flight Control System, OFP 4.2.2 as installed in the F-14A Tomcat for this test is satisfactory for the all-weather aircraft carrier landing mission.

4.2 ENHANCING CHARACTERISTICS

- Dramatically improved bank angle control characteristics in the power approach configuration with DFCS roll SAS on (paragraph 2.2.3.1).

4.3 PART II DEFICIENCIES (AS DEFINED IN APPENDIX D)

- Severe pitch change characteristics during configuration changes.
(Paragraph 2.2.2.1)
- Difficult angle of attack control characteristics in the power approach configuration. (Paragraph 2.2.2.2)

4.4 PART III DEFICIENCIES (AS DEFINED IN APPENDIX D)

- Obscured and non-adjustably lit fault display. (Paragraph 2.2.4.1)

CHAPTER 5 RECOMMENDATIONS

5.1 GENERAL

- Include the characteristics in paragraphs 4.2 in future designs
- Correct the deficiencies in paragraph 4.3 as soon as practicable.
- Avoid the deficiency in paragraph 4.4 in future designs.

5.2 SPECIFIC

- Increase the gain of the pitch rate feedback into the pitch stability augmentation system with the landing gear not up and locked to reduce the amount of uncommanded pitch changes during configuration changes (paragraph 2.2.2.1).
- Increase the pitch SAS control authority and / or increase the gain on the angle of attack feedback in the power approach configuration (paragraph 2.2.2.2).
- Modify the DFCS control box location and lighting to allow the pilot to easily determine the DFCS status (paragraph 2.2.4.1).

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APPENDICES

APPENDIX A. F-14A TOMCAT DIGITAL FLIGHT CONTROL SYSTEM (DFCS) FLIGHT CONTROL DESCRIPTION

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FLIGHT CONTROL DESCRIPTION

1 FLIGHT CONTROL SURFACES

1.1 GENERAL

Flight control is achieved through an irreversible hydraulic power system operated by a control stick and rudder pedals. A general layout of the F-14A Tomcat is depicted in figure A-1.

1.2 HORIZONTAL STABILIZERS

1.2.1 Longitudinal Control

Aircraft longitudinal control is accomplished by the symmetric deflection of independently actuated horizontal stabilizers. Control stick motion is mechanically

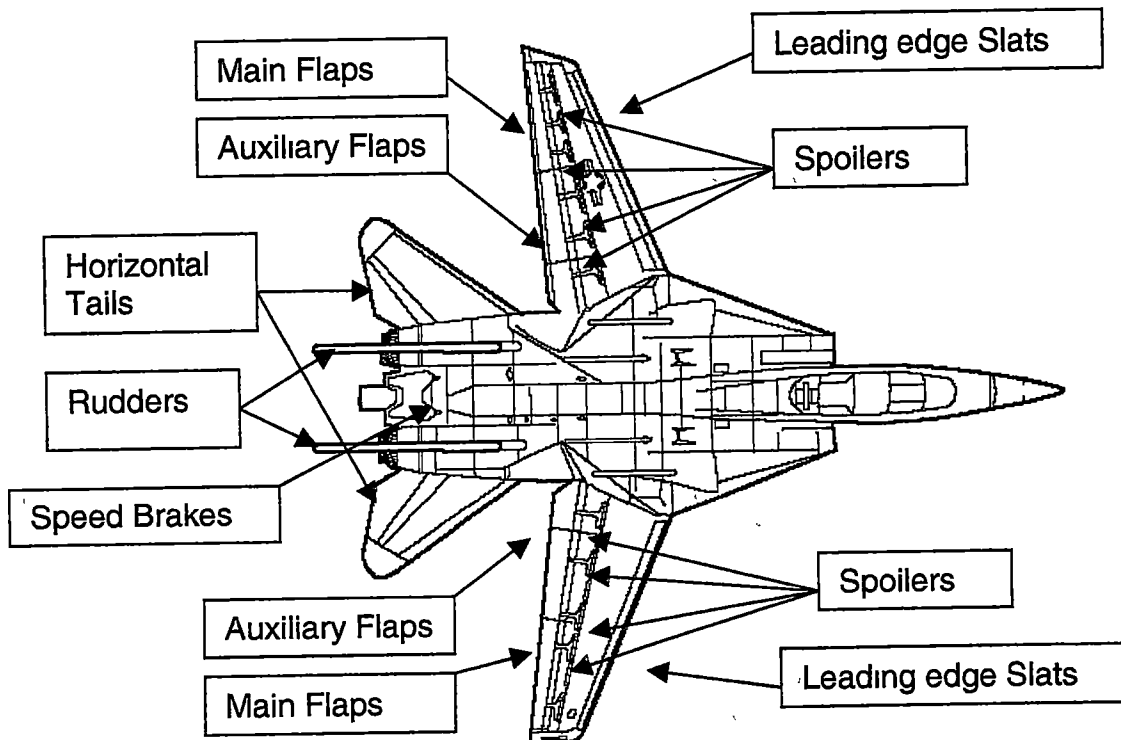


Figure A-1. F-14 FLIGHT CONTROL SURFACES

transmitted to the horizontal stabilizers by pushrods and bellcranks to dual tandem actuators independently powered by the flight and combined hydraulic systems. A third independent flight control hydraulic source is provided by the backup hydraulic system if both primary hydraulic systems fail. Range of horizontal stabilizer deflection for pitch control is -12° to $+35^{\circ}$ (pitch SAS on) and -12° to $+33^{\circ}$ (pitch SAS off). The longitudinal control system is depicted in figure A-2.

1.2.2 Lateral Control

Aircraft lateral control is effected by differential displacement of the horizontal stabilizers and augmented by using spoilers at wing sweep positions less than 57° . Lateral control stick movements operate mechanical mixing assemblies for differential deflection of the horizontal stabilizers. The range of deflection for differential stabilizers is 12° up / 12° down (24° split) (roll SAS on) and 7° up / 7° down (14° split) (roll SAS off). Differential stabilizer deflection is accomplished by mechanically summing pitch and roll

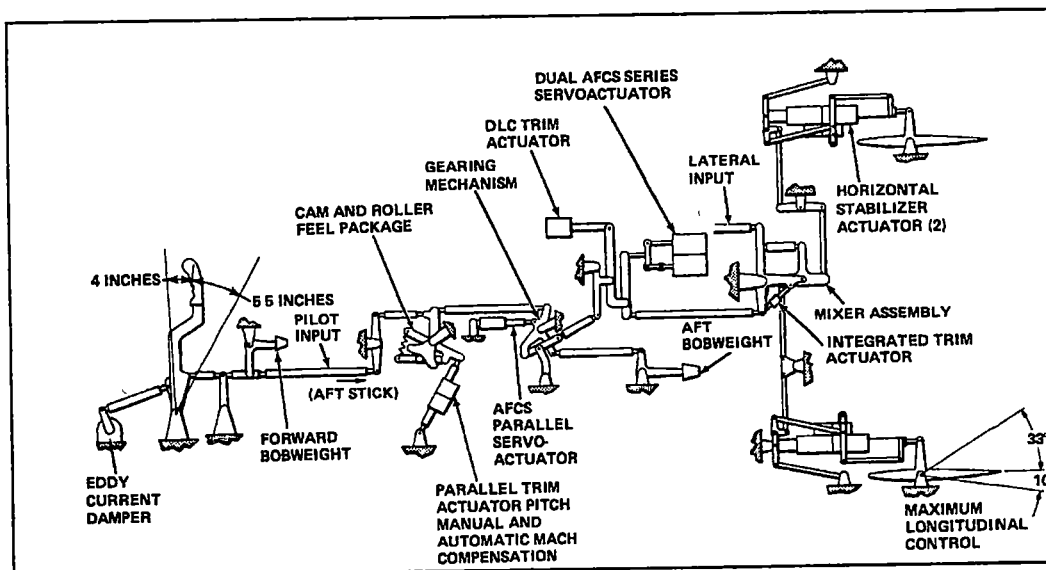


Figure A-2. LONGITUDINAL CONTROL SYSTEM

commands at the pitch-roll mixer assembly. Non-linear stick-to-stabilizer gearing provides appropriate stick sensitivity for responsive and smooth control. The lateral control system is depicted in figure A-3.

1.3 SPOILERS

1.3.1 Lateral Control

Four spoiler control surfaces located on the upper surface of each wing, as depicted in figure 1-1, augment lateral control power when the wings are forward of 57°. They function by destroying lift on the down going wing. The spoilers are electrically activated with lateral stick movement and are hydraulically actuated by the combined hydraulic system (two inboard spoilers on each wing) and the outboard spoiler module (two outboard spoilers on each wing). The range of deflection for the spoilers is $-4\frac{1}{2}^{\circ}$ to $+55^{\circ}$. The spoiler control system is depicted in figure A-4.

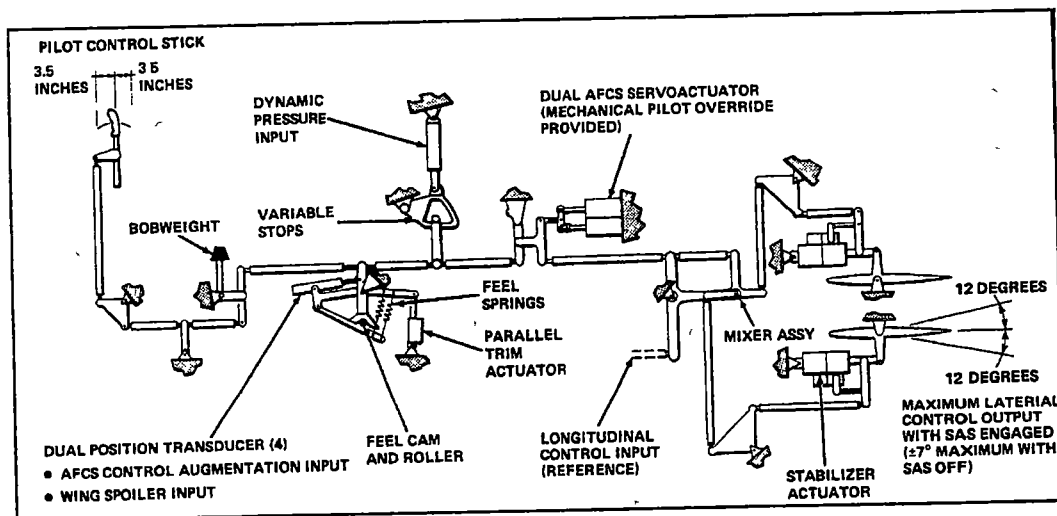


Figure A-3. LATERAL CONTROL SYSTEM

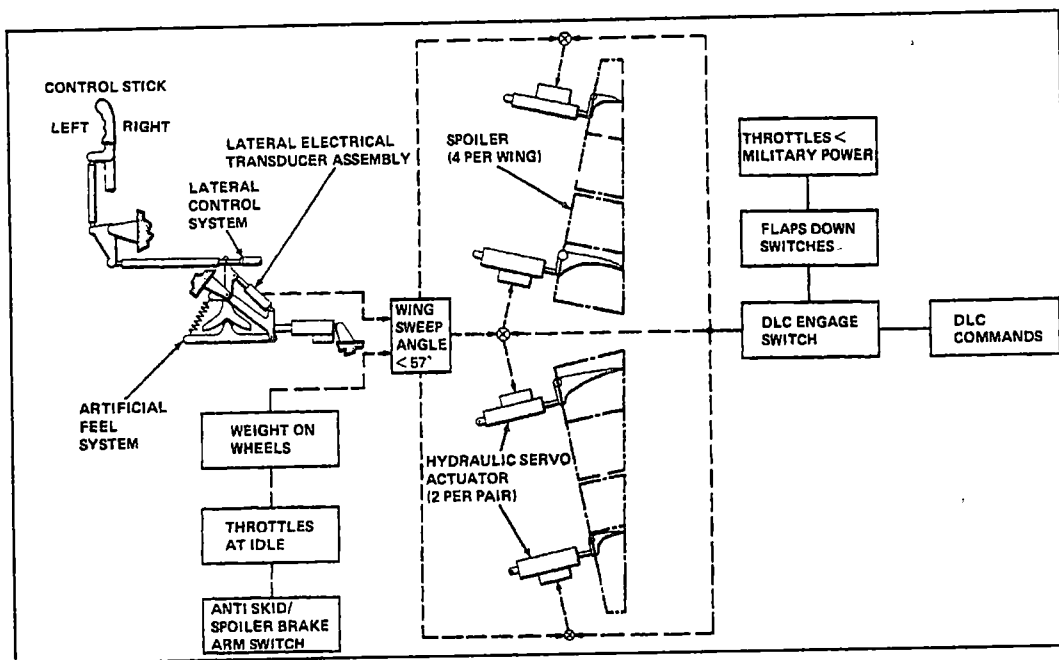


Figure A-4. SPOILER CONTROL SYSTEM

1.3.2 Direct Lift Control

The inboard two spoilers on each wing are also used symmetrically in the landing configuration with flaps full down for direct lift control (DLC) to provide additional glideslope control. DLC is electrically activated by the chaff pushbutton located on control stick, and the inboard set of spoilers can be modulated incrementally between $-4\frac{1}{2}^{\circ}$ to $+55^{\circ}$ by the thumbwheel located on the control stick.

1.3.3 Ground Roll Braking

Aerodynamic ground roll braking is provided by symmetric deflection of all spoilers to $+55^{\circ}$. Ground-roll braking is controlled by the Anti-Skid/Spoiler Brake switch on the pilot left vertical console and requires weight on wheels and both throttles at idle to activate.

1.4 DUAL RUDDERS

1.4.1 Directional Control

Directional control is accomplished by the symmetric deflection of dual rudders, depicted in figure 1-1, which are mechanically activated via rudder pedals located in the front cockpit. Yaw commands are transmitted mechanically from the rudder pedals to the rudder hydraulic actuators by pushrods and bellcranks. Tandem hydraulic actuators are powered independently by the flight and combined hydraulic systems. A third independent flight control hydraulic source is provided by the backup hydraulic system, which will power the rudders at a reduced rate if both primary hydraulic systems fail. The range of rudder deflection is from 30° left to 30° right. The directional control system is depicted in figure A-5.

