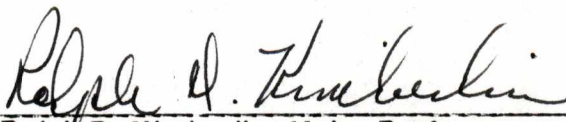


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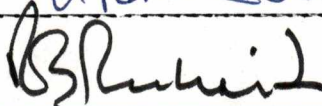
I am submitting herewith a thesis written by Thomas Cropper entitled "Flying Qualities and Performance Evaluation of the TA-7C Airplane". I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Aviation Systems.



Ralph D. Kimberlin, Major Professor

We have read this thesis
and recommend its acceptance:





Accepted for the Council:



Vice Provost
and Dean of the Graduate School

FLYING QUALITIES AND PERFORMANCE EVALUATION
OF THE TA-7C AIRPLANE

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Thomas Cropper

December 1989

DISCLAIMER

The technical data included in this thesis are actual flight test data collected during a limited scope flying qualities and performance evaluation of a United States Navy TA-7C airplane. All enhancing characteristics and deficiencies attributed to the aircraft and its systems are the sole opinion of the author, and do not necessarily represent the official position of the Naval Air Test Center, the Naval Air Systems Command, or the United States Navy. Similarly, the recommended corrections to the documented deficiencies are presented by the author for the sole purpose of fulfilling the requirements of this thesis, and are not attributable to any of the aforementioned authorities.

ABSTRACT

Poor serviceability of rapidly aging TA-4J airplanes currently in service with overseas U. S. Navy base defense squadrons has prompted a search for a capable low cost replacement. Limited scope testing was conducted on the TA-7C airplane to evaluate its potential as a replacement aircraft for the base defense mission. Tests were completed during ground evaluations totaling 2.3 hrs and four test flights totaling 6.0 hrs. Flying qualities and performance testing was conducted on production representative airplanes based upon typical mission utilization.

Flight testing revealed poor sustained turning performance which will not allow effective jinking against anti-aircraft artillery. Poor instantaneous turning performance will not allow effective execution of a defensive turn against missiles. These two major deficiencies will result in probable loss of aircraft and should be corrected prior to operational deployment. Flight testing also revealed several deficiencies which should be corrected as soon as practicable if found economically feasible.

The TA-7C demonstrated excellent potential for the base defense mission, and will be satisfactory upon correction of the major deficiencies. A replacement engine and incorporation of a leading edge extension to the wing are among the numerous airframe modifications recommended to correct the deficiencies discovered during the evaluation. Where practical, predictions of improved performance are estimated.

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1. INTRODUCTION

1.1 BACKGROUND

The TA-7C airplane was evaluated as a potential replacement for the rapidly aging TA-4J currently employed as a base defense platform for overseas U. S. Navy bases. The replacement must fulfill the mission requirements of land-based interceptor and all-weather ground attack aircraft with potential for emergency deployment aboard United States Navy aircraft carriers. The airplane should be capable of quick reaction launches, short-range air-to-air offense, precise air-to-ground weapons delivery, and all-weather operation. Reliability, simplicity, ease of maintenance, and minimal flyaway cost are essential features.

1.2 PURPOSE

The purpose of this test was to conduct a limited scope evaluation of the flying qualities, performance, and mission utility of the TA-7C airplane for the base defense mission.

1.3 DESCRIPTION OF TEST AIRPLANE

The TA-7C CORSAIR II is a two-place, tandem seat trainer version of the A-7E attack airplane produced by Vought Corporation. The airplane is designed for carrier or land-based operations and is equipped for visual and instrument flight operations. Principal airplane dimensions and features are presented in appendix A, figures 1 and 2. The airplane is powered by a single Allison TF41-A-402D turbofan engine capable of producing 15,300 lb uninstalled static thrust at sea level, standard day. Empty weight is 20,500 lb with a maximum internal fuel load of 10,200 lb, with capability to carry 8100 lb external fuel. Airplane features include a

shoulder-mounted wing with a 35 degree leading edge sweep and 5 degree negative dihedral, leading and trailing edge flaps, all-moving unit horizontal tail, and eight ordnance stations. Primary flight controls consist of a single rudder, ailerons, spoiler-deflectors, and a unit horizontal tail, all controlled by control sticks and rudder pedals in each cockpit. All control surfaces are hydraulically powered and irreversible. Secondary flight controls consist of a single fuselage-mounted speed brake, and leading and trailing edge flaps. Automatic maneuvering leading and trailing edge flaps are designed to improve departure characteristics. Pitch, roll, and yaw trim is controlled from either cockpit. The airplane has an automatic flight control system (AFCS) which provides yaw stabilization, control augmentation in pitch and roll axes, and an aileron-rudder interconnect. Retractable hydraulically operated tricycle landing gear with nosewheel steering is also included.

The navigation-delivery system is designed to assist the pilot in navigating to the target, release armament on target, and return. The system is designed to determine the geographic position of the airplane and the release point for a computed weapon release. The system use a tactical computer, various sensors and displays. The AN/ASN-91 Tactical Computer use inputs from the AN/ASN-90 Inertial Measurement Set (IMS) and other sensors for total system integration as presented in appendix B, figure 1. Steering and target information are presented on the Heads-Up Display (HUD). A detailed description of the airplane is presented in the operating manual, reference 1. The test airplanes, U. S. Navy Bureau Numbers (BuNo) 154361, 154402, and 154407 were representative of production airplanes.

1.4 SCOPE OF TEST

Evaluation of the TA-7C airplane was conducted during 2.3 hours of ground tests and four flights totaling 6.0 hours. Ground tests consisted of a cockpit human engineering evaluation, ground handling, and flight control mechanical characteristics tests. All flight tests were conducted from the front cockpit in daylight visual meteorological conditions (VMC) at the Naval Air Test Center, Patuxent River, Md. The test envelope is presented in appendix C, table I. Airplane loading for all flights was two pilots, full internal fuel, and external stores as depicted in appendix C, figure 1.

Test configurations are presented in appendix C, table II. All flights were flown within the limitations imposed by the operating manual. Flight tests were conducted with control augmentation engaged and automatic maneuvering flaps (AMF). A summary of test conditions is presented in appendix C, table III. Gross weight during tests varied between 22,300 and 35,500 lb. The TA-7C airplane was evaluated against the requirements of Military Specifications MIL-F-8785C, MIL-D-8708B, and MIL-STD-203F (references 2,3, and 4, respectively).

1.5 METHOD OF TEST

Performance testing was conducted as described in the Fixed Wing Performance Flight Test Manual, reference 5. Flying qualities evaluations were flown using the techniques of Fixed Wing Stability and Control Flight Test Manual, reference 6. Human engineering cockpit evaluation was conducted with the evaluator positioned at design eye position (DEP), wearing the flight equipment listed in appendix D, table I. Critical anthropometric data of the evaluator are presented in appendix D, table II. Contractor recommended speeds for takeoff, climb, cruise, descent, and

landing were used in establishing flight conditions for performance data. Data were gathered manually by utilizing production cockpit instruments, hand-held force gauge, stopwatch, tape measure, protractor, and a hand-held 35mm camera (cockpit evaluation). Control stick forces and displacements were measured at the base of the control stick handgrip. Rudder pedal forces and displacements were estimated. Sideslip angles were estimated using the sideslip release heading comparison. Exact sideslip angles were not available. Handling qualities ratings (HQR) were assigned using the Cooper-Harper Scale published in reference 7 and presented in appendix E, table I. Data were recorded on data cards and a portable voice tape recorder. Performance data were reduced using a Hewlett-Packard 9816 computer and the U. S. Naval Test Pilot School Fixed Wing Data Reduction Program. Deficiencies noted were assigned a rating as defined in appendix E, figure I.

1.6 MISSION PROFILE

The typical mission required of the replacement airplane will consist of operations in tropical or sub-tropical areas such as Guantanamo Bay, Cuba and Cubi Point, Phillipines. There are two base defense mission roles of equal importance. In the interceptor role, the airplane should maintain combat air patrol (CAP) station 50 nmi from the defended point under ground control intercept (GCI) control. In the ground attack role, the airplane will be required to accurately deliver weapons in close proximity to friendly forces countering insurgent ground forces. Both roles require short notice launches and a nominal on-station time of 1.5 hrs. The replacement airplane should be capable of takeoff and landing on 8000 ft runways in tropical temperatures at maximum takeoff gross weight.

2. RESULTS AND DISCUSSION

2.1 COCKPIT EVALUATION

2.1.1 General

The cockpit evaluation was conducted from the forward cockpit during a two hour ground evaluation and in flight during mission utility tests. During ground tests the pilot's seat was adjusted such that the evaluator's eye was at the DEP of 31.5 inches as specified in reference 4. During flight tests the pilot's seat was adjusted for optimum pilot comfort.

2.1.2 Field of View

External field of view (FOV) was evaluated during ground operations and in flight during formation flight, weapons delivery, cruise, and landings. A rectilinear total vision plot of the forward cockpit is presented in appendix F, figure 1. The forward FOV was restricted by the canopy bow, engine monitoring system (EMS) control, command transfer panel and two windscreen bows. Aft FOV was restricted by the ejection seat, aft bulkheads, and canopy frame and bow. Forward FOV was improved when the seat was raised 2 to 3 inches above the design eye point; however, the pilot was required to lean forward and down to reference HUD displays. Aft FOV did not improve significantly with the use of rear view mirrors or when the pilot turned to look right or left of the ejection seat. The restricted forward FOV will result in difficult acquisition of ground and airborne targets. The restricted aft FOV will hamper pilot lookout, requiring frequent turns and recurrent pilot lookout to avoid undetected rear quarter attacks.

2.1.3 Heads-Up Display Instantaneous Field of View

The HUD instantaneous field of view was qualitatively evaluated for size during air-to-ground weapons delivery. Airplane heading and the upper one-fourth of the altitude and airspeed scales were out of view when the pilot's back was against the seat. The pilot had to move his head down and lean forward in order to see the total HUD field of view. The small instantaneous HUD field of view will require the pilot to move his head forward during dive bombing runs, resulting in poor body position during g onset at recovery.

2.1.4 AN/ASN-91 Tactical Computer Control

The AN/ASN-91 tactical computer control was evaluated for location and mission utility. The tactical computer was located on the right console as shown in figure 1.