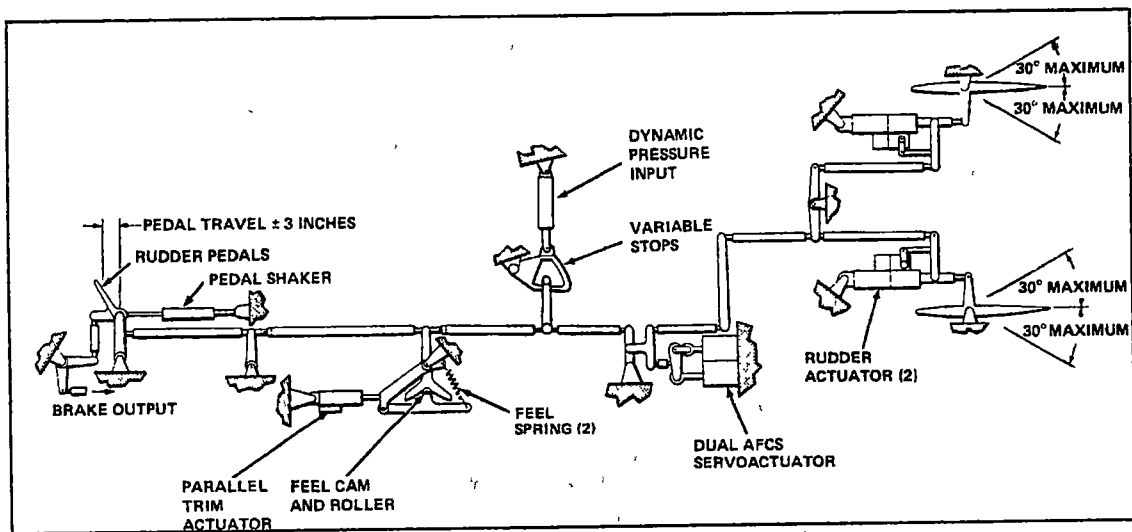


Figure A-5. DIRECTIONAL CONTROL SYSTEM

1.5 SPEED BRAKES

The speed brakes are located on the upper and lower surfaces on the aft portion of the fuselage as depicted in figure A-1. They are electrically activated via the speed brake switch located on inboard throttle and hydraulically actuated by the combined hydraulic system.

1.6 WING SWEEP

Wing sweep is normally electrically controlled via the wing sweep control switch, located on the inboard throttle, in the front cockpit but can also be mechanically controlled by the emergency wing sweep handle located inboard of the throttle quadrant. Normal wing sweep range is from 20° to 68°. On deck, with weight on wheels, the wings can be swept to 75° to reduce wingspan for parking. Normally the wing sweep position is automatically controlled based on Mach number and altitude provided by the central air data computer (CADC). The wings can also be manually swept aft (but not forward) of the CADC calculated limit using the manual fore/aft positions of the wing sweep control switch.

2 HIGH LIFT SYSTEM

2.1 MAIN FLAPS

The main flaps on each wing consist of the two single-slotted outboard flap sections, as depicted in figure A-1. They are used for takeoff, landing, and maneuvering. The main flaps can be incrementally lowered or raised from 0° to -35° down with the flap handle. The main flaps can also be partially extended up to 10° down using the thumbwheel on control stick during up and away flight to provide enhanced lift for maneuvering. The flap handle, located outboard the throttles, is used to manually command the flaps and slats to the takeoff and landing position. Flap handle commands

are transmitted mechanically by a control cable to the flap and slat control box, which raises and lowers the flaps via a torque tube assembly. The torque tube assembly is hydraulically powered by the combined hydraulic system. In the event of a combined hydraulic system failure, outboard spoiler module fluid is automatically directed to a backup hydraulic motor to lower the main flaps and slats only.

2.2 AUXILIARY FLAPS

The auxiliary flaps consist of the inboard flap section on each wing and are powered by the combined hydraulic system. The auxiliary flaps are mechanically controlled via the flap handle and can be incrementally lowered from 0° to -35° down. Wings must be forward of 22° to lower the auxiliary flaps.

2.3 LEADING EDGE SLATS

The leading edge slats are comprised of two sections on each wing, both of which are driven simultaneously by a single driveshaft. The slats are mechanically linked to the main flaps and are extended anytime the main flaps are extended.

3 CONTROLS AND INDICATORS

3.1 CONTROLS

3.1.1 Center-Mounted Control Stick

The center-mounted control stick, located in front cockpit, mechanically controls the horizontal stabilizers for longitudinal (symmetrical) and lateral (differential) control. Lateral stick movement also electrically controls the spoilers for secondary roll control and the thumbwheel mounted on the stick controls the spoilers for direct lift control. The control stick is depicted in figure A-6.

3.1.2 Thumbwheel

The thumbwheel, located on left side of control stick, electrically extends and retracts the main flaps and slats up to 10° down for maneuvering flight, and controls the symmetric extension of the spoilers with the main flaps down and DLC button actuated for direct lift control. The thumbwheel is depicted in figure A-6.

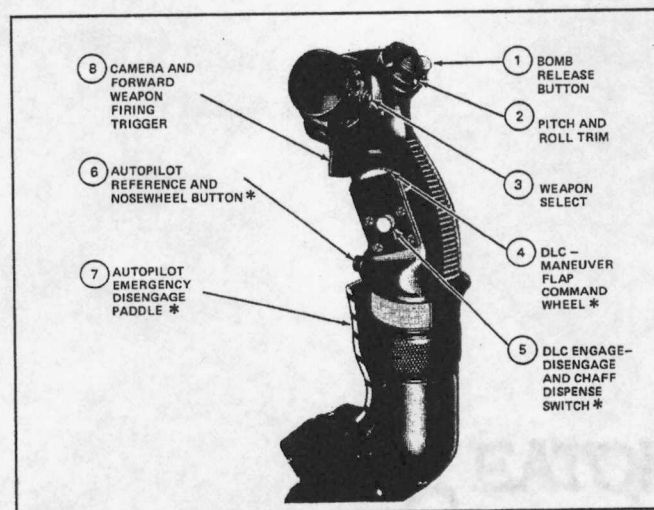


Figure A-6. F-14 CONTROL STICK

3.1.3 Rudder Pedals

The conventional rudder pedals are located in front cockpit. The rudder pedals mechanically control the dual rudders, which always act symmetrically.

3.1.4 Speed Brake Switch

The speed brake switch is located on the inboard throttle in front cockpit. The switch is spring loaded for incremental extension. Retraction is not incremental. The speed brake switch is depicted in figure A-7.

3.1.5 Flap Handle

The flap handle is located on left side of throttle quadrant in front cockpit as shown in figure A-7. Actuation of the handle mechanically controls the extension and retraction of the main and auxiliary flaps and leading edge slats. The flap handle can be incrementally lowered or raised for partial flap/slat extension.

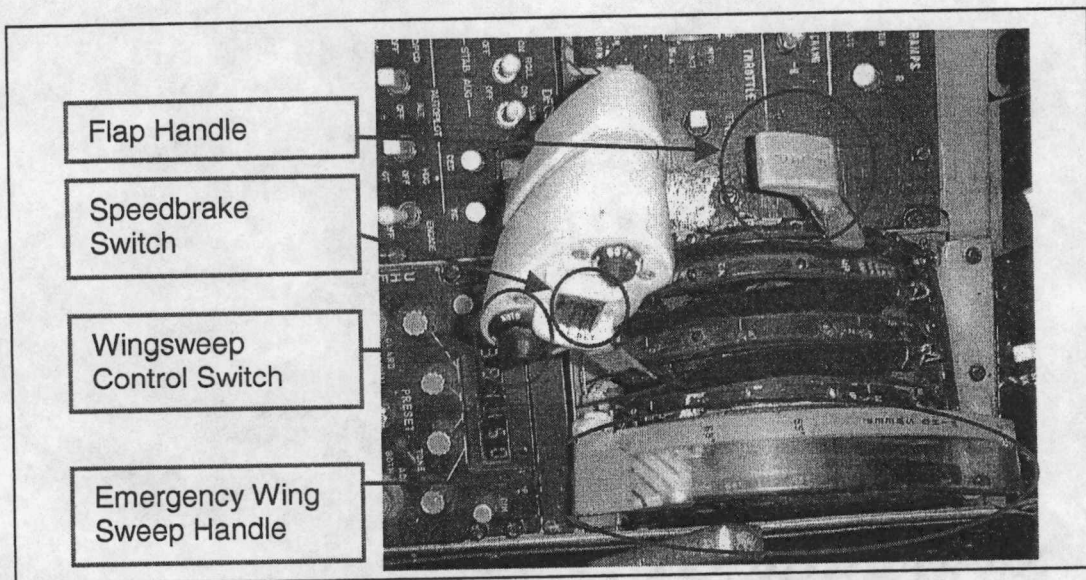


Figure A-7. F-14 THROTTLE QUADRANT

3.1.6 Emergency Wing Sweep Handle

The emergency wing sweep handle is located on inboard side of throttle quadrant, and mechanically positions the wings. The wing's position always matches the handle position (excluding mechanical failure). The emergency wing sweep handle is shown in figure A-7.

3.1.7 Wing Sweep Control Switch

Wing sweep normal operation is accomplished using the wing sweep control switch located on inboard throttle. The three-mode switch, AUTO, MANUAL, BOMB, electrically positions the emergency wing sweep handle. Wing sweep control can be accomplished either manually or according to a wing sweep computer derived program.

AUTO mode: Wings are electrically programmed by CADC according to Mach number and altitude

MANUAL mode: Wings are electrically moved forward and aft manually by pilot.

Manual forward will move wings only to CADC computed forward limit. If CADC computed forward limit moves aft of manual selected position, and then wing sweep will automatically enter and remain in AUTO mode

BOMB mode. Wings electrically positioned at 55° unless wings are already aft of 55°, in which case they will remain at their current position. If the CADC computed forward limit moves aft of 55°, wing sweep will

follow the auto programming until the CADC limit is forward of 55° and will then remain at 55°

The wing sweep control switch is shown in figure A-7.

3.2 INDICATORS

3.2.1 Flight Control Surface Indicator

The flight control surface indicator is located on lower left vertical console in front cockpit and indicates the position of all control surfaces. The horizontal tail trailing edge position indicates from 35° up to 15° down. The rudders indicate from 30° left to 30° right. The spoiler indicators located at the top of the indicator show the inboard and outboard spoiler pair's relative position with the wing (flush, extended >0°, drooped to -4 ½ °). The flight control surface indicator is shown in figure A-8.

3.2.2 Flap Indicator

The flap, slat, and speed brake indicator is located on the pilot's left vertical console. It indicates the main flap, slat, and speed brake position (fully retracted, partially extended, fully extended) and power off status. There is no indication of auxiliary flap position. The flap indicator is shown in figure A-9.

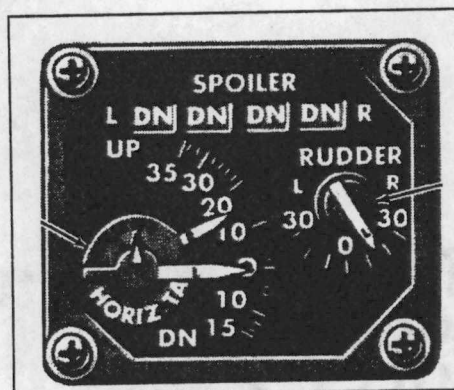


Figure A-8. Flight Control Surface Indicator

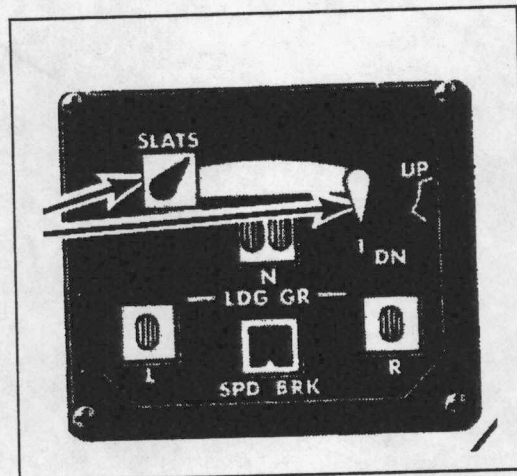


Figure A-9. FLAP INDICATOR

3.2.3 Wing Sweep Indicator

The wing sweep indicator is located on upper right instrument panel in front cockpit. It indicates the actual wing position (tape), manually commanded position (Captain's bars), CADC computed optimum position (pointer), and wing sweep mode currently selected. The wing sweep indicator is shown in figure A-10.

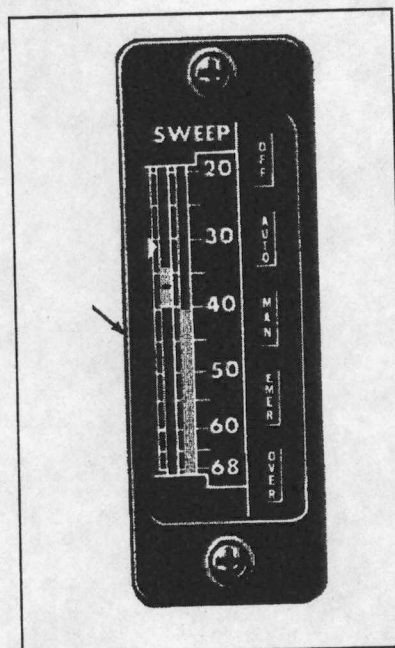


Figure A-10. WING SWEEP INDICATOR

4 FLIGHT CONTROL AUGMENTATION

4.1 AUTOMATIC FLIGHT CONTROL SYSTEM (AFCS)

The original F-14 Tomcat AFCS incorporated an analog stability augmentation system, an autopilot and auxiliary control functions for spoiler control, rudder authority control, lateral stick authority control, and Mach trim compensation

4.2 DIGITAL FLIGHT CONTROL SYSTEM (DFCS)

The DFCS was designed to replace the AFCS and incorporation into the F-14A commenced in 1999. The DFCS retains all the functions of the AFCS with the addition of an automatic rudder interconnect.