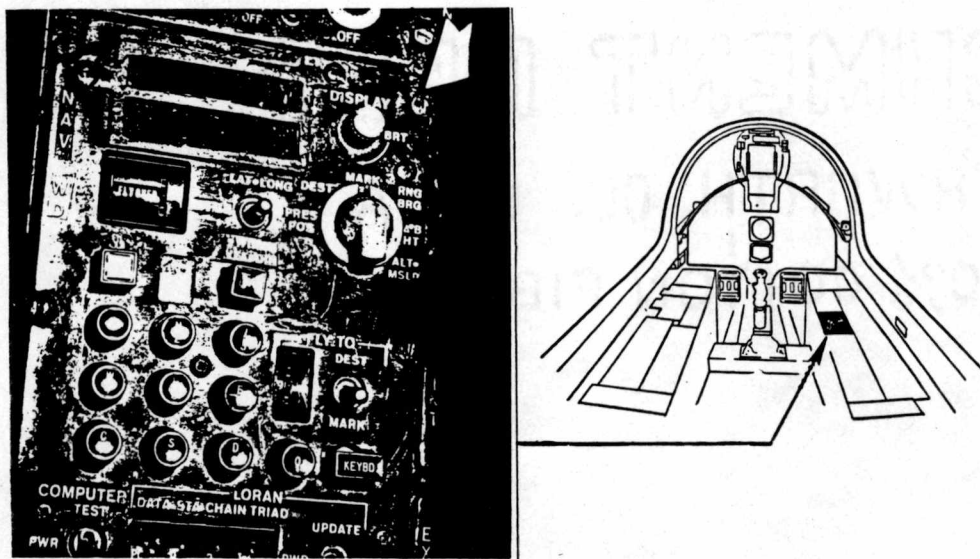


Figure 1

AN/ASN-91 TACTICAL COMPUTER LOCATION

Tactical computer control and entry of geographic coordinates could only be accomplished with the right hand. The pilot was required to look down and to his right to confirm or monitor computer modes and coordinates. Entry of coordinates required moving the right hand off the control stick. Since the left hand was moved to the control stick, there was not continuous throttle control. When the pilot was required to look down inside the cockpit to monitor the tactical computer, outside visual reference was interrupted. During high speed low altitude ingress to target, the pilot will be required to fly the airplane left-handed with limited outside visual reference during computer entries, resulting in degraded airspeed, altitude, and timing control.

2.2 MECHANICAL CHARACTERISTICS

2.2.1 General

Longitudinal, lateral, and directional control system mechanical characteristics were measured on the ground and verified in flight in configurations CR and PA1. A summary of test results is presented in table I. Data are presented in appendix G, figures 1 through 3.

2.2.2 Longitudinal

Breakout plus friction force was the same for forward and aft control stick motion and provided positive control feel around trim. There was essentially no control freeplay. Control centering appeared absolute. Stick oscillations generated by stick raps were deadbeat and did not result in airplane motion. The positive centering and zero freeplay will allow the pilot to make precise pitch corrections during aiming tasks. The longitudinal mechanical characteristics are satisfactory and met the requirements of the specifications.

TABLE I
TA-7C FLIGHT CONTROL SYSTEM MECHANICAL CHARACTERISTICS

CONTROL SYSTEM	BREAKOUT, PLUS FRICTION (lb)		FREEPLAY (in)		CENTERING	DAMPING
	MEASURED SPECIFICATION LIMIT (HAND HELD)		MIN	MAX		
Longitudinal	1 (Forward and Aft)	$\frac{1}{2}$	3	Essentially 0	Absolute	Deadbeat
Lateral	1	$\frac{1}{2}$	2	1/16	Absolute	Deadbeat
Directional	8-10	1	7	3/16	Positive, within 1/16 inch	Deadbeat

2.2.3 Lateral

Lateral breakout plus friction force was the same for left and right stick motion. Freeplay was not objectionable. Control stick centering was essentially absolute. Control stick oscillations generated by stick raps were deadbeat and did not result in airplane motion. The minimal freeplay and absolute centering of the lateral control stick will allow the pilot to make precise, small lateral control inputs very easily. The lateral control mechanical characteristics are mission suitable and fulfilled the requirements of the specifications.

2.2.4 Directional

Breakout plus friction force was the same for both pedals. Freeplay was small and not objectionable. Rudder pedal oscillations generated by pedal raps were deadbeat and did not result in airplane motion. The minimal freeplay allowed the pilot to make small directional corrections during nosewheel steering operation, resulting in precise ground tracking. The directional control mechanical characteristics are satisfactory but failed specification requirements.

2.3 FLYING QUALITIES

2.3.1 Non-Maneuvering Static Stability

2.3.1.1 Configuration CR

Static longitudinal stability, as indicated by the variation of longitudinal control stick force and position with airspeed, was evaluated at 10,000 ft mean sea level (MSL), 250 knots observed airspeed (KOAS). Data are presented in appendix G, figure 4. Stick force and position gradients indicated positive static stability throughout the test airspeed band. Force and displacements gradients were shallow. The gradients

were steeper within 5 kt of trim, but decreased to an average force gradient of 1 lb per 10 KOAS at airspeeds outside this range. During dive bombing in which rapid increases in airspeed occur, the pilot will be able to maintain dive angle without excessive stick forces, resulting in minimal pilot fatigue. The static stability characteristics in configuration CR are satisfactory and met the requirements of the specifications.

2.3.1.2 Configuration PA1

Static longitudinal stability, as indicated by the variation of longitudinal control stick force and position with airspeed, was evaluated at 10,000 ft MSL, 143 KOAS. Data are presented in appendix G, figure 5. The force gradients, though shallow, indicated positive static stability throughout the test airspeed band. Displacement gradients were very shallow ($\frac{1}{4}$ inch per 10 KOAS) outside the apparent trim speed band. These shallow stick force and position gradients did not provide sufficient cues to the pilot that the airplane had accelerated or decelerated from trimmed approach airspeed. Maintaining trimmed speed within 5 KOAS during simulated instrument approach was difficult and required very small ($\frac{1}{4}$ inch), light control stick inputs every 3 to 5 sec (HQR-5). During landing approaches, the pilot will have only small force and position cues when off optimum approach speed, resulting in difficult airspeed control.

2.3.2 Flight Path Stability

Flight path stability, as indicated by the variation of flight path angle with airspeed, was evaluated at 7000 to 9000 ft MSL at optimum approach speed of 132 KOAS. Data are presented in appendix G, figure 6. Flight path angle did not change appreciably within 6 kt of trim airspeed indicating strong flight path stability. Flight path angle versus airspeed

gradient was flat at airspeeds faster than optimum, but changed rapidly at 9 kt below trimmed approach speed. During landing approaches, airspeed control (within 3 kts) was difficult.

The large airspeed deviations which occurred during glideslope corrections required several power corrections to correct back to optimum approach speed. During carrier approaches, airspeed corrections will require frequent power changes, resulting in difficult glideslope control and excessive pilot workload.

2.3.3 Longitudinal Maneuvering Stability

2.3.3.1 Configuration P

Longitudinal maneuvering stability, as indicated by the variation of longitudinal control stick force and position with normal accelerations, was evaluated at 10,000 ft MSL, 400 KOAS. Data are presented in appendix G, figures 7 through 9. Control stick force gradients were linear and positive (7 lb per g) indicating positive maneuvering stability. During maneuvering, establishing and holding 4g required high (22 lb) control forces. To aggressively maneuver the airplane the attack pilot will encounter high stick forces resulting in pilot fatigue.

2.3.3.2 Configuration WO

Longitudinal maneuvering stability, as indicated by the variation of longitudinal control stick force and position with normal acceleration, was evaluated at 10,000 ft MSL, 160 KOAS and in the landing pattern. Data are represented in appendix G, figures 10 and 11. Control stick force gradients were linear and positive (10 lb per g) indicating positive maneuvering stability. During turns to downwind in the landing pattern, stick forces were light to moderate and comfortable. The pilot will be able

to easily and comfortably maneuver the airplane during approaches. The maneuvering stability characteristics in configuration WO are satisfactory and met the specification requirements.

2.3.3.3 Dynamic Control Forces

Dynamic longitudinal control force characteristics, as indicated by the variation in control force with normal acceleration during sudden pullups, was evaluated in configuration P at 10,000 ft MSL, 400 KOAS. Data are presented in appendix G, figure 7. Stick force per g was essentially the same during sudden and steady pulls. The buildup of control force during the maneuvers led the buildup of load factor. The pilot will be able to quickly apply stick force during defensive maneuvering, resulting in predictable load factor onset. The dynamic longitudinal control force characteristics in configuration P are mission suitable and met the requirements of the specifications.

2.3.4 Roll Mode

2.3.4.1 Configuration CR

Roll mode time constant was evaluated at 10,000 ft MSL and 400 KOAS. The roll mode time constant was approximately 1/3 second and roll response was quick and predictable. Capturing a 60 deg angle of bank (within 2 deg) from a 40 deg per sec (approximate) roll rate was fairly easy, requiring only that the stick be returned to center 3 to 5 deg prior to the desired bank angle (HQR-3). The pilot will be able to precisely establish and match desired angle of bank during formation maneuvering. The roll mode characteristics in configuration CR are desirable and met the requirements of the specifications.

2.3.4.2. Configuration PA1

Roll mode time constant was evaluated at 10,000 ft MSL and 135 KOAS in configuration PA1. The roll mode time constant was approximately 1/4 second. Roll response to small aileron inputs was very quick, but somewhat jerky. Capturing a 20 deg angle of bank (within 2 deg) was fairly easy and predictable using small stick deflections. However, when using stick deflections of one-half or more an abrupt acceleration from zero roll rate to the steady state roll occurred making angle of bank changes very difficult. During landing approaches, the pilot will be required to make small lateral control inputs to avoid abrupt roll rate onset.

2.4 PERFORMANCE

2.4.1 General

All performance data presented are, unless otherwise noted, flight test data which have been referred to a standard gross weight of 35,000 lb.

2.4.2 Takeoff Performance

Takeoff performance was evaluated in configuration TO during four takeoffs on dry concrete runways. Test day data are presented in table II. Contractor estimated takeoff distances and airspeeds were substantiated by results. Test day takeoff distances were slightly shorter than those projected by the contractor. The pilot will be able to takeoff on standard 8000 ft U. S. Navy runways allowing multi-theater deployment capability. The takeoff performance of the TA-7C airplane is satisfactory. Further testing of takeoff performance at high ambient temperatures and high gross weights is recommended to ensure mission capabilities.

2.4.3 Climb Performance

Climb performance was evaluated in configuration CL, commencing

TABLE II
TEST DAY TAKEOFF PERFORMANCE

GROSS WEIGHT (lb)	TEMPERATURE (deg F)	RELATIVE WIND DIRECTION/ SPEED (deg/kt)	LIFTOFF SPEED/ DISTANCE (kt/ft)	CONTRACTOR CLIMB SPEED TIME DISTANCE (sec) (nmi)	INTERCEPT FUEL (lb)
30,400 (Load A)	79	030/10	147/2800	80 5	200
33,200 (Load B)	62	350/5	150/3200	79 5	300
30,500 (Load C)	54	350/4	145/2600	- -	-
33,500	66	020/10	151/3600	72 4	200

at 5000 ft MSL, using the climb schedules presented in table III.

Data are presented in appendix H, figures 1 through 9. A climb from 5000 to 15,000 ft MSL with loading D (six 500 lb bombs) required over 3 minutes and 21 nmi. Even with loading A (pylons only) the same climb required over 2 minutes and 16 nmi. To facilitate high altitude weapons delivery from low altitude ingress, the pilot will be required to climb early, allowing early acquisition by enemy radars and eliminating the element of surprise, which may result in loss of the airplane to surface-to-air missiles.

2.4.4 Level Flight Performance

2.4.4.1 Range and Endurance

Level cruise performance was evaluated in configuration CR at the conditions listed in appendix C, table III. Data are presented in appendix H, figures 10 and 11. A summary of test results is presented in table IV. Maximum endurance fuel flow at 10,000 ft MSL was such that, based upon 5000 lb mission fuel, the on station time during base defense airborne alert missions was 2.3 hr. Maximum range fuel flow at 20,000 ft MSL was such that, based on 5000 lb mission fuel, the high altitude mission radius was 500 nmi. The level cruise performance is satisfactory and fulfilled the specification requirements.

2.4.4.2. Level Acceleration

Level acceleration performance was evaluated in configuration P at the conditions listed in appendix C, table III. Plots of standard day data are presented in appendix H, figures 12 and 13. A summary of test day data is presented in table V. Approximately 90 sec were required to accelerate from 250 to 450 KOAS under standard day, standard gross weight conditions at 5000 ft MSL. At test day conditions the acceleration

TABLE III

CLIMB SCHEDULE

LOADING	CLIMB SCHEDULES
A	385 KOAS to 20,000 ft, 0.77M to 25,000 ft (Contractor Recommended)
B	250 KOAS to 10,000 ft, accelerate, 0.75M to 25,000 ft
D	340 KOAS to 20,000 ft, 0.75M to 25,000 ft (Contractor Recommended)

TABLE IV
CRUISE PERFORMANCE

ALTITUDE (ft MSL)	MAXIMUM AIRSPEED (KOAS)	ENDURANCE FUEL FLOW (lb/hr)	MAXIMUM RANGE AIRSPEED (KOAS)	FUEL FLOW (lb/hr)	SPECIFIC RANGE (nmi/lb)
500	225	3000	345	3800	0.09
5,000	225	2500	290	3000	0.10
10,000	220	2100	285	2500	0.13
20,000	225	1750	265	1800	0.20

TABLE V
TEST DAY LEVEL ACCELERATION DATA

ALTITUDE (ft MSL)	GROSS WEIGHT (lb)	TIME TO ACCELERATE 250-450/KOAS (sec)
5,000 (AMF ON)	24,700	50
10,000 (AMF ON)	23,400	73
10,000 (AMF OFF)	26,100	83

time from 340 to 500 KOAS (5000 ft MSL) was 70 sec. The excessive time required to accelerate will require the pilot to begin accelerating far from the target during low altitude weapons delivery, resulting in increased fuel consumption and difficulty in coordinated attacks during multiple airplane strikes.

2.4.4.3 Maximum Speed

The maximum level speed was determined from level acceleration referred flight data. Calculation of maximum speed is presented in appendix H, figure 13. The maximum attainable speed at 5000 ft MSL, level flight was 501 knots true airspeed (KTAS). The base defense pilot will be able to attain high speed during medium altitude road reconnaissance, resulting in minimum time in small arms fire envelopes. The maximum level speed in configuration P is satisfactory.

2.4.5 Turn Performance

2.4.5.1 Sustained Turn Performance

Sustained turn performance was evaluated in configuration P at 5000 and 10,000 ft MSL at 200, 300 and 400 KOAS. Data is presented in appendix H, figures 14 and 15. A summary of sustained turn performance is presented in table VI. The maximum sustained load factor and sustained turn rate were very low in comparison with current threat aircraft. Airspeed bled off rapidly at load factors above maximum sustained. The low sustained load factor will not allow the pilot to jink effectively against anti-aircraft artillery during weapons delivery, resulting in possible loss of airplane and crew.

TABLE VI
SUSTAINED TURN PERFORMANCE

ALTITUDE (ft MSL)	MAXIMUM SUSTAINED LOAD FACTOR	MAXIMUM SUSTAINED TURN RATE (deg/sec)	MINIMUM SUSTAINED TURN RADIUS (nmi)
5,000	3.0	8	0.5
10,000	2.5	7.5	0.5

2.4.5.2 Instantaneous Turn Performance

Instantaneous turn performance was evaluated in configuration P at 10,000 ft MSL and 200, 300 and 400 KOAS. Data are presented in appendix H, figures 15 through 18. A summary of instantaneous turn performance is presented in table VII. Maximum instantaneous load factor and turn rate were extremely low in comparison with current threat aircraft. Maintaining maximum instantaneous load factor operating at military rated thrust required a 40 deg nosedown attitude. The extremely low instantaneous turn performance will not allow the pilot to effectively execute a defensive turn against missiles, with loss of airplane and crew highly probable.

2.4.5.3 Buffet Onset

Airframe buffet onset was evaluated at 10,000 ft MSL, and 200, 300 and 400 KOAS. Buffet onset occurred up to 1% g prior to limit buffet. An increase in turn rate of 3 deg per sec (35%) could be achieved between buffet onset and limit buffet. The airframe buffet did not provide the pilot with sufficient cues of airplane energy states during aggressive maneuvering. The early buffet onset will require the pilot to reference the angle of attack gauge during defensive maneuvering, resulting in interrupted outside scan and high pilot workload.

2.4.6 Descent Performance

Descent performance was evaluated in configuration DE1 and DE2 at the test conditions presented in appendix C, table III. Data are presented in appendix H, figures 16 through 21. A summary of test results for descents from 25,000 to 5000 ft MSL is presented in table VIII.

Maintaining airspeed during the descent was easy, but maintaining AOA

TABLE VIII
INSTANTANEOUS TURN PERFORMANCE

ALTITUDE (ft MSL)	MAXIMUM INSTANTANEOUS LOAD FACTOR	MAXIMUM INSTANTANEOUS TURN RATE (deg/sec)	MINIMUM INSTANTANEOUS TURN RADIUS (nmi)
10,000	6.2	13	0.5

TABLE VIII

DESCENT PERFORMANCE

DESCENT SCHEDULE	FUEL REQUIRED (lb)	TIME REQUIRED (min)	DISTANCE REQUIRED (nmi)
250 KOAS Idle Power Speedbrake Out	40	3	15
14 Units AOA Idle Power Speedbrake In	100	8	38

was slightly harder due to apparent AOA system lags. Very little fuel was used in either descent. The contractor maximum range descent (14 units AOA) was 5 min longer than the speedbrake out descent, but saved 150 lb of fuel, since fuel was required in level flight for 5 min after level off from the speedbrake out descent. The minimum fuel required during descents will allow more fuel available for mission performance.

2.4.7 Landing Performance

Landing performance was evaluated in configuration L during two landings on dry concrete runways. Test day data are presented in table IX. Contractor estimated data indicated shorter stopping distances and slower landing speeds than test results. Aerodynamic braking was moderately effective as approximately 2200 ft were required to slow from 135 to 100 KOAS. Brake effectiveness was excellent in that, at 23,200 lb, the airplane was slowed from 100 KOAS to a full stop in 1200 ft. The pilot will be able to land and stop the airplane on standard U. S. Navy runways allowing multi-theater deployment capability. The landing performance of the TA-7C is satisfactory. Further testing of landing performance at high gross weights and on wet runway environments is strongly recommended.

2.4.8 Engine Response

Engine response to throttle lever motion was evaluated in configuration PA1 during Fresnel lens landing approaches. In the range of 81 to 92% RPM throttle response was slow during power addition commands and took up to 4 to 5 seconds from throttle lever motion to newly stabilized RPM. Power reduction commands in this range were not as slow and generally took 2 to 3 seconds for stabilized RPM. The long time required during power change commands often resulted in the pilot

TABLE IX
TEST DAY LANDING PERFORMANCE

GROSS WEIGHT (lb)	TEMPERATURE (deg F)	RELATIVE WIND (deg/kt)	AIRSPEED (KOAS)	LANDING DISTANCE (ft)
26,400	59	010/7	150	5,000
23,200	63	340/10	135	3,400

passing through the glideslope before the power change took effect. This resulted in large throttle motions to correct and subsequent larger motions to re-correct. Maintaining proper glideslope was very difficult, requiring large throttle motions and extremely timely anticipation of engine acceleration. During carrier landing approaches the extremely poor engine response will result in large glideslope deviations requiring waveoffs.

2.4.9 Combat Radius

A mission profile was generated from flight test data to determine combat radius. Loading A data was used and therefore does not reflect drag due to external stores. A sample mission profile is presented in appendix H, table I. Based upon the mission profile, combat radius was 463 nmi. The airplane will be capable of medium range operations without aerial refueling, resulting in autonomous operation.

2.5 POTENTIAL SOLUTIONS TO DEFICIENCIES

2.5.1 Safety of Flight/Mission Accomplishment Deficiencies

2.5.1.1 General.

This investigation revealed a total of three deficiencies which must be corrected prior to operational deployment to ensure safety of flight and mission accomplishment.

2.5.1.2 Poor climb performance in configuration CR.

This deficiency (paragraph 2.4.3) is the result of insufficient specific excess power. Specific excess power (P_s) is a function of velocity, gross weight, thrust and drag as shown in equation (1).

$$P_s = \frac{V (T-D)}{W} \quad (1)$$

For a given velocity and weight, P_s can be increased by either increasing thrust, reducing drag, or doing both.

To increase thrust available, two prospective engines have been selected to replace the TF-41-A-402D engine currently installed. Comparison of the current and two candidate engines is presented in table X.

A primary consideration for selection of a replacement engine is physical dimensions. Since the current TF41 engine has approximately 38 inches of exhaust tailpipe which would be replaced by the new engine afterburner and nozzle sections, the additional engine lengths pose no significant problem. The approximate 3 inch radius increase of either prospective engine will probably require airframe rework. However, in the author's opinion, the improvement in thrust available would justify the cost of rework. From table X, it appears that either engine is well suited and would provide greatly improved thrust. In consideration of maintaining a high degree of commonality in the naval aviation supply system, selection of the General Electric F110 is recommended. This engine is currently employed in the F-16N adversary and the F-14A Plus fleet defense aircraft.