4.2.1 Up and Away Automatic Rudder Interconnect (UA-ARI)

Enhances departure resistance, spin recovery and high angle of attack flying qualities with the landing gear retracted. Improvements include:

Differential Tail Fadeout (DTFO)

Increased Roll Rate

Lateral Stick-to-Rudder Interconnect (LSRI)

Low airspeed/high angle of attack cross control (LSXC)

Wing Rock Suppression

Spin Recovery Function

Spoiler Failure Management

4.2.2 Power Approach Automatic Rudder Interconnect (PA-ARI)

Enhances landing approach flying qualities when the landing gear is extended.

Improvements include:

Roll Rate Command

LSRI

Dutch Roll damping

Spiral Mode stabilization

Modified Spoiler Gearing

4.2.3 DFCS Hardware

The DFCS utilizes existing aircraft sensors, interfaces, series servoactuators, and actuator authorities with the addition of a rudder pedal position transducer, pitch/roll voter monitor, and an angle of attack / Mach redundancy management algorithm. The autopilot and automatic carrier landing functions of the AFCS are replicated in the DFCS in digital format. The DFCS consists of three computers, one for each axis (pitch, roll and yaw) which replaces the three AFCS computers.

Each computer has two distinct and independent processors called channels (one "A" and one "B" channel for each axis). All channels share data through cross channel data links. A schematic of the sensors and hardware required by DFCS is depicted in figure A-11.

Additionally, the AFCS control box has been replaced by a new DFCS control box, installed on the pilot's left side console. The DFCS control box retains all functions of the AFCS control box, including stability augmentation selection switches for pitch, roll, and yaw and autopilot selection switches, with the addition of a digital fault display. The DFCS control box is depicted in figure A-12.

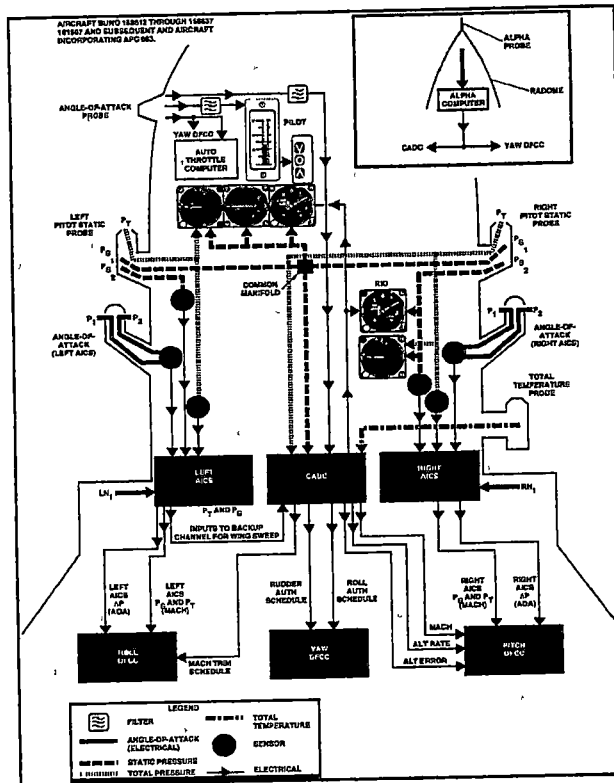


Figure A-11. DFCS SENSORS AND HARDWARE

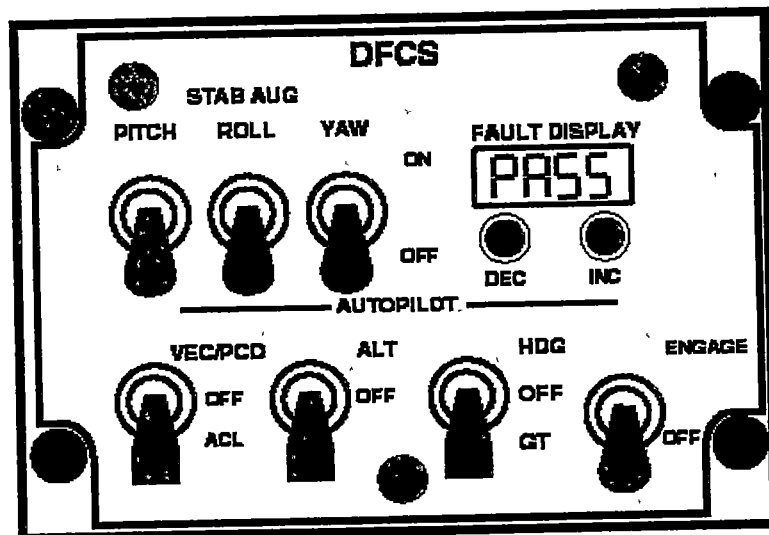


Figure A-12. DFCS CONTROL BOX

4.3 DFCS SOFTWARE UPDATES

4.3.1 OFP 4.1.1

OFP 4.1.1 was the interim fleet release software that included a correction for a deficiency found in OFP 4.1. The correction is to the roll rate mis-compare detection threshold that is based upon the actual airplane roll rate (vice constant 30 deg/sec as with OFP 4.1). This change minimizes the airplane flight control response when such a failure is detected and the bad gyro isolated. In essence, a smaller mis-compare threshold is used for detection when the airplane is experiencing very little roll rate and is linearly increased to a larger mis-compare tolerance at higher roll rates. (Released AUG 1998)

4.3.2 OFP 4.2

OFP 4.2 was intended to be the fleet release software for deployment and supported (hardware and software) corrections to a single point of failure to the pitch, roll, and yaw computer power supplies. It also includes corrections for the autopilot altitude hold and IBIT improvements. OFP 4.2 and subsequent software are only compatible with the production hardware flight control computers, which include a modified power supply. This software was preempted due to deficiencies detected during flight test with the autopilot altitude hold functionality. (Release preempted).

4.3.3 OFP 4.2.1

OFP 4.2.1 was a follow-on software to correct deficiencies detected during flight test with the autopilot altitude hold functionality. In addition, a software correction to a single point of failure detected during ground test of both AFCS and DFCS aircraft that results in a simultaneous dual roll rate sensor failure and uncommanded roll with roll

SAS engaged. This software release was preempted due to the recent operational impact of IBIT detected CADC failures. (Release preempted).

4.3.4 OFP 4.2.2

OFP 4.2.2 is a follow-on software build to correct deficiencies identified during initial fleet operations concerning IBIT detected CADC failures. This correction expanded the tolerances of CADC related IBIT tests to eliminate nuisance faults. This software includes all the functionality improvements in OFP 4.2 and 4.2.1. (Released AUG 1999).

4.4 UP AND AWAY ARI (UA-ARI)

DFCS Up and Away improvements include differential tail fadeout, increased roll rate, lateral stick to rudder interconnect, low speed cross control, wing rock suppression, spin recovery and spoiler management. The regions of operation for these functions are depicted in figure A-13.

4.4.1 Differential Tail Fadeout (DTFO)

DTFO significantly improves departure resistance by reducing differential tail authority at elevated Mach and AOA regions of the flight envelope. The DTFO starts to reduce full differential tail authority (± 12 deg) at about 13 units AOA with a minimum differential tail authority (max fadeout) (± 2 deg) at about 30 units AOA. This fadeout schedule becomes more restrictive above about 0.6 Mach. DTFO and LSRI control laws provide increased departure resistance by effectively eliminating lateral stick induced departures.

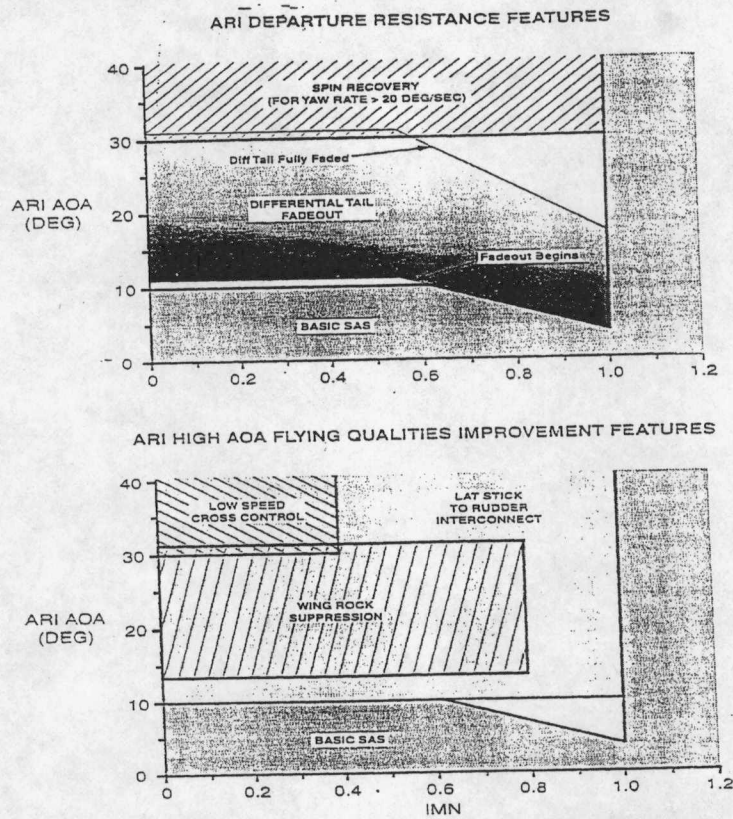


Figure A-13. DFCS UP AND AWAY ARI FUNCTIONS

4.4.2 Increased Roll Rate

Improvements in DFCS allow the ROLL SAS to remain ON all the time, and therefore, greater differential tail authority is available during maneuvering at low AOA. DFCS roll rate limiting with ROLL SAS ON is 200 deg/sec vice 180 deg/sec with AFCS. The major difference is that the DFCS flight control laws automatically fadeout differential tail authority at higher Mach and AOA to provide for departure resistance during maneuvering.

4.4.3 Lateral Stick to Rudder Interconnect (LSRI)

LSRI significantly improves high AOA maneuvering flying qualities by enabling the pilot to more predictably roll the airplane at elevated AOA with lateral stick alone.

The LSRI starts to fade in coordinated rudder authority at about 13 units AOA with full lateral stick commanded rudder authority (± 19 deg rudder) available at about 25 units AOA. The LSRI control laws are designed to provide the F-14 enhanced maneuvering capability at elevated AOA and coupled with differential tail fadeout (DTFO) control laws, are designed to provide increased departure resistance by effectively eliminating lateral stick induced departures.

4.4.4 Low Speed Cross Control (LSXC)

LSXC provides gross maneuvering capability at low airspeeds where differential tail and rudder authority is ineffective. Above about 30 units AOA and below 0.4 Mach the DFCS will recognize control inputs of > 1.75 in rudder pedal and > 1.0 inch opposite lateral stick and thereby override DTFO and LSRI control laws to allow the pilot to command up to ± 10 deg differential tail and 30 deg opposite rudder (cross control). The DFCS will override LSXC authority if any of the following are detected: AOA < 30 units, Mach > 0.4 , or yaw rate > 20 deg/sec with AOA > 30 units.

4.4.5 Wing Rock Suppression (WRS)

WRS is designed to significantly improves high AOA maneuvering flying qualities by using differential tail and rudder SAS to minimize the effects of wing rock at elevated AOA. These control laws are active between about 20 and 30 units AOA. The gains are constant up to about 28 units AOA and are then faded out up to 30 units AOA. It is proposed to extend WRS control laws > 30 units AOA in next software update OFP 4.4.

4.4.6 Spin recovery (SR)

The DFCS inputs spin recovery controls in an upright spin immediately upon detection of AOA > 30 deg and yaw rate > 20 deg/sec. As with all DFCS flight control

laws, the system does not move the control stick and rudder and can only apply the maximum SAS flight control surface authorities (± 5 deg differential tail – stick into and 19 deg rudder – opposite). It is important to note that the pilot can always achieve greater control surface authority with mechanical control inputs (± 12 deg differential tail and 30 deg rudder) if applied in the appropriate direction. If misapplied control inputs are utilized the DFCS will reduce the pro-spin control inputs to a maximum of ± 2 deg differential tail (pro-spin) and 11 deg rudder (pro-spin). Hence, the flight control position indicator could possibly alert the pilot to misapplied recovery controls.

4.4.7 Spoiler Failure Management

The DFCS monitors each individual spoiler panel independently and is capable of detecting malfunctions of the individual panels. When a malfunction is detected, the affected spoiler panel will be electrically failed down and its corresponding spoiler panel on the opposite wing will also be failed down (isolated). In the event that a malfunctioning spoiler panel cannot be failed to the down position, the spoiler panel on the opposite wing will be reactivated (within 2 sec) to help oppose a “stuck up” spoiler. The SPOIL FLR ORIDE switches have been removed from the DFCS airplane and this functionality is automatically provided without any aircrew interface requirements. The ROLL A and PITCH A computer segregations (channels) provide “control” and “monitor” functions for the inboard spoilers, respectively. The PITCH B and YAW B computer segregations provide “control” and “monitor” functions for the outboard spoilers, respectfully. If either one of the “control” or “monitor” computer segregations fail, you will lose the respective spoiler pair. Thus, a complete failure of the pitch computer will result in the loss of all spoilers. In addition, a complete failure of the roll computer will result in the loss of all spoilers due to a dual lateral stick position fault. This is because two of the

three lateral stick position inputs are processed by the roll computer, i.e. roll stick transducer 2 into ROLL A and roll stick transducer 3 into ROLL B (roll stick transducer 1 is into PITCH B).

4.5 POWER APPROACH ARI (PA-ARI)

4.5.1 Modified Spoiler Gearing

With DFCS, the PA spoiler-gearing schedule is modified to provide more predictable roll response with lateral stick deflection and is shown in figure A-14. To provide the appropriate spoiler gearing for all landing configurations, the DFCS uses the PA spoiler gearing whenever the landing gear or main flaps are down.

4.5.2 Lateral Stick to Rudder Interconnect (LSRI)

LSRI significantly improves precision approach flying qualities by enabling the pilot to more predictably roll the airplane with lateral stick alone. The LSRI automatically inputs coordinated rudder during rolling maneuvers (lineup corrections) to significantly reduce adverse yaw and subsequently Dutch roll characteristics to greatly enhance centerline control during approach.