Selection of this engine carries a small penalty, in that it increases empty gross weight by 800 lb. The effect of the increased engine weight on center of gravity requires further investigation. The outstanding thrust available utilizing afterburner will result in superior climb performance. From calculations presented in appendix I, figure 1, it is shown that P_s improves 31.2 ft/sec at military power and 243.8 ft/sec at maximum afterburner. This equates to approximate 5000ft MSL, 385 KT

Table X

CANDIDATE ENGINE COMPARISON

Engine	Weight (lb)	Length (in)	Diameter(1) (in)	Thrust(2) (lb)
Allison TF41	3018	102.6	40	15,300
General Electric F110	3800	181.9	46.5	17,000/ 28,600
Pratt and Whitney F100	3033	191.2	46.5	14,670/ 23,830

Notes: (1) Total Diameter including accessory casing
(2) Military Rated Thrust/Maximum Thrust

climb rates of 6000 ft/min and 19,000 ft/min at military power and maximum afterburner, respectively. Installation of the improved engine will also remove the deficiency of poor level acceleration performance. Further testing with the replacement engine installed is recommended to determine center of gravity changes, structural limitations and actual climb performance improvements.

Another way to increase P_s is to reduce drag. A drag reduction program may yield small reductions in drag resulting in small P_s improvements. The magnitude of P_s increase with a drag reduction is substantially smaller than the P_s increase achieved by thrust increase. In the opinion of the author, the deficiency is most effectively overcome by installation of the F110 engine.

2.5.1.3 Poor Sustained Turn Performance.

Maximum sustained turn performance is a function of thrust available, gross weight, and maximum lift-to-drag ratio as shown in equation (2).

$$N_z (\text{max sust}) = (T/W)(L/D)_{\text{max}} \quad (2)$$

In order to improve maximum sustained 'g' at a given weight, either thrust or maximum lift-to-drag ratio $(L/D)_{\text{max}}$ must be increased. $(L/D)_{\text{max}}$ is an aerodynamic property of the airplane and is assumed to be maximized through the automatic maneuvering leading and trailing edge flaps.

Using only thrust increases, substantial gains can be achieved in $N_z(\text{max sust})$. For a constant weight and configuration, any percentage improvement in thrust available results in an equivalent percentage improvement in $N_z(\text{max sust})$ ie., a 10% change in thrust results in a 10% change in $N_z(\text{max sust})$. Incorporating the replacement engine selected in

paragraph 2.5.1.2 results in thrust available increases of:

$$\text{Military Rated Thrust: } \frac{17,000 - 15,300}{15,300} = 11.1\%$$

$$\text{Maximum Afterburner Thrust: } \frac{28,600 - 15,300}{15,300} = 86.9\%$$

Therefore an impressive gain of 87% in $N_z(\text{max sust})$ can be attained. At a gross weight of 35,000 lb and 5000 ft MSL, the previous maximum sustained 'g' of 3 would increase to 3.3 at military power and 5.6 at maximum afterburner. This substantial improvement in sustained turn performance through incorporation of the replacement engine would eliminate the deficiency. Therefore, replacing the current engine with the General Electric F110 engine is further substantiated.

2.5.1.4 Poor Instantaneous Turn Performance.

Maximum instantaneous turning performance is a function of the maximum lift (L_{max}) that can be generated by the aircraft body as shown in equation (3).

$$(L_{\text{max}}) = (W)(N_{z\text{max}}) = 1/2 \rho V^2 S (C_{l\text{max}}) \quad (3)$$

From equation (3) it can be seen that for a given weight, altitude, and velocity, maximum lift can be changed by varying either wing area (S), maximum lift coefficient ($C_{l\text{max}}$), or both.

Reference 8 documents impressive gains in instantaneous turning performance with the incorporation of wing leading edge extensions (LEX). Gains of 50% instantaneous and 25% sustained turning performance were attained in airplanes with similar taper ratios and wing sweep. These performance improvements were gained with only a 10% increase in wing area. Essentially, the LEX generates a strong vortex core of high energy which creates strong negative pressures on the upper surface of the wing.

These negative pressures generate additional lift force which grows with angle of attack. The strong pressure gradients over the inboard section of the wing also inhibit the normal tendency for the boundary layer to move outboard at high angle of attack. However, incorporation of the LEX moves the wing aerodynamic center forward. With no change in center of gravity location, this results in a reduced static margin.

The proposed offset to this destabilizing influence is to shift the center of gravity forward so as to maintain an unchanged positive static margin as depicted in appendix I, figure 2. To accomplish this, it is recommended that a fuel feed tank be installed in the rear cockpit space and that the aft ejection seat, flight controls and cockpit instruments and equipment be removed. This fuel tank would be continuously replenished by wing and fuselage fuel to maintain the more forward center of gravity. The fuel tank could be merely a repositioning of the current aft fuel cell or an additional tank to provide extra fuel allowing additional afterburner operation time. Current arrangement of the fuel system is presented in appendix I, figure 4.

The incorporation of the LEX and forward fuel feed tank will require airframe rework. Wind tunnel testing of LEX effects will be necessary prior to flight testing. The potential for an increase in instantaneous turn performance of up to 50%, or even a nominal 30%, would justify the cost of rework.

Considering this nominal 30% increase in instantaneous turn performance, a decrease in corner speed of approximately 70 kts at 10,000 ft MSL could be expected as calculated in appendix I, figure 3. This results in an additional 3 deg/sec turn rate and a reduction in turn radius of 1200ft

(0.2 nm). The exceptional instantaneous turn performance anticipated with incorporation of the leading edge extension would correct this deficiency and possibly the early buffet onset discussed in paragraph 2.4.5.3. A depiction of the proposed LEX installation is presented in appendix I, figure 5.

2.5.2 Significant Pilot Compensation Deficiencies

2.5.2.1 General

This investigation revealed a total of five deficiencies which should be corrected as soon as practicable in order to improve the mission effectiveness of the airplane.

2.5.2.2 Poor Engine Response During Landing Approaches

This deficiency (paragraph 2.4.8) is a result of the slow acceleration schedule of the TF41 engine. Installation of the new F110 engine will require testing to document engine response during landings. However, testing of the F110 engine installed in the F-14A+ aircraft revealed excellent engine response during actual approaches and landings aboard naval aircraft carriers. Improved engine response can be expected with incorporation of the F110 engine and should eliminate the deficiency. Further testing is recommended to ensure improved engine response with the F110 engine installed.

2.5.2.3 Difficult Airspeed Control During Landing Approaches

Flight path stability is directly related to the drag polar of the airplane. As indicated by data presented in appendix G, figure 6 the region over which drag is essentially constant is about 15 kts. This area encompasses the region of optimum approach speed. As discussed in paragraph 2.3.2, large airspeed deviations will require numerous power

corrections to maintain optimum approach speed. To improve this adverse characteristic the drag polar of the airplane will need to be changed.

The airplane as currently configured for approach lies in the "bucket" of the drag or thrust required curve. In order to alleviate this situation and the associated poor flying qualities, the parasitic drag coefficient (C_{do}) must be increased. As depicted in appendix I, figure 6, this can effectively move the approach speed from the region of the "bucket" to the "frontside" of the thrust required curve. This region of the drag curve has a higher drag gradient with airspeed which will improve flight path and airspeed control with no change in optimum approach speed required.

To increase parasitic drag, the flat plate of the aircraft body can be increased. This could be accomplished with speed brakes, spoilers, larger flap deflections or a combination of these. Speed brakes would perhaps be the most effective means of increasing C_{do} but there does not appear to be a provision to employ fuselage mounted speedbrakes without greatly affecting airflow over the horizontal stabilizer and tail. The most attractive solution would be to increase the flap deflection used in the approach configuration. The current deflection of 40 deg could be increased to 50 to 60 deg to increase parasitic drag. Maintaining sufficient clearance with weapons racks is a consideration in determining the optimum deflection. Reference 9 details lift, drag, and pitching moment coefficient changes with flap deflections. For flap deflections between 40 and 60 deg there is only a small increase in lift coefficient. Beyond 60 deg flap deflection there is essentially no increase. However, the change in parasite drag increases fairly proportionally to flap deflection angles.

The pitching moment change of the wing section is a nosedown contribution but this is possibly offset by the flap position being above the vertical center of gravity location.

As flap deflection is increased to the 50 to 60 deg recommended the small increase in lift coefficient would allow a slower approach speed. Yet this speed reduction may partially offset the gains in airspeed control. An important by-product of the higher drag is the higher thrust required. This higher RPM operating range typically results in quicker engine response to throttle movement which will make small glideslope changes easier. A flight path angle versus airspeed gradient of 0.05 deg/kt is a suitable initial target value. Further testing is recommended with flap deflections in excess of the current 40 deflection to document changes in flight path stability airspeed control, and pitching moments.

Another option is the use of spoiler deflection to increase drag. The large spoiler deflection required to increase parasitic drag sufficiently would result in rather large increases in approach speed which could not be acceptable. While direct lift control (DLC) is also an option the relative cost associated with reworking the lateral flight controls does not seem justified. The use of split ailerons similar to those employed on the A-10 aircraft or a split rudder also warrants consideration. These solutions may require more extensive design and flight test efforts than the relatively simple increase in flap deflection. Nonetheless, should flight tests reveal unacceptable flying qualities as a result of new flap settings these potential solutions are available.

As a final consideration in the solution to this deficiency the waveoff performance must be evaluated. The thrust available in military or

afterburner operation with incorporation of the F110 engine would most likely provide adequate waveoff performance even with the higher parasitic drag associated with the increased flap deflection.

2.5.2.4 Shallow stick position and force gradients in configuration PA1.

The flight control system mechanical characteristics as well as as force and displacements versus control surface deflection are dependent upon engineering design. Irreversible flight controls require artificial feel devices to simulate airload forces. Typically, flight control system designs employ bungee cords which, acting essentially as springs, provide control stick force proportional to control stick displacement. The actual control surface deflection corresponding to control stick deflection is determined by the gearing design. As discussed, the control stick force and position gradients were satisfactory in configuration CR. To maintain the satisfactory characteristics in configuration CR and remedy the deficiency in configuration PA1, a landing gear or flap interconnect device is recommended. This device would alter longitudinal control system gearing and force gradients with lowering of the landing gear or flaps. Basically, the system should provide higher forces as well as greater control stick deflections versus airspeed. The flap interconnect probably would require little airframe rework and is physically close to the longitudinal flight control gearing allowing easy installation.

2.5.2.5 Heavy longitudinal stick force required during maneuvering.

Control system designs of irreversible flight controls typically employ bobweight devices to reduce the probability of airplane overstress. Essentially, normal accelerations generated by control stick deflection act on a mass positioned in the control system. This mass is positioned on a

lever arm forward of the control stick so that normal accelerations act on the mass to produce a force opposite to the aft stick motion. Additionally, viscous dampers are employed which provide forces proportional to stick rates and opposite stick to motion. Under conditions of constant airspeed and normal acceleration the stick position is constant and the viscous damper forces are zero. To reduce maneuvering forces a smaller mass bobweight targeting a stick force per g of 4 lb/g is recommended. Further testing is required to document longitudinal maneuvering stick forces with the smaller bobweight incorporated. Remedy of this deficiency is essential when considering the large increase in maneuvering normal accelerations to be gained with incorporation of the LEX and new engine.

2.5.2.6 Restricted external field of view.

To remedy this deficiency caused by the forward FOV restriction a wrap-around canopy employing no windscreen bows is recommended. Aft FOV would be improved with removal of the aft ejection seat and instrument panel. However, the aft bulkhead would still restrict aft FOV. This bulkhead is an integral structural feature. An attempt to improve aft FOV would require fuselage structure and canopy redesign which does not appear to be economically feasible. Aft FOV has traditionally been a difficult feature to optimize and this case is no different. The incorporation of the wrap-around windscreen should greatly improve forward FOV, is highly desirable, and appears economically feasible.

2.5.2.7 Poor Location of the AN/ASN-91 Tactical Computer Control

A solution to this deficiency would be installation of an Up Front Control (UFC) similar to that employed in the F-18 Hornet. As depicted in figure 2, the UFC would be placed directly forward of the pilot just below

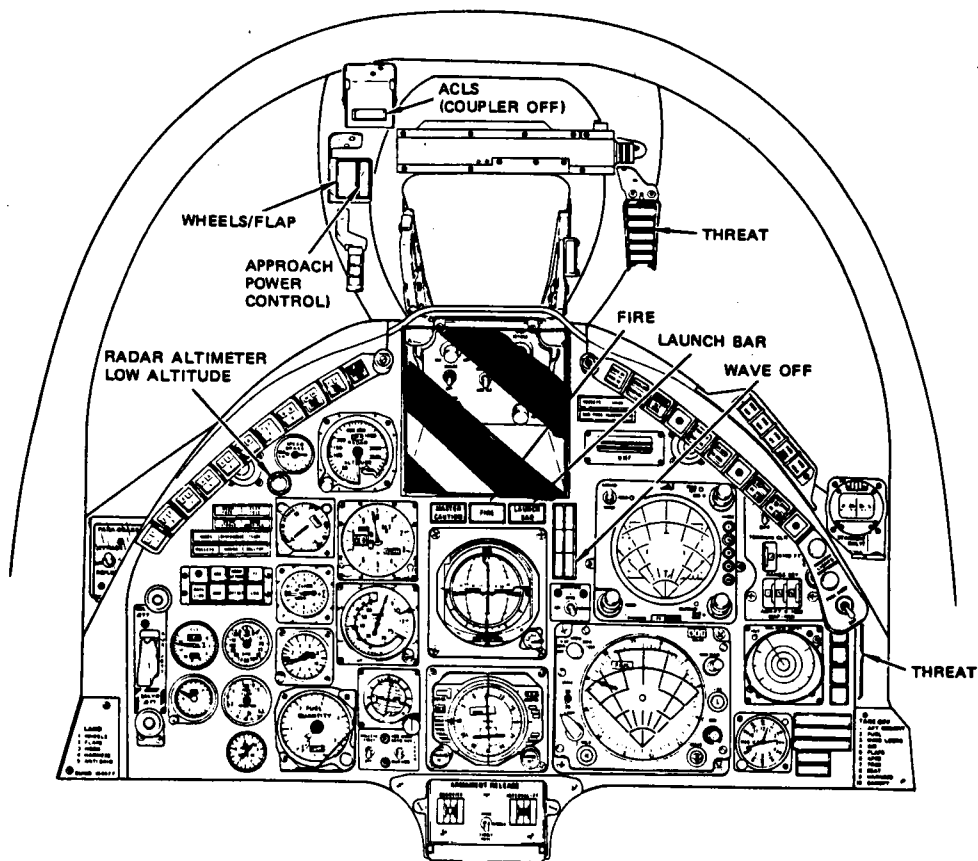


Figure 2

DEPICTION OF UP FRONT CONTROL LOCATION

the heads up display. This location allows the pilot access to the control with either hand thus enabling keyboard entry of data while maintaining visual reference outside the cockpit. Incorporation of the UFC should allow for better altitude, airspeed, and timing control during low altitude ingress to targets. Though perhaps not economically feasible, incorporation of a mission computer which allows UFC control of TACAN, IFF, and radios is worthy of investigation.

2.5.2.8 Excessively Short Roll Mode Time Constant in Configuration PA

This deficiency (paragraph 2.3.4.2) appears to the pilot as a very quick change in roll rate when lateral control is displaced from or returned to trim. This type of airplane response requires the pilot to shape inputs carefully to obtain desired bank angle changes. This aircraft characteristic can be compensated for by a command path prefilter. Command path prefilters can modify the response of an aircraft to a pilots input by changing the shape of the input. The prefilters do not change the aircraft's inherent dynamics but rather the nature of the pilot's input. In particular, a lag prefilter is recommended for approach configurations. The lag prefilter smoothes the pilot command, as depicted in appendix I, figure 7, and therefore makes the resultant aircraft response appear to be more sluggish. Fine tuning of the prefilter lag would be required to ensure that flying qualities are improved and not degraded by such incorporation.

2.5.2.9 Small HUD Instantaneous Field of View

This deficiency (paragraph 2.1.3) is essentially dependent upon the design considerations of the HUD as depicted in appendix I, figure 8. The characteristics of exit optic size and distance from the pilot's eyes to the

virtual image, as discussed in reference 16, directly determine instantaneous FOV. An increase of the instantaneous field of view requires a larger exit optic or closer positioning of the pilot's eyes. Positioning the pilot closer to the HUD is probably not acceptable considering ejection body position and the possible obstruction of the ejection path by the HUD. Increasing the exit optic size is a possible solution. Consideration must be given to cockpit space requirements to accommodate the larger devices and optical design changes necessary in the internal mechanism. One other solution may be the addition of a extra combiner glass.

Any of these solutions would improve HUD instantaneous field of view given a major cockpit redesign. However, it appears that it may not be economically feasible to correct this deficiency considering the scope and magnitude of other cockpit design changes necessary to accommodate improvements to the HUD instantaneous field of view.

3. CONCLUSIONS AND RECOMMENDATIONS

3.1 GENERAL

The TA-7C airplane demonstrates excellent potential for the base defense mission. Due to the limited scope of this evaluation and the lack of specialized flight test instrumentation, further testing is recommended under a more extensive range of flight conditions and with a full complement of flying qualities and performance instrumentation.

3.2 SUMMARY OF DEFICIENCIES AND RECOMMENDATIONS

A. The climb performance in configuration CR is poor and unsuitable for the base defense mission. The author recommends replacement of the current TF41 engine with the F110 engine which provides clearly superior climb rates.

B. The sustained turn performance is inferior. The installation of the F110 engine provides for significantly improved turn rates and radii.

C. The instantaneous turn performance is poor. Installation of a leading edge extension will allow greater turn rates and smaller turn radii.

D. The poor engine response during landing approaches make glideslope control difficult. Installation of the F110 engine and its improved acceleration schedule is recommended.

E. Difficult airspeed control is encountered during landing approaches. Increasing trailing edge flap deflection from 40 degrees to 50 or 60 degrees should improve airspeed control and move the approach speed away from the backside of the drag polar.

F. The control stick force and displacement cues present during landing approaches are insufficient. A flap interconnect device is recommended to provide steeper force and displacement gradients.

G. The maneuvering longitudinal control forces are too heavy. A relatively easy solution is use of a smaller mass bobweight in the flight control system.

H. The external field of view is restricted by windscreen bows. A wrap-around windscreen will provide essentially unrestricted forward field of view.

I. The AN/ASN-91 tactical computer control location may induce pilot vertigo in instrument meteorological conditions. Provision for an Up Front Control similar to the F-18 design is recommended.

J. The roll mode time constant in configuration PA was excessively short. A lag prefilter which effectively shapes the pilot's input while preserving the aircraft inherent dynamics is proposed.

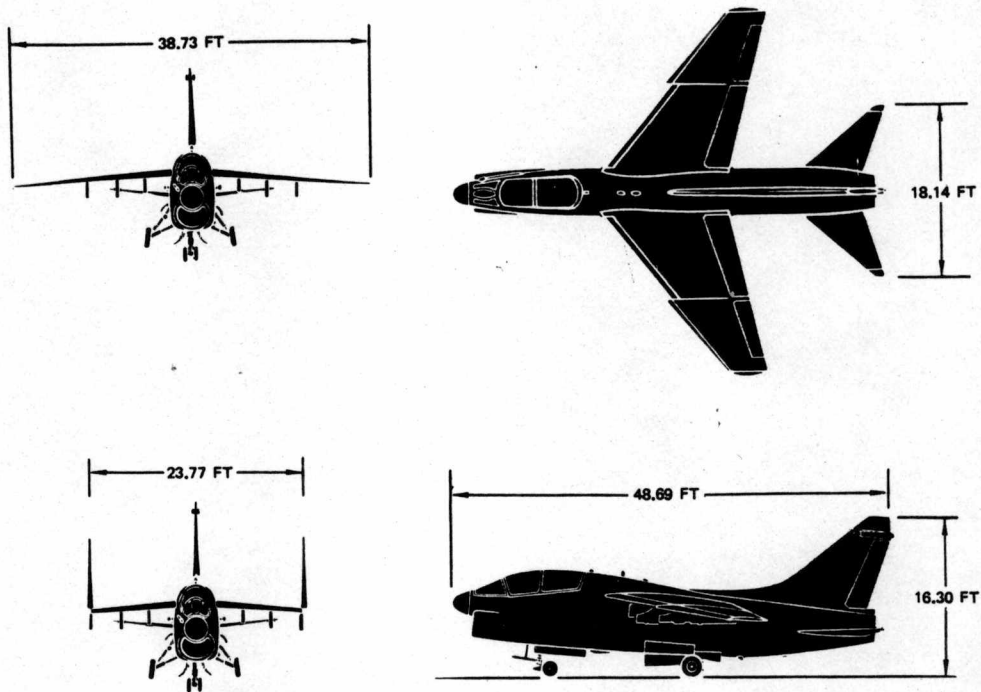
K. The Heads Up Display instantaneous field of view was too small. A larger exit optic or an extra combiner glass plate are possible solutions. However, the economy of a cockpit rework to accomodate HUD changes is questionable.