4.5.3 Dutch Roll Damping (DRD)

The Dutch roll damping function provides sideslip rate feedback to the rudder to reduce directional nose wandering during approach. Airplane roll rate, yaw rate, lateral acceleration, Mach number, and angle of attack are used to calculate sideslip rate. Damping is improved by a factor of two over AFCS.

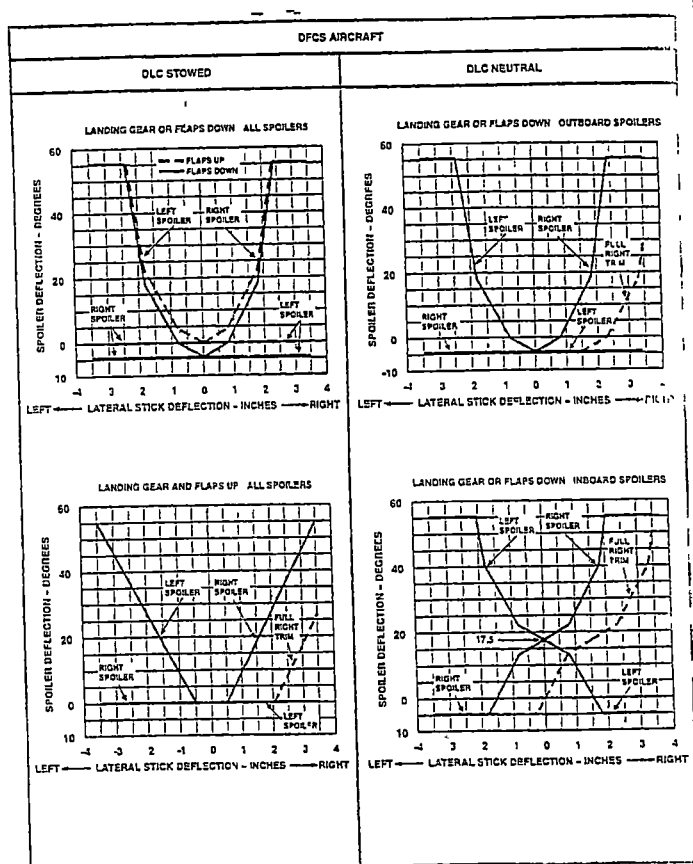


Figure A-14. SPOILER GEARING

4.5.4 Spiral Mode Stabilization (SMS)

Provides for a stabilized bank angle when established (as during an approach turn). When a bank angle is set and the lateral control stick neutralized (released to the neutral trim lateral stick position), the DFCS will attempt to maintain that bank angle (the greater the bank angle the less effective this functionality).

4.5.5 Roll Rate Command (RRC)

RRC provides a more sensitive and predictable roll response in the approach configuration. Lateral stick deflection commands a linear increase in roll rate such that one inch of lateral stick provides a 20 deg/sec roll rate (controlled by roll SAS)

regardless of airspeed/AOA during landing approach. In addition, the lateral stick spoiler breakout is 0.1 inch vice the previous 0.5 inch with AFCS, providing increased roll sensitivity.

4.6 STABILITY AUGMENTATION SYSTEM (SAS)

4.6.1 Stability Augmentation Controls

DFCS is electrically controlled by three manually operated STAB AUG toggle switches on the upper half of the DFCS control panel (DCP) (one for each axis: pitch, roll, and yaw) located on the left console in the front cockpit, figure 4-2. SAS is engaged by placing these switches to ON during normal post-start procedures. All switches normally remain ON during flight. Deselection of the Roll or Yaw SAS switch will disable the affected SAS axis and all ARI functions. Deselection of the Pitch SAS switch will disable the pitch SAS.

4.6.2 Stability Augmentation Authority

The DFCS manages all the control laws through the control surfaces, however it is limited to the authority provided by the existing SAS actuators (same series servo SAS actuators as for AFCS). These SAS control surface authorities are:

Pitch $\pm 3^\circ$ horizontal tail

Roll $\pm 5^\circ$ differential tail

Yaw $\pm 19^\circ$ rudder

The pilot can augment these control surface authorities by mechanically applying the appropriate control application to the mechanical limits of the control surface unless otherwise limited by the DFCS to preserve departure resistance. These mechanical control surface authority limits are:

Pitch -10° TED to $+33^{\circ}$ TEU horizontal tail

Roll $\pm 12^{\circ}$ differential tail / 24° split (ROLL SAS ON)

$\pm 7^{\circ}$ differential tail / 14° split (ROLL SAS OFF)

Yaw $\pm 30^{\circ}$ rudder

(For example, if the pilot commands 11 deg of mechanical rudder via the rudder pedals, the yaw SAS authority can still provide up to an additional ± 19 deg of rudder from that position and therefore can provide a combined rudder authority up to 30 deg. However, in no case can the mechanical limits of the control surface be exceeded (i.e. unable to command > 30 deg rudder))

5 DFCS FAULT REPORTING

5.1 DFCS CONTROL BOX FAULT DISPLAY

DFCS faults detected during an Initiated Built in Test (IBIT), or during an internal DFCS continuous BIT (OFP) are displayed in the fault display window on the DFCS control box (DCP). Faults will only be displayed in the fault display on deck with weight on wheels. In flight detected failures (FLT) may be reviewed post-landing and can be cleared by simultaneously depressing and holding the increment and decrement buttons down for 10 sec.

5.2 CAUTION/ADVISORY INDICATOR LIGHTS

DFCS faults that indicate a reduction in operational functionality or a reduced DFCS redundancy are also indicated by the illumination of a caution or indicator light on the Caution/Advisory Indicator (CAI) panel, located on the pilot's lower right console. The DFCS caution lights located on the CAI panel are depicted in figure A-15.

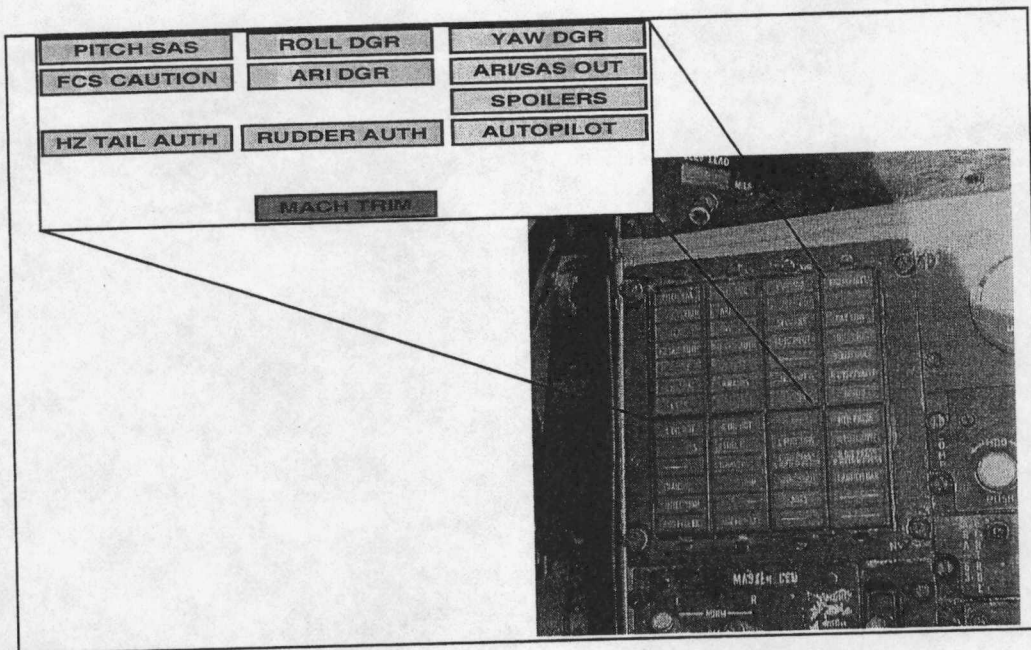


Figure A-15. DFCS CAUTION LIGHTS

5.2.1 ARI DGR Caution Light.

In the absence of ARI/SAS OUT caution light, if illuminated with ROLL DGR caution light indicates partial loss of roll SAS and/or ARI functionality. Likewise, if illuminated with YAW DGR caution light indicates partial loss of yaw SAS and/or ARI functionality.

5.2.2 ARI/SAS OUT Caution Light.

If illuminated by itself, indicates ROLL or YAW STAB AUG switch OFF or a dual landing gear handle position fault with the flaps down. If illuminated with ROLL DGR caution light indicates total loss of roll SAS and ARI functionality. If illuminated with YAW DGR caution light indicates total loss of yaw SAS and ARI functionality.

5.2.3 FCS CAUTION light.

This caution light by itself indicates no lost DFCS system functionality, but a loss of DFCS sensor input redundancy.

5.2.4 PITCH SAS caution light.

This caution light by itself indicates partial or total loss of pitch SAS. If illuminated with additional caution lights may indicate computer malfunction.

5.2.5 ROLL DGR caution light

This caution light illuminated with ARI DGR caution light indicates partial loss of roll SAS and ARI functionality. If also illuminated with ARI/SAS OUT caution light indicates total loss of roll SAS and/or ARI functionality.

5.2.6 YAW DGR caution light.

This caution light illuminated with ARI DGR caution light indicates partial loss of yaw SAS and ARI functionality. If also illuminated with ARI/SAS OUT caution light indicates total loss of yaw SAS and/or ARI functionality.

6 ARTIFICIAL FEEL

6.1 LONGITUDINAL STICK

Artificial feel in the longitudinal control system is located within control system's mechanical linkages, force links, and bobweights. A negligible break out force is required and longitudinal stick forces vary non-linearly with rate of stick movement and N_z . A spring-loaded cam and roller assembly produces breakout force when the stick is displaced from neutral trim and provides increasing stick forces proportional to control stick displacement. Control stick forces, proportional to normal acceleration and pitch acceleration, are produced by fore and aft bobweights. An eddy current damper that

resists large, rapid control deflections minimizes aircraft overstress from abrupt stick inputs

6.2 LATERAL STICK

Artificial feel in the lateral control system is located within control system's mechanical linkages. The lateral feel mechanism is a spring roller cam assembly with a neutral stick position detent and a constant stick deflection force gradient.

6.3 RUDDERS

Artificial feel in the directional control system is located within control system's mechanical linkages and is provided with a spring roller-cam mechanism similar to the longitudinal and lateral feel systems. Rudder force with pedal deflection is nonlinear with a relatively steep gradient about the neutral detent and a gradually decreasing gradient with increased pedal travel

7 TRIM

7.1 LONGITUDINAL TRIM

Longitudinal trim is provided by symmetrical deflection of the horizontal stabilizers. Trim is effected by varying the neutral position of the cam and roller feel assembly, which physically repositions the neutral location of the control stick, with an electromechanical screwjack actuator. The manual pitch trim button on the stick is a five-position switch that is spring loaded to the center (off) position. The fore-aft switch positions produce corresponding nosedown and noseup trim, respectively. The manual trim switch is deactivated when the autopilot is engaged. Longitudinal trim authority is 9° trailing edge down (TED) to $+35^\circ$ trailing edge up (TEU). The trim rate is 1° per second.

7.2 LATERAL TRIM

Lateral trim is provided by differential deflection of the horizontal stabilizers. The wing spoilers are not actuated for lateral trim control. Left or right deflection of the manual trim button on the control stick produces corresponding stick movement by adjusting the neutral position of the spring roller cam feel assembly which provides left or right wing down trim, respectively. The manual trim switch is deactivated when the autopilot is engaged. Lateral trim authority is 3° TED / 3° TEU (6° split). The trim rate is $3/8^{\circ}$ per second.

7.3 RUDDER TRIM

Rudder trim is provided by the symmetrical deflection of the dual rudders. Trim is effected by varying the neutral position of the feel assembly with an electromechanical screwjack actuator. Rudder trim control is actuated by a three position switch located on the left console outboard of the throttle quadrant. Left and right lateral switch movement commands left and right rudder trim, respectively. The switch is spring loaded to the neutral (off) position. Trim movement produces an associated movement of the rudder pedals, rudders, and rudder indicator. Rudder trim authority is 7° left to 7° right, and the trim rate is 1.13° per second.

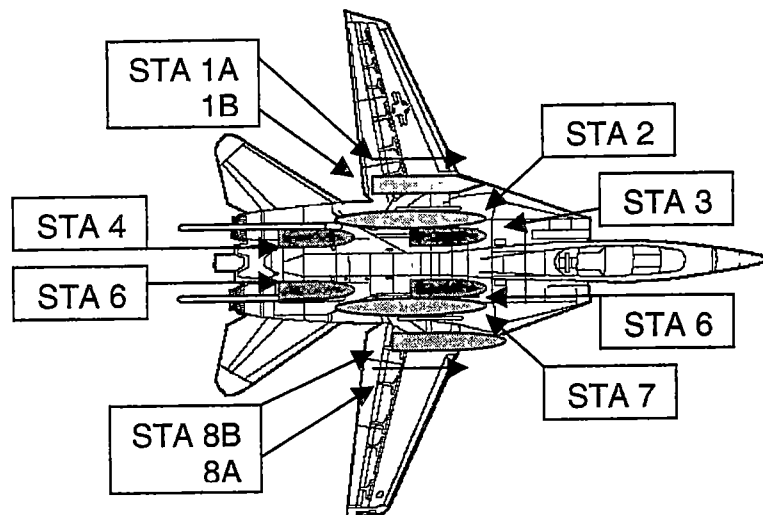
7.4 AUTOMATIC TRIM (HORIZONTAL TAIL ONLY)

Integrated trim automatically adjusts horizontal tail deflection symmetrically for pitch changes due to flap, slat, or speed brake operation. Mach trim automatically offsets the aircraft's pitch down tendency at high mach numbers. When the altitude hold mode of the autopilot is engaged, automatic pitch trim maintains the aircraft in a level attitude.