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REFERENCES

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APPENDIXES



OTHER DIMENSIONS			
WING		HORIZONTAL STABILIZER	VERTICAL STABILIZER
Area	375.00 sq ft	Area	93.75 sq ft
Aspect ratio	4	Sweep 1/4 chord	45°
Incidence (root and tip)	-1°	Dihedral	5° 25 min
Sweep 1/4 chord	35°		
Dihedral	-5°		
		Area	115.20 sq ft
		Sweep	43° 9 min

Figure 1
TA-7C PHYSICAL DIMENSIONS

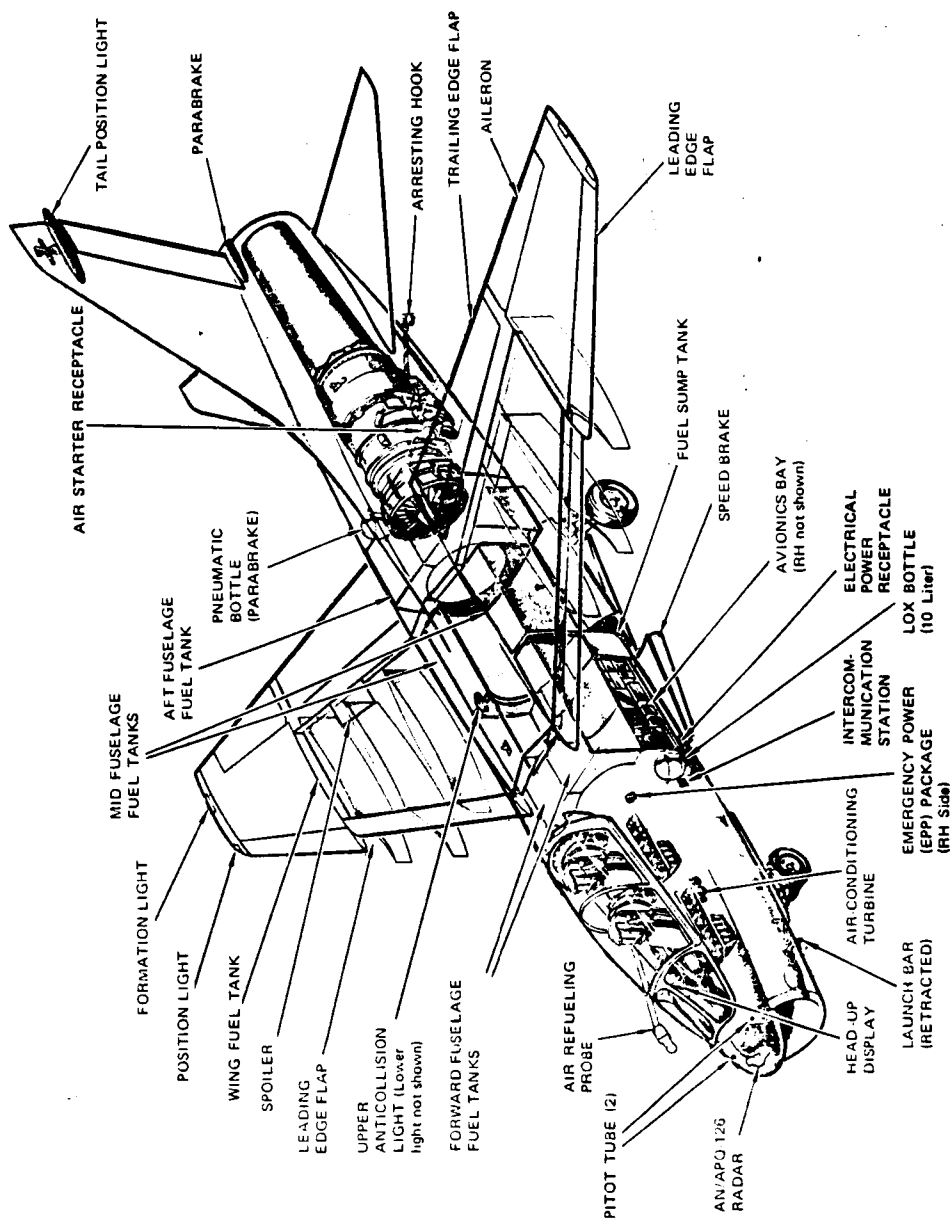


Figure 2
TA-7C GENERAL ARRANGEMENT

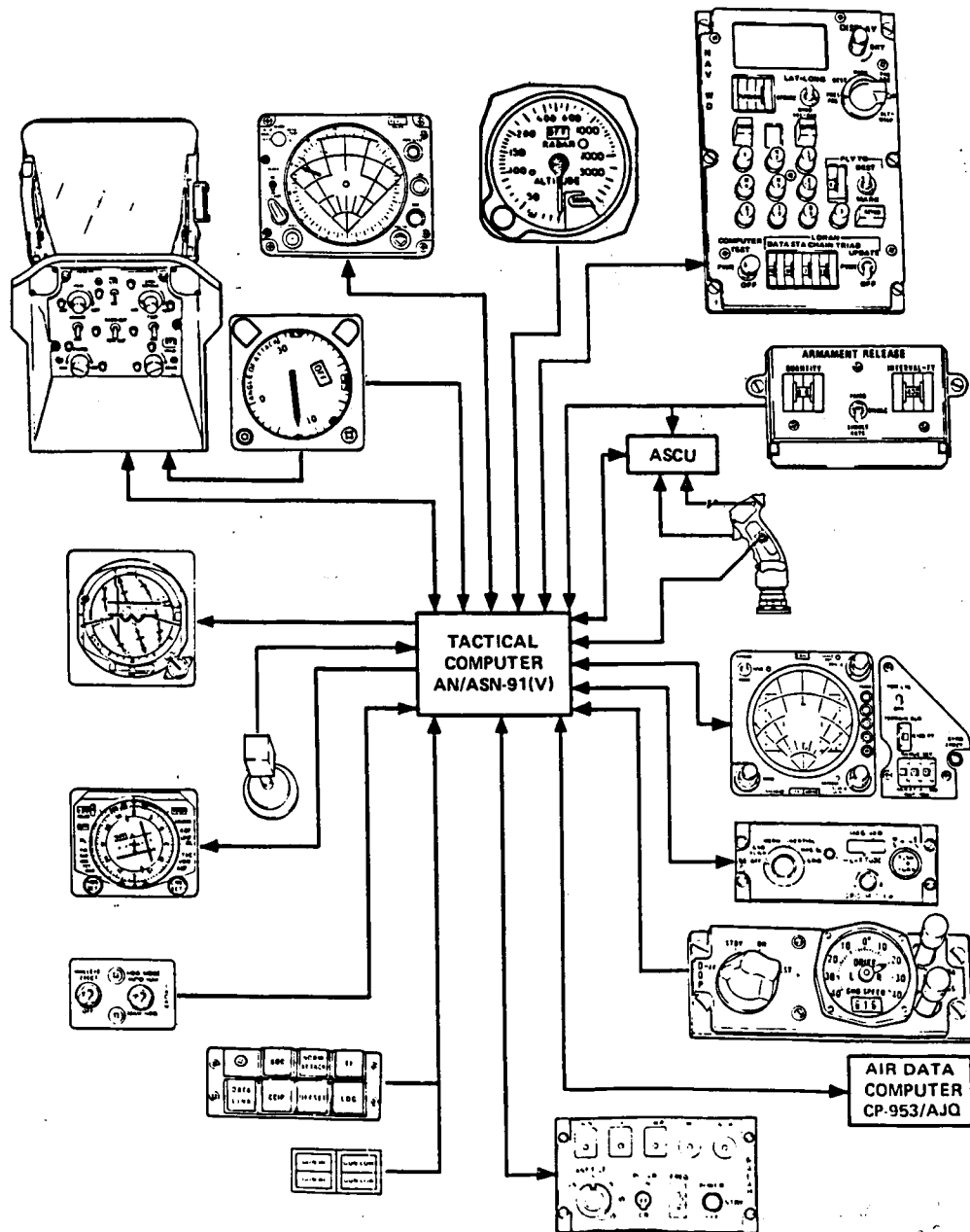
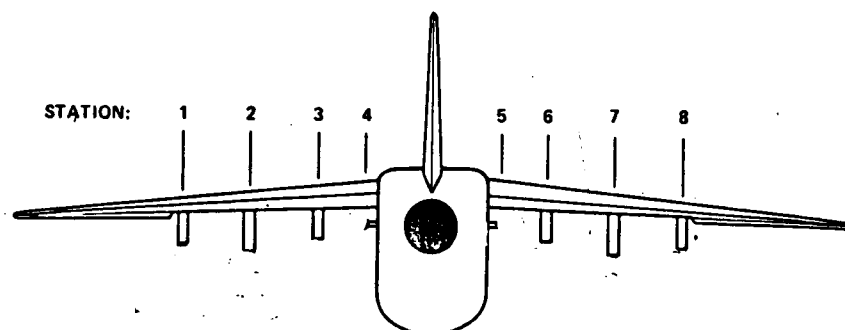


Figure 1
WEAPON SYSTEM INTEGRATION



FLIGHT NUMBER	LOAD	EXTERNAL STORES (1)
1	A	BRU-10 stations 1 and 8
2	B	BRU-10 station 1, 2, 3, 6, 7, and 8, AERO 10 station 3
3	C	BRU-10/TER/3 MK76 (2) stations 1 and 8
4	D	BRU-10/TER/3 MK82I (2) stations 1 and 8

- Notes: (1) AERO 1D - 300 gallon drop tank (full fuel)
 TER - Triple ejector rack
 BRU-10 - Station pylon rack
 (2) Inert weapons
 MK-76 - 25 lb Practice Bomb
 MK-82 - 500 lb Practice Bomb

Figure 1
 TA-7C ARMAMENT STATIONS

Table I
TA-7C EVALUATION TEST ENVELOPE

PARAMETER	TEST ENVELOPE
Airspeed	0 -510 KOAS (0.88M)
Altitude	0 -28,000 ft MSL
Load Factor	1/2 to 5 1/2
Center of Gravity (1)	23.9 to 31.2% MAC

Note: (1) Contractor Limitation 18-33.5% MAC

Table II

TA-7C EVALUATION TEST CONFIGURATIONS

CONFIGURATION	LANDING GEAR	FLAPS	SPEED BRAKE	POWER (1)
Ground (GR)	Down	A/R	In	A/R
Taxi (TX)	Down	A/R	In	A/R
Takeoff (TO)	Down	25	In	MIL
Climb (CL)	Up	Up	In	MIL
Cruise (CR)	UP	Up	In	TLF
Power (P)	Up	Up	In	MIL
Descent 1 (DE1)	Up	Up	Out	IDLE
Descent 2 (DE2)	Up	Up	In	IDLE
Power Approach 1 (PA1)	Down	Down	In	TNA
Power Approach 2 (PA2)	Down	Up	In	TNA
Waveoff (WO)	Down	Down	In	MIL
Landing (L)	Down	In	IDLE	

Note: (1) A/R - As Required
MIL - Military Rated Thrust
TLF - Thrust for Level Flight
TNA - Thrust for Normal Approach

Table III
TA-7C EVALUATION TEST CONDITIONS

TEST	CONFIGURATION	ALTITUDE (1) (FT MSL)	AIRSPEED (KOAS)	GROSS WEIGHT (LB)	CENTER OF GRAVITY (% MAC)
Cockpit Evaluation	All	All	All	N/A	N/A
Ground Handling	TX	Ground	0-30	23,050-33,300	27.5-28.6
Mechanical Characteristics	GR	Ground	0	N/A	N/A
	CR	20,000	250	28,350	28.5
	PAI	10,000	145	23,150	27.7
Longitudinal Flying	P	10,000	400	25,150	29.7
	CR	10,000	200-400	29,100	28.1
	PAI	10,000	134-175	22,900	27.7
	WO	10,000	160	29,150	28.7
	P	10,000	400	28,550	29.0
Lateral-Directional Flying Qualities	CR	10,000	250-400	23,350-25,950	26.7-28.9
	PAI	10,000-15,000	-175	23,650-28,450	27.2-28.5
Stall Characteristics	CR	20,000-25,000	115-260	27,150-33,300	28.6-30.0
	PAI	15,000-20,000	130-200	29,350	28.7
Takeoff and Landing Flying Qualities	TO,L	Ground-1,000	0-210	23,050-33,300	27.5-28.6
	CR	10,000	175-200	27,450	29.4
	PAI	10,000	140-180	26,750	30.0
Trimmability and Mission Tasks	All	Ground- 25,000	0-510	23,050-33,300	26.7-30.0
Takeoff and Landing Performance	TO	Ground-500	0-385	29,850-33,000	28.6-28.7
	L			23,050-28,350	27.5-28.5

Table III
TA-7C EVALUATION TEST CONDITIONS

TEST	CONFIGURATION	ALTITUDE (1) (FT MSL)	AIRSPEED (KOAS)	GROSS WEIGHT (LB)	CENTER OF GRAVITY (% MAC)
Climb and Descent Performance	CL	5,000-25,000	250-385	26,450-30,150	27.8-30.0
	DE1 DE2	10,000-25,000	195-205		
Level Flight Performance	CR P	5,000-2,500	175-370	24,750-29,050	28.8-29.9
Turn Performance	P		200-400	23,950-25,950	29.0-29.9
Airplane Systems	All	- All	All	27,900-32,100	28.6-30.5

Note: (1) Field elevation 38 ft MSL.

Table I
SUMMER FLIGHT GEAR

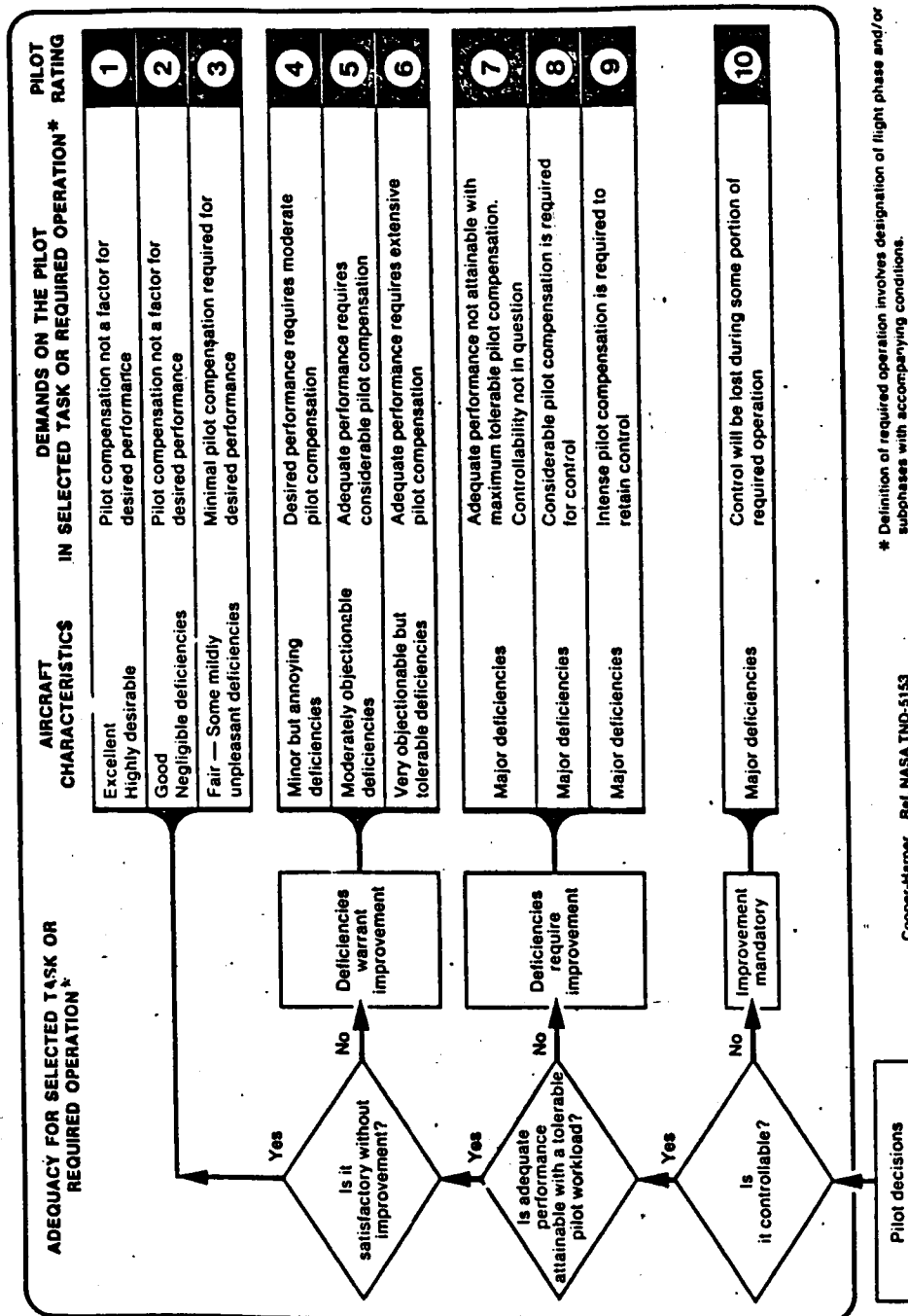
ITEM	PART NUMBER
Coveralls, Flying	MIL-C-83141
Boats, Flying	MIL-B-21408
Gloves, Flying	MIL-G-81188
Coveralls, Anti G	MIL-C-5085
Harness, Personnel, Torso Suit	829A5142-5MR.
Helmet, Flyers Protective	954AS300-3
Mask, Oxygen Regulator	834-75-02

Table II

CRITICAL ANTHROPOMETRIC DATA FOR
THOMAS A. CROPPER

PARAMETER	MEASUREMENT	PERCENTILE
Sitting Eye Height	33.8 in	96%
Trunk Height	26.2 in	98%
Sitting Height	38.2 in	95%
Buttock-Knee Length	24.0 in	50%
Functional Reach	32.5 in	75%
Shoulder Width	20.1 in	90%
Stature	71.0 in	70%
Weight	190 lb	90%

Table I
HANDLING QUALITIES RATING SCALE



* Definition of required operation involves designation of flight phase and/or subphases with accompanying conditions.

Cooper-Harper Ref. NASA TND-5153

DEFINITION OF DEFICIENCIES

Safety of Flight/Mission Accomplishment Deficiency

A deficiency, the correction of which is necessary because it adversely affects:

- a. Airworthiness of the aircraft.
- b. The ability of the aircraft to accomplish its primary or secondary mission.
- c. The effectiveness of the crew as an essential subsystem.
- d. The safety of the crew or the integrity of an essential subsystem.

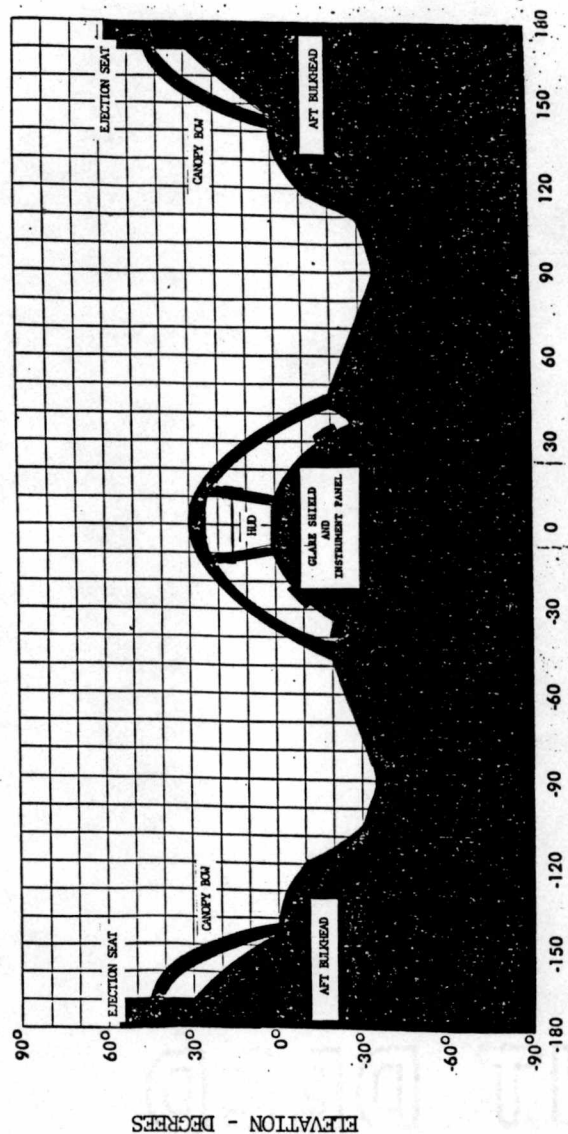
In this regard, a real likelihood of injury or damage must exist. Remote possibilities or unlikely sequences of events shall not be used as a basis for safety items.