APPENDIX B. TESTS AND TEST CONDITIONS

Load	STATION									
	1A	1B	2	3	4	5	6	7	8B	8A
Fighter 1 (F1)	AIM-9	AIM-54	DT	--	AIM-7	--	--	DT	Lantirn	AIM-9
Fighter 2 (F2)	AIM-9	--	DT	--	AIM-7	--	--	DT		
Strike 1 (S1)	AIM-9	--	DT	GBU 12	AIM-7	--	GBU 12	DT	Lantirn	AIM-9
Strike 2 (S2)	AIM-9		DT	LGTR				DT	Lantirn	--
Recon (R)	AIM-9	--	DT	--	ALR167	TARPS	--	DT	--	AIM-9
Training 1 (T1)	AIM-9	--	DT	--	--	--	--	DT	Lantirn	--
Training 2 (T2)	--	--	DT	--	--	--	--	DT	--	AIM-9
Air Demo (D)	--	--	--	--	--	--	--	--	--	--

Figure B-1. F-14 TEST LOADINGS



Air-Air Missiles. AIM-9. 180lb

AIM-7. 370lb

AIM-54. 1000lb

Bombs: GBU-12 580lb

LGTR 50lb

Targeting/Recon

Lantirn pod

610lb TARPS pod. 1750lb

ALR167. 520lb

Fuel: Drop Tank (DT). 2400lb - full

400lb - empty

Figure B-2. F-14A EXTERNAL STATIONS AND TEST STORES

Table B-1. LONGITUDINAL STABILITY TESTS

Test	Gross Weight (x1000lb)	CG (% MAC)	Config / Load	Thrust	Altitude (ft MSL)	Airspeed (KIAS)	Data Obtained
Mechanical Characteristics	610 555	17-205	CR / T1 PA / T1	TLF ⁽¹⁾	15,000 2,000	300 145	• BO+F • Freeplay • Centering • Oscillations
Short Period	605 55.3	17-20	CR / T1 PA / T1	TLF	15,000 2,000	300 144	• A/C response to pitch doublet
Phugoid	605 55.3	17-20	CR / T1 PA / T1	TLF	15,000 2,000	250 144	• A/C response to airspeed deviations
Non-maneuvering Static Stability	600 55.0	17-20	CR / T1 PA / T1	TLF	15,000 2,000	250 143	• V, δ_s, F_s (high and low)
Maneuvering Stability - Steady Turns	595 54.5	17-20	CR / T1 PA / T1	TLF	15,000 2,000	400 142	• F_s, n_z, AOA
Configuration Change Gear Extend	540	18.0	CR to PA / T1	TLF	1,200	250	• F_s, δ_s • HQR Altitude Control $\pm 50/100$ ft
Gear Up	540	18.0	PA to CR / T1	MAX	100	150	• F_s, δ_s • HQR. Attitude Control $\pm 1 / 2^\circ$
Trim System Char	540	18.0	CR / T1 PA / T1	TLF	1,2K-20,000 600-1,200	190-400 135-160	• Authority • Sensitivity

Note. 2 TLF-Thrust for Level Flight

Table B-2. -LATERAL-DIRECTIONAL STABILITY / ROLL PERFORMANCE TESTS

Test	Gross Weight (x1000lb)	CG (% MAC)	Config / Load	Thrust	Altitude (ft MSL)	Airspeed (KIAS)	Data Obtained
Roll mode / damping	59.5 54.0	17-20	CR / T1 PA / T1	TLF ⁽¹⁾	15,000 2,000	300 140	Time to zero roll rate from steady roll
Spiral Stability	59.3 53.5	17-20	CR / T1 PA / T1	TLF	15,000 2,000	300 140	Time to 2x or 1/2 bank angle
Steady Heading Sideslip	53.5	17-20	PA / T1	TLF	2,000	140	$\delta_r, Fr, \delta_{a1}, Fa, \phi, \beta, ROC/D, Fs$ - Limiting input
Roll Sensitivity	53.0	17-20	PA / T1	TLF	2,000	138	- Trimshot $Wf, rpm, V_{trim}, H_{po}$ T_{30} with BO+F plus 1 lb / 3 lb
Roll Performance	58.5 53.0	17-20	CR / T1 PA / T1	TLF	15,000 2,000	300 138	- CR T_{360} Full stick 1 g roll - PA T_{30} Full stick 1 g roll
Aileron Yaw	58.3 54.0	17-20	CR / T1 PA / T1	TLF	15,000 2,000	250 140	Sideslip due to abrupt lateral input
Dutch Roll	58.0 54.0	17-20	CR / T1 PA / T1	TLF	15,000 2,000	250 140	$\Delta\beta, \Delta\psi, \Delta\phi$, Estimate ϕ/β ratio

Note 1 TLF-Thrust for Level Flight

Table B-3. APPROACH AND LANDING TESTS

Test	Gross Weight (x1000lb)	CG (% MAC)	Config / Load	Thrust	Altitude (ft MSL)	Airspeed (KIAS)	Data Obtained
ILS Approach / Landing	51-55	17 0-20 0	PA / F1,F2,S1,S2, T1,T2,R,D	A/R ⁽¹⁾	1,200 - surf	250 - 135	• HQR AOA maint $\pm 1/2$un • HQR Glideslope control ± 2 NW • HQR Azimuth control $\pm 1/2$ NW • HQR Centerline control $\pm 5/10$ ft (NW=ILS needle width deflection)
No Flap ILS Approach / Landing	54.0	17 0-20 0	PA-NF / T1	A/R	1,200 - surf	250- 154	• HQR AOA maint $\pm 1/2$un • HQR Glideslope control ± 2 NW • HQR Azimuth control $\pm 1/2$ NW • HQR Centerline control $\pm 5/10$ ft • PIO Tendencies
Visual Landing Pattern Normal Landings	51 0-54 0	17 0-20 0	PA / F1,F2,S1,S2, T1,T2,R,D	A/R	800 - surf	135-140	• HQR AOA maint $\pm 1/2$un • HQR Glideslope control $\pm 1/2^\circ$ / 1/2° • HQR Centerline control $\pm 5/10$ ft • PIO Tendencies
Visual Landing Pattern Offset Landings	51 0-54 0	17 0-20 0	PA / F1,F2,S1,S2, T1,T2,R,D	A/R	800 - surf	135-140	• HQR AOA maint $\pm 1/2$un • HQR Glideslope control $\pm 1/2^\circ$ / 1/2° • HQR Centerline control $\pm 5/10$ ft • PIO Tendencies

Note 1 A/R - As Required

Table B-4. FLYING QUALITIES SPECIFICATION SUMMARY

Para.	Topic	Specification Synopsis
4.1.8	Dangerous flight conditions	
4.1.8.1	Warnings and indications	Approach to dangerous condition shall be clear and unambiguous (stall warning/Mach buffet/normal vibration) to recognize impending dangers and take preventive action.
4.1.8.2	Devices for indication, warning, prevention and recovery	Shall perform their function when needed, but shall not limit flight within the operational envelope. Inadvertent operation shall not create a hazard and failure shall be indicated.
4.1.11	General flying qualities requirements	
4.1.11.1	Buffet	Shall be no objectionable buffet which will detract from executing the mission.
4.1.11.4	Failures	No single point failure of any component or system shall result in a dangerous or intolerable flying qualities.
4.1.11.5	Control margin	Aerodynamic control power, control surface rate and hinge moment shall be sufficient to assure safety throughout the combined range of all attainable α 's and β .
4.1.11.6	Pilot-induced oscillations (PIO)	Shall be no tendency for pilot induced oscillations resulting from pilot's efforts to control aircraft.
4.1.11.7	Residual oscillations	Sustained residual oscillations in calm air shall not interfere with the pilot's ability to perform required tasks
4.1.11.8	Control cross-coupling	No controller shall create an objectionable secondary response
4.1.12	General flight control system characteristics	The mechanical characteristics must be compatible with nonmechanical portions of the control system and airframe dynamic characteristics (includes the combined effect of friction and preload, lost motion, flexibility, mass imbalance and inertia, nonlinear gearing and rate limiting).
4.1.12.1	Control centering and breakout forces	Pitch, roll and yaw controls shall exhibit positive centering and the combined effects of centering, breakout force and force gradient shall not produce objectionable flight characteristics.
4.1.12.2	Cockpit control freeplay	Freeplay (position) shall not result in objectionable flight characteristics
4.1.12.6	Damping	All control systems oscillations shall be well damped unless the oscillations are not objectionable
4.1.13	General trim requirements	
4.1.13.1	Trim system irreversibility	Trim device shall maintain setting indefinitely unless changed by pilot, automatic interconnect or augmentation device. Interconnects or augmentation shall return trim to exact initial setting after deselect.
4.1.13.2	Rate of trim operation	Shall operate rapidly enough to enable low control forces under changing conditions yet not cause oversensitivity or trim precision difficulties under changing conditions such as dives & level accels
4.1.13.3	Stalling of trim systems	Stalling of a trim system due to aerodynamic loads shall not result in an unsafe condition.
4.1.13.4	Transients and trim changes	Trim changes for operation of control devices shall not impose excessive forces without use of trimmer control

Table B-5. LONGITUDINAL FLYING QUALITIES RELATED SPECIFICATIONS

Para.	Topic	Specification Synopsis
4.2.1	Pitch attitude dynamic response	
4.2.5	Pitch trim changes	Changes cause by control devices shall not be larger than 10 lb at peak in time interval of at least 5 sec
4.2.7	Pitch axis control power	
4.2.7.2	Pitch axis control power in maneuvering flight	Develop with pitch control alone n_o (-) to n_o (+)
4.2.7.3	Pitch axis control power in takeoff	Shall not restrict performance and for nosewheel aircraft shall be possible to obtain liftoff pitch attitude at $0.9 V_{min}$
4.2.7.4	Pitch axis control power in landing	Nosewheel can be gently lowered to the ground at speeds down to $0.9 V_{min}$
4.2.8.1	Pitch axis control forces: steady-state control force per g	No objectionable nonlinearities within range of 0 to 3 g. Outside this range, local gradient can differ no more than 50% from average gradient except above $0.85n_l$
4.2.8.2	Pitch axis control forces: transient control force per g	The minimum Fs/n shall not be objectionable to the pilot
4.2.8.5	Pitch axis control breakout forces	Shall be IAW Table XX (1/2 to 1 lb for class IV)
4.2.8.6.1	Pitch axis control force limits - takeoff	Shall be within 30 lb pull to 10 lb push (class IV-L)
4.2.8.6.2	Pitch axis control force limits - landing	Aircraft trimmed for approach, shall be <35 lb pull
4.2.8.7	Pitch axis trim systems	Shall be capable of reducing steady-state forces to zero
4.2.9.2	Pitch axis control displacements--maneuvering	Control motions in maneuvering flight shall not be so large or small so as to be objectionable
4.3.1.2	Steady-state flight path response to attitude change	Curve of γ vs. KTAS shall have a slope at $V_{o_{min}}$ which is negative or less positive than $0.06^\circ/\text{kt}$. Slope at 5 knots less than $V_{o_{min}}$ shall not be more than $0.05^\circ/\text{kt}$ more positive than at $V_{o_{min}}$
4.4.1	Speed response to attitude change	Shall be no tendency for airspeed to diverge aperiodically.

Table B-6. LATERAL-DIRECTIONAL FLYING QUALITIES RELATED SPECIFICATION

Para.	Topic	Specification Synopsis
4.5.1	Roll response to roll controller	
4.5.1.1	Roll mode	Time constant shall be no greater than that specified in Table XXIV
4.5.1.2	Spiral Stability	Time to double less than 12 sec from bank up to 20 deg
4.5.3	Linearity of roll response to roll controller	No objectionable non-linearities in variation of roll response with roll control deflection or force
4.5.5	Roll characteristics in steady sideslip	An increase or no change in bank angle shall accompany an increase in sideslip in same direction. Right or zero roll-control deflection and force shall accompany right sideslip. Linear for level I and II
4.5.6	Roll axis control for takeoff and landing in crosswind	Shall be possible to takeoff and land in 90 degree crosswind up to 30 kts
4.5.8	Roll axis control power	
4.5.8.1	Roll axis response to roll control inputs	Shall be in accordance with Tables XXX - XXXIII
4.5.8.2	Roll axis control power in steady sideslips	Positive effective dihedral shall never be so great that more than 75% of roll control power available is required
4.5.8.3	Roll axis control power	Shall be possible to taxi at any angle in 45 kt wind. Shall maintain straight path on takeoff and landing in 30 kt crosswind. Shall be able to maintain wings level w/ 10 deg sideslip in PA (not requiring more than 75% control power)
4.5.9	Roll axis control forces and displacements	
4.5.9.1	Roll control displacements	No physical interference with the pilots body, seat, or cockpit
4.5.9.2	Roll axis	Force shall not be so large as to be objectionable to the pilot.
4.5.9.3	Roll control sensitivity	Shall be in accordance with Table XXXVII
4.5.9.4	Roll axis control centering and breakout force	BO+F shall be more than 1/2 lb and less than 1 lb
4.5.9.5	Roll axis control force limits	
4.5.9.5.1	Roll axis control force limits in steady turns	Shall be possible to maintain steady turns in either directions with the yaw controls free up to 60 deg with maximum 5 lb force required
4.5.9.5.2	Roll axis control force limits in dives and pullouts	Shall not exceed 10 lb
4.5.9.5.3	Roll axis control force limits in crosswinds	Shall be able to takeoff and land in crosswinds up to 30 kt with forces not greater than 20 lb.
4.5.9.5.4	Roll axis control force limits in steady sideslips	Positive effective dihedral shall never be so great that more than 10 lb roll-stick force is required for sideslip angles that might be experienced in service employment
4.5.9.5.7	Roll axis control force limits	Shall not exceed 10 lb for at least 5 seconds

Table B-6. LATERAL-DIRECTIONAL FLYING QUALITIES RELATED SPECIFICATION (CON'T)

Para.	Topic	Specification Synopsis
4.6.1	Yaw axis response to yaw and side-force controllers	
4.6.1.2	Steady sideslips	Right pedal commands right β , etc. Essentially linear deflection variation between -15 and 15 deg. Increase in pedal deflection required for increase in β . Force variation essentially linear (-10 to +10). Force never reduced to zero. An increase in right bank angle shall accompany an increase in right sideslip, etc. Left roll-control deflection and force shall accompany left sideslips, etc. Essentially linear deflection vs. force
4.6.2	Yaw axis response to roll controller	Shall be in accordance with Figure 235 and Table XLIII
4.6.4	Yaw axis control for takeoff and landing in crosswinds	Shall be possible to takeoff and land in 30 kt crosswind
4.6.6	Yaw axis control power	Directional stability and control characteristics shall enable the pilot to balance yawing moments and control yaw sideslip
4.6.6.1	Yaw axis control power for takeoff, landing, and taxi	Shall be possible to taxi in 45 kt wind. Shall be able to maintain straight path on takeoff and landing. Directional control shall be available from aerodynamic forces only above 50 kt
4.6.7	Yaw axis control forces	Coordination can be achieved without unduly high control forces, while not too sensitive such that improperly coordinated inputs will degrade flying qualities
4.6.7.4	Yaw axis control force limits in crosswinds	Shall be possible to takeoff and land in 30 kt crosswinds with no more than 100 lb pedal force
4.6.7.10	Yaw axis control for limits-control mode changes	Not greater than 10 lb plus BO+F for at least 5 seconds
4.6.7.11	Yaw axis breakout forces	BO+F forces between 1 and 7 lb.
4.8.1	Cross-axis coupling in roll maneuvers	No overstress or dangerous flight conditions from yaw or pitch motions, sideslip or AOA changes resulting from yaw-control free, maximum performance 360° rolls
4.8.2	Crosstalk between pitch and roll controllers	Intentional inputs to one axis will not cause objectionable inputs to another
4.8.3	Control harmony	Simultaneous forces not to exceed 20 lb pitch, 15 lb roll, 175 lb yaw

Table B-7. HIGH AOA AND STALL RELATED SPECIFICATION

Para	Topic	Specification Synopsis
4.8.4	Flight at high angle of attack	
4.8.4 1	Warning Cues	Warning or indication of approach to stall or loss of aircraft control shall be clear and unambiguous.

Note: (1) Flight Phase categories listed:
A - Air-to-Air Combat (CO), Ground Attack (GA), Close Formation Flying (FF)
B - Climb (CL), Cruise (CR), Descent (D)
C - Takeoff (TO), Approach (PA), Waveoff/Go-Around (WO), Landing (L)

APPENDIX C. DETAILED METHOD OF TEST

1. GENERAL

This detailed method of test describes specific procedures and techniques used during those events in the Tests and Test Conditions Matrix, table B-1 to B-6, not covered by the USNTPS FTM-103, reference 3, or which require further amplifying information.

2. LANDING PATTERN-DAY LANDINGS

Numerous day/VFR landings were performed in configuration PA to establish a baseline of performance and handling characteristics. The day carrier visual landing pattern was entered by over flying the aircraft carrier landing area at 800ft AGL at 350-450 KIAS, with wings swept back to 68°, and executing a 4-6 g level break turn to the downwind heading. Lineup and altitude deviations were evaluated to determine the flying qualities of the aircraft. Lateral offsets of up to 100 ft were established by overshooting or undershooting the edge of the runway and corrections to centerline were initiated at 150-300 ft AGL. Altitude deviations up to ± 100 ft at $\frac{3}{4}$ mile on final were evaluated and adjustments were made to achieve a normal glidepath by $\frac{1}{8}$ - $\frac{1}{4}$ mile. The day visual carrier landing pattern is depicted in figure C-1.

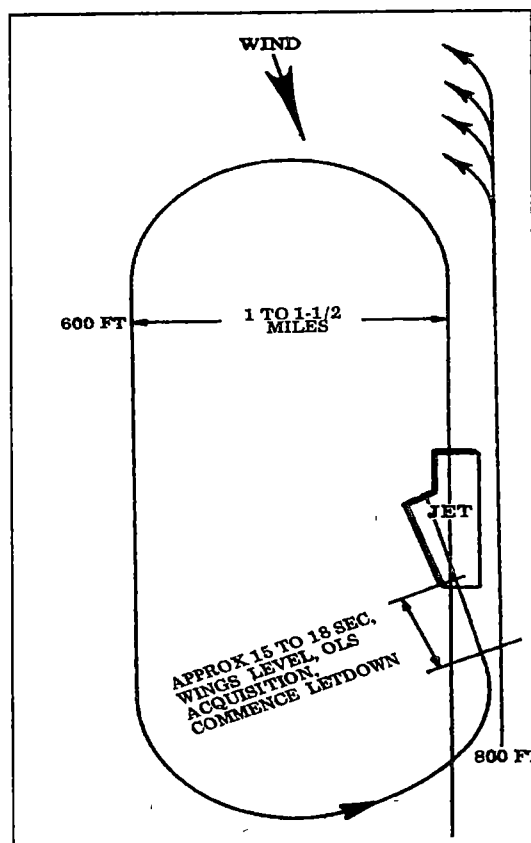


Figure C-1. DAY VISUAL LANDING PATTERN

3. LANDING PATTERN-NIGHT/IFR LANDINGS

Numerous night / IFR landings were performed in configuration PA and PA-NF to establish a baseline of performance and handling characteristics during straight-in ILS approaches. Lineup and altitude deviations were evaluated to determine the flying qualities of the aircraft. Lateral offset of up to 100 ft were evaluated and corrections to centerline were initiated at 100-400 ft AGL. Altitude deviations up to ± 100 ft at $\frac{3}{4}$ mile on final were evaluated and adjustments were made to achieve a normal glidepath by $\frac{1}{8}$ - $\frac{1}{4}$ mile. The night/IFR carrier ILS approach is depicted in figure C-2.

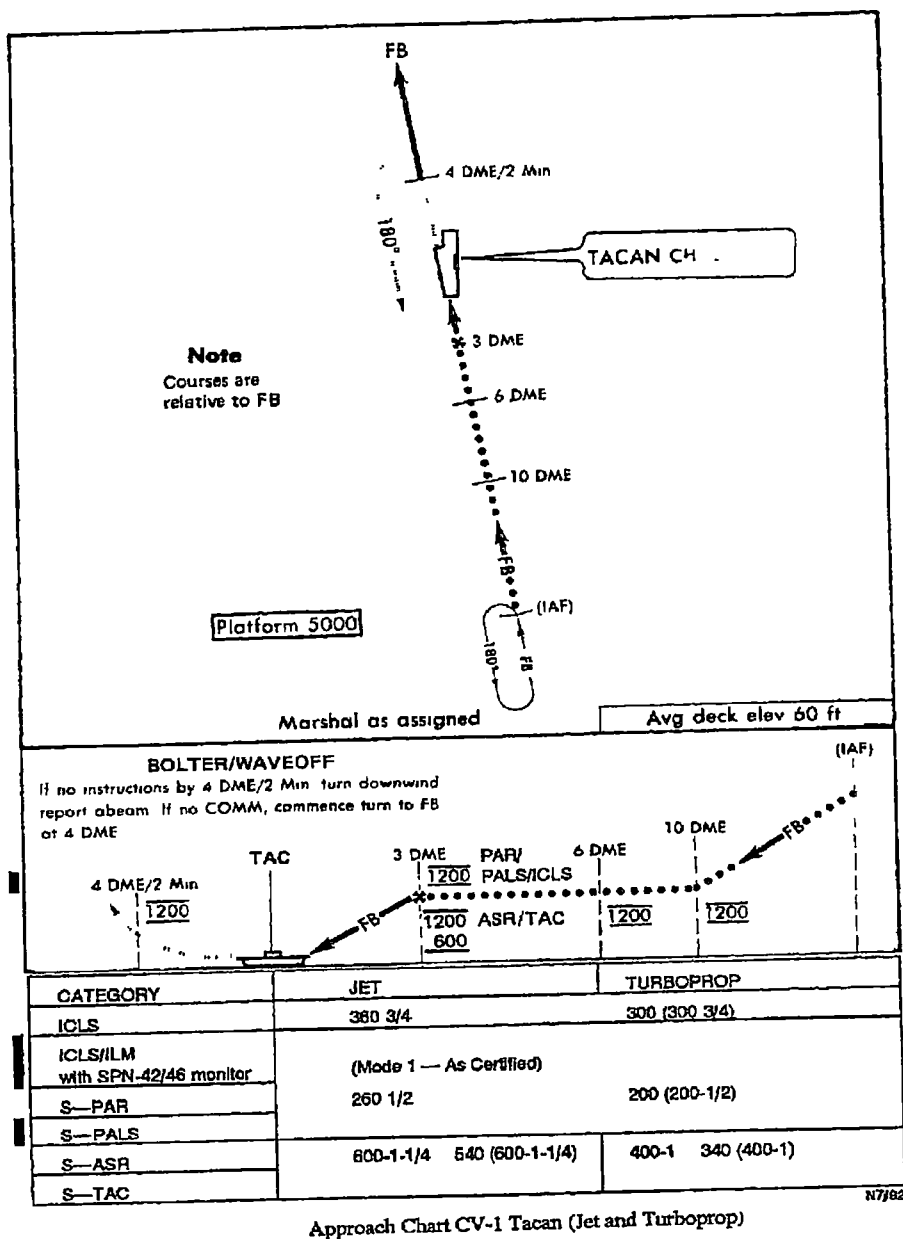


Figure C-2. NIGHT / IFR ILS APPROACH

APPENDIX D.RATING SCALES AND DEFINITIONS

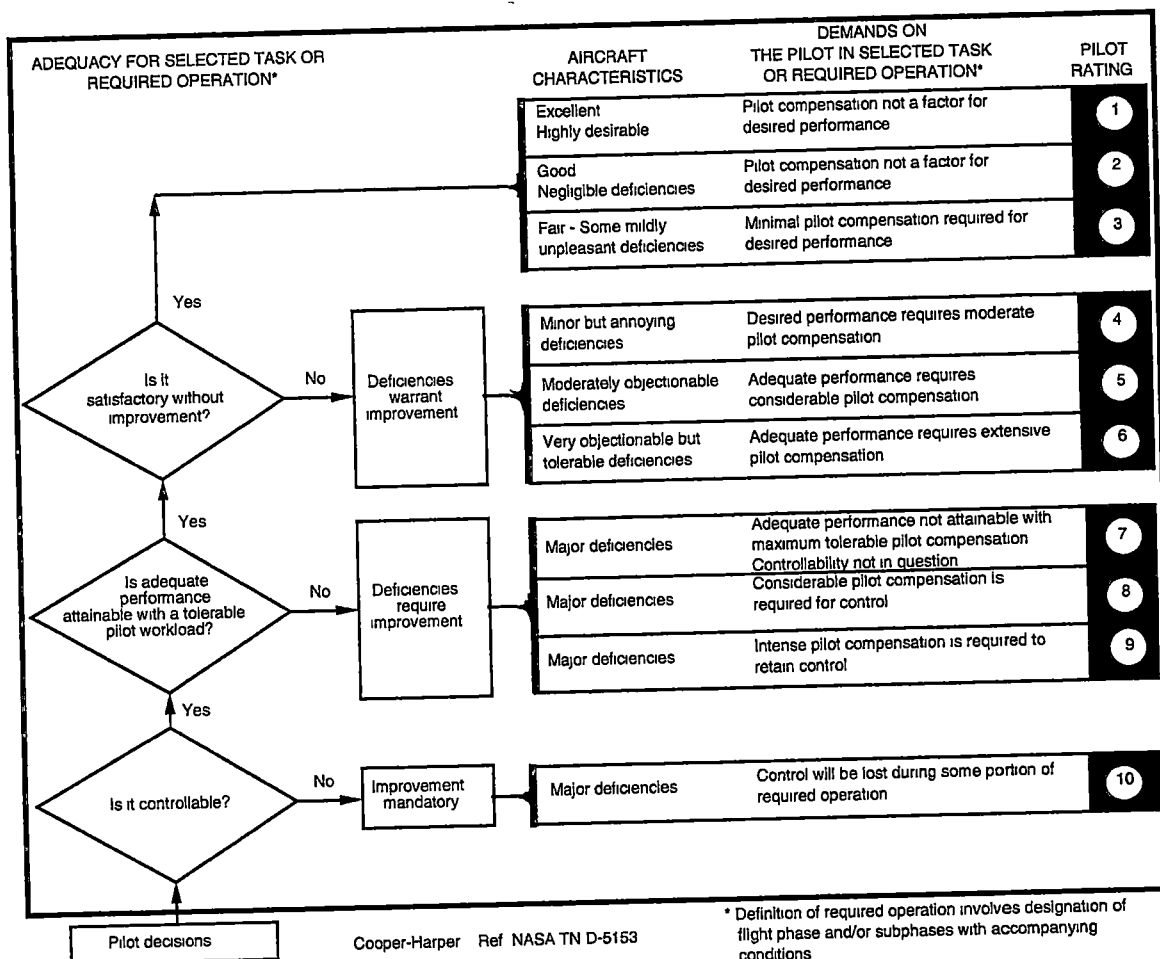


Figure D-1. COOPER-HARPER RATING SCALE

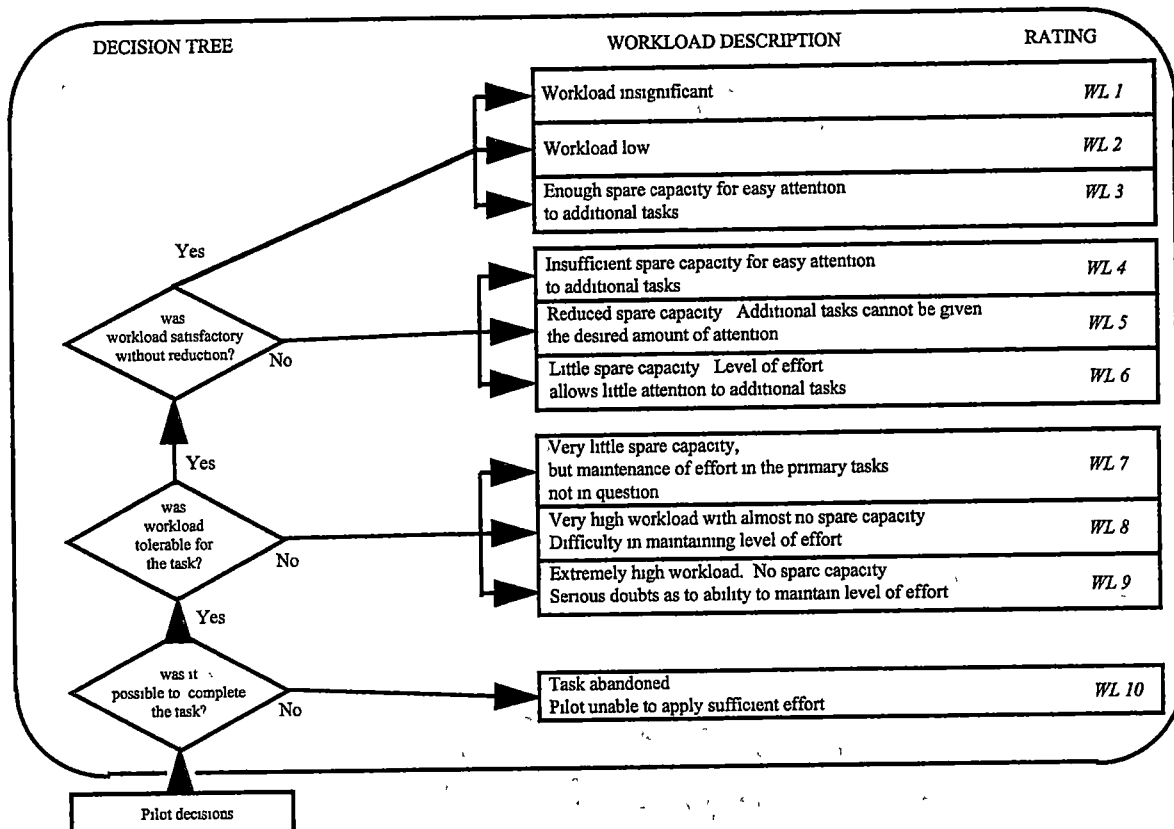


Figure D-2. BEDFORD WORKLOAD RATING SCALE

For abrupt maneuvers / tight control:

Observation	Result	PIO Rating
Divergent oscillation ⁽¹⁾	Freeze/release the control	5
Oscillations	Reduce gain/abandon task	4
Undesirable motions	Degraded tolerance/ considerable effort	3
Undesirable motions	Modify technique	2
No undesirable motions	--	1

Note: (1) If divergent oscillations for normal control/disturbance: PIO rating of 6

Figure D-3. PIO RATING SCALE

Part I indicates a deficiency, the correction of which was necessary because it adversely affects:

- Air worthiness of the aircraft or system.
- The capability of the aircraft or system to accomplish its primary or secondary mission.
- The safety of the crew or the integrity of an essential subsystem. In this regard, a real likelihood of injury or damage must exist. Remote possibilities or unlikely sequences of events shall not be used as a basis for safety items.

Part II Indicates a deficiency of lesser severity than a Part I which does not substantially reduce the ability of the aircraft or system to accomplish its primary or secondary mission, but the correction of which will result in significant improvement in the operational cost, effectiveness, reliability, maintainability, or safety of the aircraft or system, or requires significant operator compensation to achieve the desired level of performance; however, the aircraft or system being tested was still capable of accomplishing its mission with a satisfactory degree of safety and effectiveness.

Part III Indicates a deficiency which was minor or that appears too impractical or costly to correct in this model but which should be avoided in future designs. Included were violations of specifications for use by the contract negotiator in final settlement of the contract.

Figure D-4. DEFICIENCY CLASSIFICATION

1. VEHICLE CONTROL AND MANAGEMENT SYSTEM CLASSIFICATIONS

1.1 FLIGHT CONTROL SYSTEM (FCS)

FCS's include all components used to transmit flight control commands from the pilot or other sources to appropriate force and moment producers. Flight control commands may result in control of aircraft flight path, attitude, airspeed, aerodynamic configuration, ride, and structural modes. Among components included are the pilot's controls, dedicated displays, and logic switching, transducers, system dynamic and air data sensors, signal computation, test devices, transmission devices, actuators, and signal transmission lines dedicated to flight control, and interfaces with related subsystems.

1.2 VEHICLE CONTROL AND MANAGEMENT SYSTEMS (VCMS)

A VCMS is an integrated combination of functions that permits an air vehicle to be controlled in a manner that allows its specified missions to be accomplished satisfactorily, and which is critical to safety of flight. An integrated vehicle control and management system is a combination of the flight controls and any other air vehicle functions or subsystems that cause, augment, or replace pilot initiated commands or provide basic, necessary data/information for the flight control subsystem to function and insure safety of flight.

1.2.1 VCMS Operational State Classifications

1.2.1.1 Operational state I (normal operation)

Operational State I is the normal state of VCMS performance, safety, and reliability. This state satisfies the Level 1 flying qualities requirements within the operational flight

envelope and Level 2 within the service envelope and the stated requirements outside of these envelopes.

1.2.1.2 Operational state II (restricted operation)

Operational State II is the state of less than normal equipment operation or performance, which involves degradation, or failure of only a portion of the overall VCMS. A minimum increase in crew workload and no or minimum degradation in mission effectiveness may result from a limited selection of normally operating VCMS modes available for use; however, the intended mission may be accomplished. This state satisfies at least Level 1 flying qualities requirements within the operational flight envelope and Level 3 within the service envelope.

1.2.1.3 Operational state III (minimum safe operation)

Operational State III is the state of degraded VCMS performance, safety, or reliability which permits safe termination of precision tracking or maneuvering tasks, and safe cruise, descent, and landing at the destination of original intent or alternate destination; but in State III pilot workload is objectionable with considerable compensation and mission effectiveness is limited. Phases of the intended mission involving precision tracking or maneuvering cannot be completed satisfactorily. This state satisfies at least Level II flying qualities requirements for Category B and C tasks, shown in Table I.

1.2.1.4 Operational state IV (controllable to an immed. emerg. landing)

Operational State IV is the state of degraded VCMS operation at which continued safe flight is not possible; however, Level II flying qualities necessary to allow engine restart attempt(s), a controlled descent, and immediate emergency landing with at least

Level III flying qualities shall remain. Pilot workload is very objectionable but tolerable for landing.

1.2.1.5 Operational state V (controllable to an evacuable flight condition)

Operational State V is the state of degraded VCMS operation at which the VCMS capability is limited to the ability required to reach a flight condition at which crew evacuation may be safely accomplished and pilot workload is intense.

1.2.2 VCMS Criticality Classification

1.2.2.1 Flight/safety critical

A function is flight/safety critical if loss of the function results in an unsafe condition or inability to maintain VCMS Operational State III.

1.2.2.2 Flight phase critical

A function is flight phase critical if loss of the function results in an unsafe condition or inability to maintain VCMS Operational State III only during specific flight phases.

1.2.2.3 Mission critical

A mission critical function is mission critical if interoperability of that function with the VCMS is essential to accomplish the mission and failure or degradation of that function could result in an unsafe flight condition or control capability below Operational State II.

1.2.2.4 Non-critical

A function is noncritical if loss of the function does not affect flight safety or result in control capability below that required for VCMS Operational State III.

1.2.2.5 Extremely remote

Extremely remote is defined as numerically equal to 1×10^{-9} .

1.2.2.6 Expressions of probability

All probabilities, unless otherwise stated are per flight hour.

2. FLIGHT PHASES

Table D- I describes the flight phases, tasks and regions of flying qualities.

TABLE D-1. FLIGHT PHASES WITH ASSOCIATED FLYING QUALITY LEVELS AND HANDLING QUALITY REGIONS

Flight Phase Categories	The similarity of tasks in many Flight Phases, plus the limited amount of evaluation data on specific Flight Phases, has led to grouping the Phases into three Categories:
Category A	Those non-terminal Flight Phases that require rapid maneuvering, precision tracking, or precise flightpath control. Included in this Category are: a. Air-to-air combat b. Ground attack c. Weapons delivery/launch d. Aerial recovery e. Reconnaissance f. In-flight refueling (receiver) g. Terrain following h. Antisubmarine search i. Close formation flying j. Low-altitude parachute extraction
Category B	Those non-terminal Flight Phases that are normally accomplished using gradual maneuvers and without precision tracking, although accurate flightpath control may be required. Included in this Category are: a. Climb b. Cruise c. Loiter d. In-flight refueling (tanker) e. Descent f. Emergency descent g. Emergency deceleration h. Aerial delivery
Category C	Terminal Flight Phases are normally accomplished using gradual maneuvers and usually require accurate flightpath control. Included in this Category are: a. Takeoff b. Catapult takeoff c. Approach d. Wave off/go-around e. Landing

TABLE D-1. FLIGHT PHASES WITH ASSOCIATED FLYING QUALITY LEVELS AND HANDLING QUALITY REGIONS (CON'T)

Levels of flying qualities	In Calm air, Level 1 is Satisfactory, Level 2 is Tolerable, and Level 3 is Controllable. In the presence of atmospheric disturbances, 3.1.5.8 states the relationship between Levels and qualitative degrees of suitability.
Qualitative degrees of suitability	The degrees of suitability are defined as:
Satisfactory	Flying qualities clearly adequate for the mission Flight Phase. Desired performance is achievable with no more than minimal pilot compensation.
Tolerable	Flying qualities adequate to accomplish the mission Flight Phase, but some increase in pilot workload or degradation in mission effectiveness, or both, exists.
Controllable	Flying qualities such that the air vehicle can be controlled in the context of the mission Flight Phase, even though pilot workload is excessive or mission effectiveness is inadequate, or both. The pilot can transition from Category A Flight Phase tasks to Category B or C Flight Phases, and Category B and C Flight Phase tasks can be completed.
Recoverable	Flying qualities such that control can be regained following loss of control due to departure, failures, or atmospheric disturbances.
Regions of Handling	For each Aircraft Normal State, the Flight Envelope is divided into three regions defined in terms of speed, altitude, and load factor, plus any other parameters which may form flight limits (such as sideslip), within which the flying qualities requirements apply.
Regions of Satisfactory Handling	Regions of the Flight Envelope derived from operational mission requirements and in which Level 1 flying qualities are required.
Regions of Tolerable Handling	Regions of the Flight Envelope derived from aircraft performance margins rather than from mission requirements.
Regions of Recoverable Handling	Regions of the Flight Envelope in which operation of the aircraft is both allowable and possible, and which the aircraft is capable of safely encountering.

APPENDIX E.. LANDING AND MAINTENANCE DATA

Table E-1. DAY CARRIER LANDING PERFORMANCE

LINE PERIOD	# APPR.	# WITH LINE UP DEV.	% WITH LINE UP DEV	# WITH MULT LINE UP DEV	% WITH MULT DEV	AVE GRADE WITH LINE UP DEV	AVE GRADE WITH NO LINE UP DEV	TOTAL AVE GRADE	# BOLTER /WAVE OFFS WITH LINE UP DEV	BOARD-ING RATE WITH LINE UP DEV	# BOLTER WAVE OFFS WITH NO LINE UP DEV	BOARD-ING RATE WITH NO LINE UP DEV	TOT DAY BOARD-ING RATE	# OFF-CENTER LNDs	% OFF-CENTER LNDs
1	104	17	16.3%	7	6.7%	3.11	3.27	3.24	0	100%	2	97.7%	98.1%	0	0.0%
2	52	11	21.2%	6	11.5%	3.27	3.32	3.31	0	100%	1	97.6%	98.1%	0	0.0%
3	108	33	30.6%	21	19.4%	2.96	3.39	3.27	2	94%	4	94.7%	94.4%	0	0.0%
4	189	49	25.9%	33	17.5%	3.27	3.29	3.28	5	90%	6	95.7%	94.2%	3	1.6%
Total/ AVE	453	110	24.3%	67	14.8%	3.15	3.32	3.28	7	94%	13	96.2%	95.6%	3	0.7%

Table E-2. NIGHT CARRIER LANDING PERFORMANCE

LINE PERIOD	# APPR.	# WITH LINE UP DEV.	% WITH LINE UP DEV	# WITH MULT LINE UP DEV	% WITH MULT DEV	AVE GRADE WITH LINE UP DEV	AVE GRADE WITH NO LINE UP DEV	TOTAL AVE GRADE	# BOLTER WAVE OFFS WITH LINE UP DEV	BOARD-ING RATE WITH LINE UP DEV	# BOLTER WAVE OFFS WITH NO LINE UP DEV	BOARD-ING RATE WITH NO LINE UP DEV	TOT DAY BOARD-ING RATE	# OFF-CENTER LNDS	% OFF-CENTER LNDS
1	62	11	17.7%	10	16.1%	3.18	3.33	3.30	2	82%	9	82.4%	82.3%	1	1.6%
2	52	17	32.7%	12	23.1%	2.97	3.23	3.15	3	82%	6	82.9%	82.7%	1	1.9%
3	68	16	23.5%	7	10.3%	2.88	3.23	3.02	4	75%	14	73.1%	73.5%	0	0.0%
4	87	20	23.0%	14	16.1%	3.20	3.53	3.45	4	80%	7	89.6%	87.4%	0	0.0%
Total/ AVE	269	64	23.8%	43	16.0%	3.06	3.33	3.23	13	80%	36	82.4%	81.8%	2	0.7%

Table E-3. DFCS RELIABILITY

DATE	# FLTS SCHD	TOT FLTS SCHD	FLTS FLOWN	FLT HRS	TOT FLT HRS	DFCS LOST FLTS	TOT DFCS LOST FLTS	OTHER MAINT LOST FLTS	OPS CANX	DFCS INCOMP RATE
7-Jan	15	15	15	24 6	24 6	0	0	0	0	0 0%
8-Jan	17	32	17	14 8	39 4	0	0	0	0	0 0%
9-Jan	4	36	4	4 0	43 4	0	0	0	0	0 0%
10-Jan	0	36	0	0.0	43 4	0	0	0	0	0 0%
11-Jan	18	54	15	24 9	68.3	0	0	1	2	0 0%
12-Jan	0	54	0	0 0	68.3	0	0	0	0	0.0%
13-Jan	18	72	16	25 8	94 1	1	1	1	0	1 4%
14-Jan	0	72	0	0 0	94 1	0	1	0	0	1 4%
15-Jan	0	72	0	0 0	94 1	0	1	0	0	1 4%
16-Jan	0	72	0	0.0	94.1	0	1	0	0	1.4%
17-Jan	16	88	16	26.2	120.3	0	1	0	0	1 1%
18-Jan	0	88	0	0.0	120 3	0	1	0	0	1.1%
19-Jan	18	106	16	26.9	147 2	0	1	2	0	0.9%
20-Jan	0	106	0	0.0	147.2	0	1	0	0	0.9%
21-Jan	0	106	0	0 0	147.2	0	1	0	0	0 9%
22-Jan	15	121	15	24.9	172 1	0	1	0	0	0.8%
23-Jan	12	133	12	20 6	192 7	0	1	0	0	0.8%
24-Jan	19	152	19	30 0	222.7	0	1	0	0	0.7%
25-Jan	0	152	0	0.0	222 7	0	1	0	0	0.7%
26-Jan	10	162	7	9.7	232 4	0	1	0	3	0 6%
27-Jan	1	163	1	3 0	235 4	0	1	0	0	0 6%
28-Jan	0	163	0	0.0	235 4	0	1	0	0	0 6%
29-Jan	0	163	0	0.0	235.4	0	1	0	0	0.6%
30-Jan	0	163	0	0 0	235.4	0	1	0	0	0 6%
31-Jan	15	178	12	18 2	253 6	0	1	3	0	0.6%
1-Feb	19	197	17	29 1	282.7	1	2	1	0	1.0%
2-Feb	18	215	15	24 1	306 8	0	2	3	0	0 9%
3-Feb	0	215	0	0 0	306 8	0	2	0	0	0 9%
4-Feb	18	233	17	28 2	335 0	0	2	1	0	0 9%
5-Feb	20	253	17	27 2	362 2	1	3	2	0	1.2%

Table E-3. DFCS RELIABILITY (CON'T)

DATE	# FLTS SCHD	TOT FLTS SCHD	FLTS FLOWN	FLT HRS	TOT FLT HRS	DFCS LOST FLTS	TOT DFCS LOST FLTS	OTHER MAINT LOST FLTS	OPS CANX	DFCS INCOMP RATE
6-Feb	8	261	7	11.7	373.9	0	3	1	0	1.1%
7-Feb	14	275	11	14.8	388.7	0	3	3	0	1.1%
8-Feb	0	275	0	0.0	388.7	0	3	0	0	1.1%
9-Feb	0	275	0	0.0	388.7	0	3	0	0	1.1%
10-Feb	0	275	0	0.0	388.7	0	3	0	0	1.1%
11-Feb	0	275	0	0.0	388.7	0	3	0	0	1.1%
12-Feb	14	289	13	21.5	410.2	0	3	1	0	1.0%
13-Feb	18	307	15	24.8	435.0	0	3	3	0	1.0%
14-Feb	12	319	7	11.1	446.1	1	4	2	2	1.3%
15-Feb	14	333	9	11.6	457.7	0	4	4	1	1.2%
16-Feb	0	333	0	0.0	457.7	0	4	0	0	1.2%
17-Feb	0	333	0	0.0	457.7	0	4	0	0	1.2%
18-Feb	0	333	0	0.0	457.7	0	4	0	0	1.2%
19-Feb	0	333	0	0.0	457.7	0	4	0	0	1.2%
20-Feb	0	333	0	0.0	457.7	0	4	0	0	1.2%
21-Feb	0	333	0	0.0	457.7	0	4	0	0	1.2%
22-Feb	12	345	10	15.4	473.1	0	4	0	2	1.2%
23-Feb	17	362	16	25.5	498.6	0	4	1	0	1.1%
24-Feb	18	380	17	27.9	526.5	0	4	1	0	1.1%
25-Feb	18	398	16	26.5	553.0	2	6	0	0	1.5%
26-Feb	0	398	0	0.0	553.0	0	6	0	0	1.5%
27-Feb	0	398	0	0.0	553.0	0	6	0	0	1.5%
28-Feb	18	416	13	21.8	574.8	1	7	4	0	1.7%
29-Feb	18	434	13	22.1	596.9	0	7	5	0	1.6%
1-Mar	13	447	13	20.1	617.0	0	7	0	0	1.6%
2-Mar	17	464	14	26.6	643.6	0	7	3	0	1.5%
3-Mar	15	479	15	28.1	671.7	0	7	0	0	1.5%
4-Mar	16	495	16	27.8	699.5	0	7	0	0	1.4%
5-Mar	17	512	16	28.9	728.4	0	7	1	0	1.4%
6-Mar	17	529	17	33.6	762.0	0	7	0	0	1.3%

Table E-3. DFCS RELIABILITY (CON'T)

DATE	# FLTS SCHD	TOT FLTS SCHD	FLTS FLOWN	FLT HRS	TOT FLT HRS	DFCS LOST FLTS	TOT DFCS LOST FLTS	OTHER MAINT LOST FLTS	OPS CANX	DFCS INCOMP. RATE
7-Mar	14	543	14	30.8	792.8	0	7	0	0	1.3%
8-Mar	2	545	2	2.5	795.3	0	7	0	0	1.3%
9-Mar	12	557	11	20.0	815.3	0	7	1	0	1.3%
10-Mar	15	572	14	22.0	837.3	0	7	1	0	1.2%
11-Mar	13	585	12	21.4	858.7	0	7	1	0	1.2%
12-Mar	9	594	8	14.7	873.4	0	7	1	0	1.2%
13-Mar	10	604	10	16.0	889.4	0	7	0	0	1.2%
14-Mar	11	615	11	27.3	916.7	0	7	0	0	1.1%
15-Mar	14	629	14	23.5	940.2	0	7	0	0	1.1%
16-Mar	10	639	8	15.9	956.1	0	7	2	0	1.1%
17-Mar	10	649	10	13.9	970.0	0	7	0	0	1.1%
<i>Total</i>	649	649	583	970.0	970.0	7	7	49	10	1.1%

Table E-4. DFCS MAINTAINABILITY

DATE	# DOWN FAULT	TOTAL # DOWN FAULT	MAINT. MAN HOURS	DAYS TO REPAIR	MTBF- DOWN (HR/ FAIL)	# UP FAULT	TOTAL # UP FAULT	MAINT. MAN HOURS	DAYS TO REPAIR	MTBF- UP (HR/ FAIL)-	MTBF TOTAL (HR/ FAIL)
7-Jan	0	0	0		24.6	1	1	2.0	5.0	24.6	24.6
8-Jan	0	0	0		39.4	0	1	0.0		39.4	39.4
9-Jan	0	0	0		43.4	0	1	0.0		43.4	43.4
10-Jan	0	0	0		43.4	0	1	0.0		43.4	43.4
11-Jan	0	0	0		68.3	0	1	0.0		68.3	68.3
12-Jan	0	0	0		68.3	0	1	0.0		68.3	68.3
13-Jan	2	2	4.0	4.0	47.1	0	1	0.0		94.1	31.4
14-Jan	0	2	0.0		47.1	0	1	0.0		94.1	31.4
15-Jan	0	2	0.0		47.1	0	1	0.0		94.1	31.4
16-Jan	0	2	0.0		47.1	0	1	0.0		94.1	31.4
17-Jan	1	3	4.0	2.0	40.1	0	1	0.0		120.3	30.1
18-Jan	0	3	0.0		40.1	0	1	0.0		120.3	30.1

Table E-4. DFCS MAINTAINABILITY (CON'T)

DATE	# DOWN FAULT	TOTAL # DOWN FAULT	MAINT. MAN HOURS	DAYS TO REPAIR	MTBF- DOWN (HR/FAI L)	# UP FAULT	TOTAL # UP FAULT	MAINT MAN HOURS	DAYS TO REPAIR	MTBF- UP (HR/ FAIL)-	MTBF TOTAL (HR/ FAIL)
19-Jan	0	3	0 0		49 1	1	2	9 0	7 0	73 6	29 4
20-Jan	0	3	0 0		49 1	0	2	0 0		73.6	29 4
21-Jan	0	3	0 0		49 1	0	2	0 0		73.6	29.4
22-Jan	0	3	0 0		57 4	0	2	0.0		86 1	34.4
23-Jan	0	3	0 0		64 2	1	3	2 0	2 0	64 2	32.1
24-Jan	0	3	0 0		74 2	0	3	0 0		74.2	37.1
25-Jan	0	3	0 0		74 2	0	3	0 0		74 2	37 1
26-Jan	0	3	0 0		77 5	1	4	0.0	27 0	58.1	33 2
27-Jan	0	3	0 0		78.5	0	4	0 0		58 9	33 6
28-Jan	0	3	0 0		78 5	0	4	0 0		58 9	33 6
29-Jan	0	3	0 0		78 5	0	4	0.0		58 9	33.6
30-Jan	0	3	0 0		78.5	0	4	0.0		58 9	33.6
31-Jan	0	3	0 0		84.5	0	4	0 0		63 4	36.2
1-Feb	1	4	0 0	0 5	70.7	2	6	2.0	17 0	47.1	28.3
2-Feb	0	4	0 0		76 7	1	7	7.0	14.0	43.8	27.9
3-Feb	0	4	0 0		76.7	0	7	0 0		43 8	27.9
4-Feb	0	4	0 0		83 8	0	7	0 0		47.9	30.5
5-Feb	1	5	1 0	0.5	72 4	1	8	2.0	38.0	45 3	27.9
6-Feb	0	5	0 0		74.8	0	8	0 0		46 7	28 8
7-Feb	0	5	0 0		77 7	0	8	0.0		48.6	29.9
8-Feb	0	5	0 0		77 7	0	8	0 0		48 6	29 9
9-Feb	0	5	0 0		77.7	0	8	0 0		48.6	29.9
10-Feb	0	5	0 0		77.7	0	8	0 0		48 6	29.9
11-Feb	0	5	0 0		77.7	0	8	0.0		48.6	29 9
12-Feb	0	5	0.0		82.0	0	8	0.0		51 3	31 6
13-Feb	0	5	0 0		87.0	0	8	0 0		54.4	33.5
14-Feb	1	6	2 0	0.5	74 4	0	8	0.0		55.8	31.9
15-Feb	0	6	0 0		76 3	0	8	0 0		57.2	32 7
16-Feb	0	6	0 0		76 3	0	8	0.0		57 2	32 7
17-Feb	0	6	0 0		76 3	0	8	0 0		57.2	32 7
18-Feb	0	6	0 0		76 3	0	8	0 0		57.2	32.7

Table E-4. DFCS MAINTAINABILITY (CON'T)

DATE	# DOWN FAULT	TOTAL # DOWN FAULT	MAINT. MAN HOURS	DAYS TO REPAIR	MTBF- DOWN (HR/ FAIL)	# UP FAULT	TOTAL # UP FAULT	MAINT. MAN HOURS	DAYS TO REPAIR	MTBF- UP (HR/ FAIL)-	MTBF TOTAL (HR/ FAIL)
19-Feb	0	6	0.0		76.3	0	8	0.0		57.2	32.7
20-Feb	0	6	0.0		76.3	0	8	0.0		57.2	32.7
21-Feb	0	6	0.0		76.3	0	8	0.0		57.2	32.7
22-Feb	0	6	0.0		78.9	1	9	2.0	21.0	52.6	31.5
23-Feb	0	6	0.0		83.1	0	9	0.0		55.4	33.2
24-Feb	0	6	0.0		87.8	0	9	0.0		58.5	35.1
25-Feb	2	8	4.0	2.0	69.1	0	9	0.0		61.4	32.5
26-Feb	0	8	0.0		69.1	0	9	0.0		61.4	32.5
27-Feb	0	8	0.0		69.1	0	9	0.0		61.4	32.5
28-Feb	1	9	30.0	1.0	63.9	0	9	0.0		63.9	31.9
29-Feb	0	9	0.0		66.3	0	9	0.0		66.3	33.2
1-Mar	0	9	0.0		68.6	0	9	0.0		68.6	34.3
2-Mar	0	9	0.0		71.5	0	9	0.0		71.5	35.8
3-Mar	0	9	0.0		74.6	0	9	0.0		74.6	37.3
4-Mar	0	9	0.0		77.7	0	9	0.0		77.7	38.9
5-Mar	0	9	0.0		80.9	0	9	0.0		80.9	40.5
6-Mar	0	9	0.0		84.7	0	9	0.0		84.7	42.3
7-Mar	0	9	0.0		88.1	0	9	0.0		88.1	44.0
8-Mar	0	9	0.0		88.4	0	9	0.0		88.4	44.2
9-Mar	1	10	2.0	1.0	81.5	0	9	0.0		90.6	42.9
10-Mar	0	10	0.0		83.7	0	9	0.0		93.0	44.1
11-Mar	0	10	0.0		85.9	0	9	0.0		95.4	45.2
12-Mar	1	11	10.0		79.4	0	9	0.0		97.0	43.7
13-Mar	0	11	0.0		80.9	1	10	2.0	3.0	88.9	42.4
14-Mar	0	11	0.0		83.3	1	11	2.0	1.0	83.3	41.7
15-Mar	1	12	2.0	1.0	78.4	1	12	2.0	1.0	78.4	39.2
16-Mar	0	12	0.0		79.7	1	13	2.0	1.0	73.5	38.2
17-Mar	1	13	0.0	0.0	74.6	2	15	5.4	0.5	64.7	34.6
TOTAL	13	13	59.0		74.6	15	15	39.4		64.7	33.4
AVE				1.0					9.2		

VITA

Richard Burr was born in Detroit, Michigan on November 15, 1966. He attended schools in the Warren Consolidated public school system, where he graduated from Charles Stuart Mott High School in June 1984. He entered the United States Naval Academy in July 1984 and received the Bachelor of Science degree in Physics upon graduation in May 1988. After completing undergraduate flight training and being designated a Naval Aviator in June 1990, he participated in Operations Southern Watch, Deny Flight, Provide Promise, and Deliberate Force during overseas deployments while flying the A-6E Intruder and F-14 Tomcat. In June of 1996 he was selected to attend the United States Test Pilot School, and upon completion was assigned as a Test Pilot and Project Officer to the Naval Weapons Test Squadron at Point Mugu, California. While stationed at Point Mugu, he entered the University of Tennessee Space Institute, Tullahoma via the distance learning program. In September of 1999, he transferred to Fighter Squadron TWO ONE ONE and, after completing another deployment to the Persian Gulf, officially received the Masters of Science degree in Aviation Science from the University of Tennessee in December 2000.

Lieutenant Commander Burr is presently flying F-14 Tomcats and working as Operations Officer at Fighter Squadron TWO ONE ONE. He is currently stationed at Naval Air Station Oceana in Virginia Beach, Virginia.