Safety Pilot Compensation Deficiency

A deficiency of lesser severity which does not substantially reduce the ability of the aircraft to accomplish its primary or secondary mission, but the correction of which will result in significant improvement in the effectiveness, maintainability, or safety of the aircraft.

Figure 1

DEFINITION OF DEFICIENCIES



AZIMUTH - DEGREES

RECTILINEAR TOTAL VISION ENVELOPE PLOT

Figure 1

RECTILINEAR TOTAL VISION ENVELOPE PLOT

MODEL TA-7C AIRPLANE
BuNo 154402

CONFIGURATION: GR
LOADING: FAMILIARIZATION
METHOD: CONTROL SWEEP
(HAND HELD DATA)

GROSS WEIGHT: 26,9000 LB
CENTER OF GRAVITY: 30.0% MAC
PRESSURE ALTITUDE: 0
TRIM AIRSPEED: 0 (ELEVATOR TRIM 5°UP)

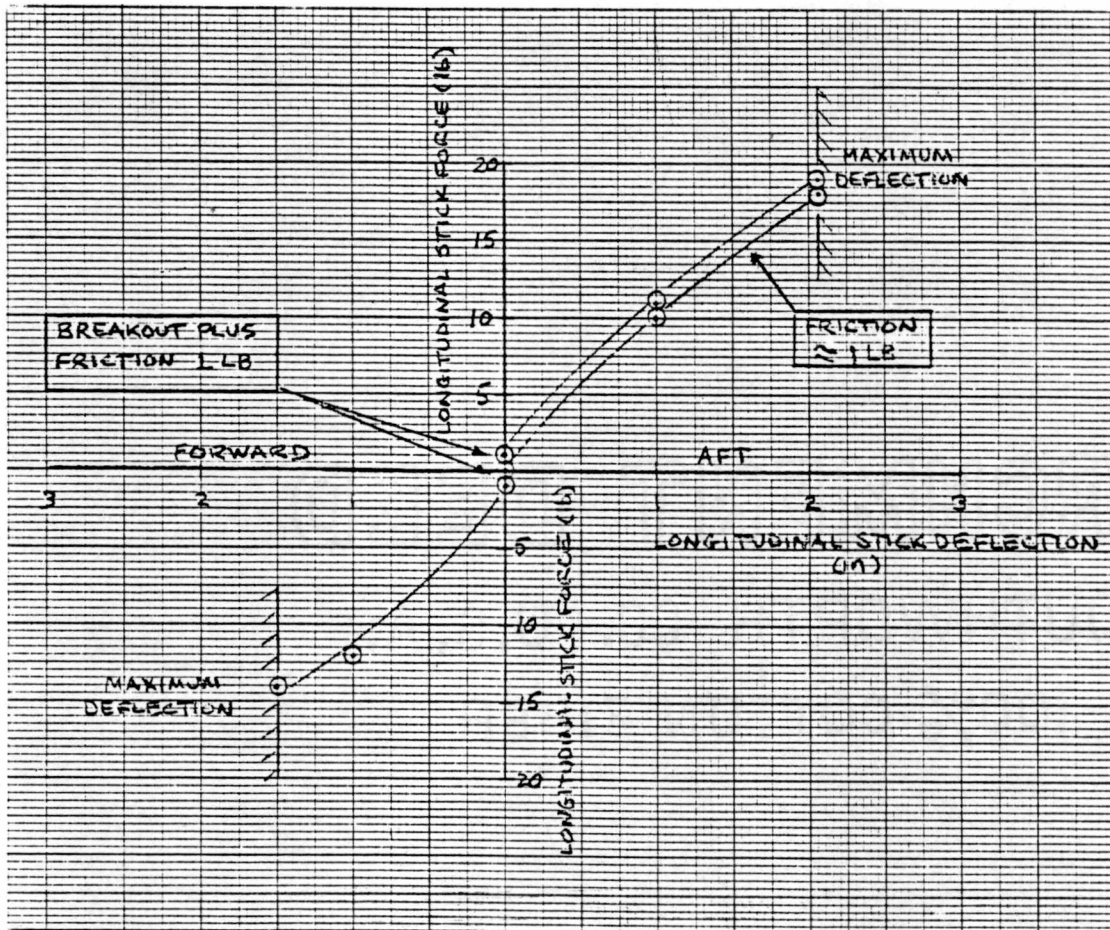


Figure 1

TA-7C LONGITUDINAL CONTROL SYSTEM MECHANICAL
CHARACTERISTICS

MODEL TA-7C AIRPLANE
BuNo 154402

CONFIGURATION: GR
LOADING: FAMILIARIZATION
METHOD: CONTROL SWEEP
(HAND HELD DATA)

GROSS WEIGHT: 26,900 LB
CENTER OF GRAVITY: 30.0% MAC
PRESSURE ALTITUDE: 0
TRIM AIRSPEED: 0 (AILERON TRIM CENTERED)

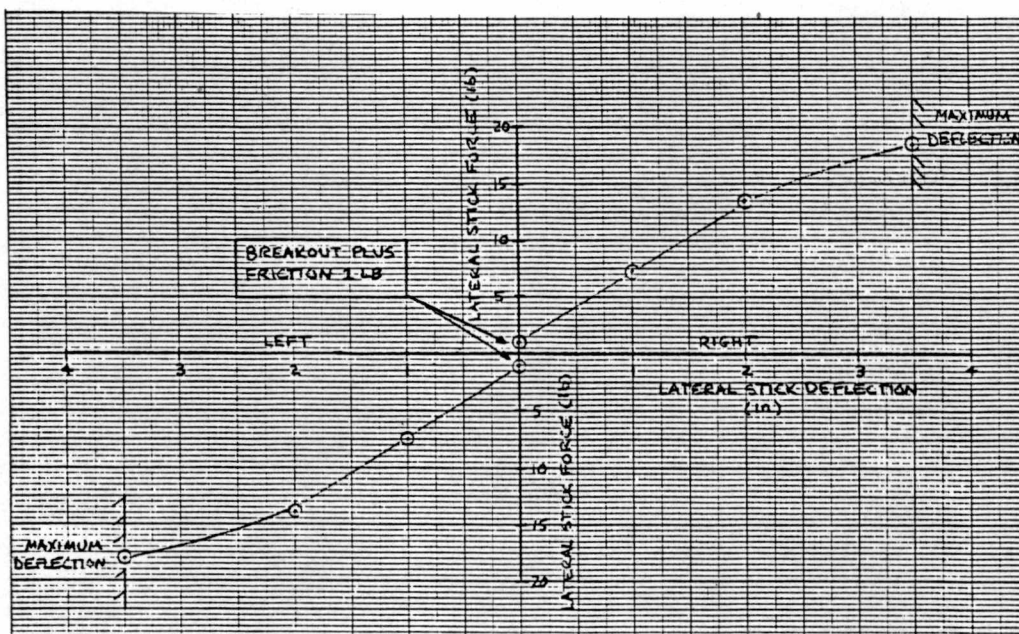


Figure 2

TA-7C LATERAL CONTROL SYSTEM MECHANICAL CHARACTERISTICS

MODEL TA-7C AIRPLANE
BuNo 154402

CONFIGURATION: GR
LOADING: FAMILIARIZATION
METHOD: CONTROL SWEEP
(HAND HELD DATA)

GROSS WEIGHT: 26,9000 LB
CENTER OF GRAVITY: 30.0% MAC
PRESSURE ALTITUDE: 0
TRIM AIRSPEED: 0 (RUDDER TRIM CENTERED)

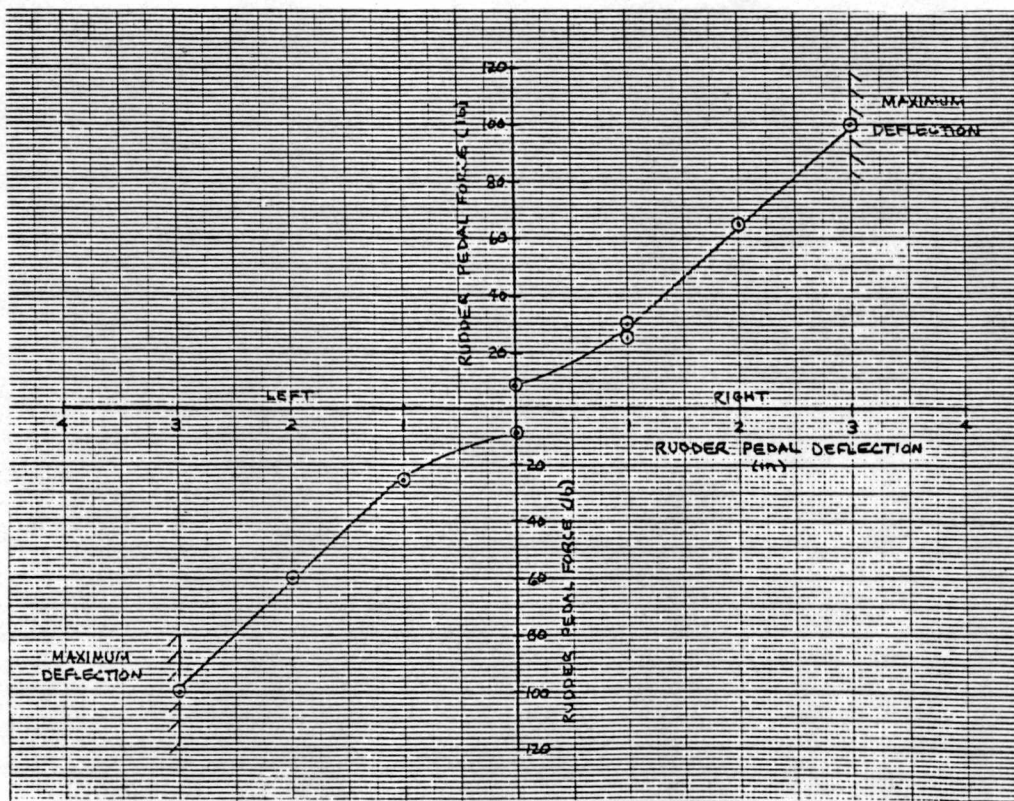


Figure 3

TA-7C DIRECTIONAL CONTROL SYSTEM MECHANICAL CHARACTERISTICS

MODEL TA-7C AIRPLANE
BuNo 154361

CONFIGURATION: CR
LOADING: FAMILIARIZATION
METHOD: STEADY POINT
POWER: THRUST FOR LEVELFLIGHT TRIM AIRSPEED: 250 KOAS

GROSS WEIGHT: 27,950 LB
CENTER OF GRAVITY: 28.6% MAC
PRESSURE ALTITUDE: 9750 FT MSL

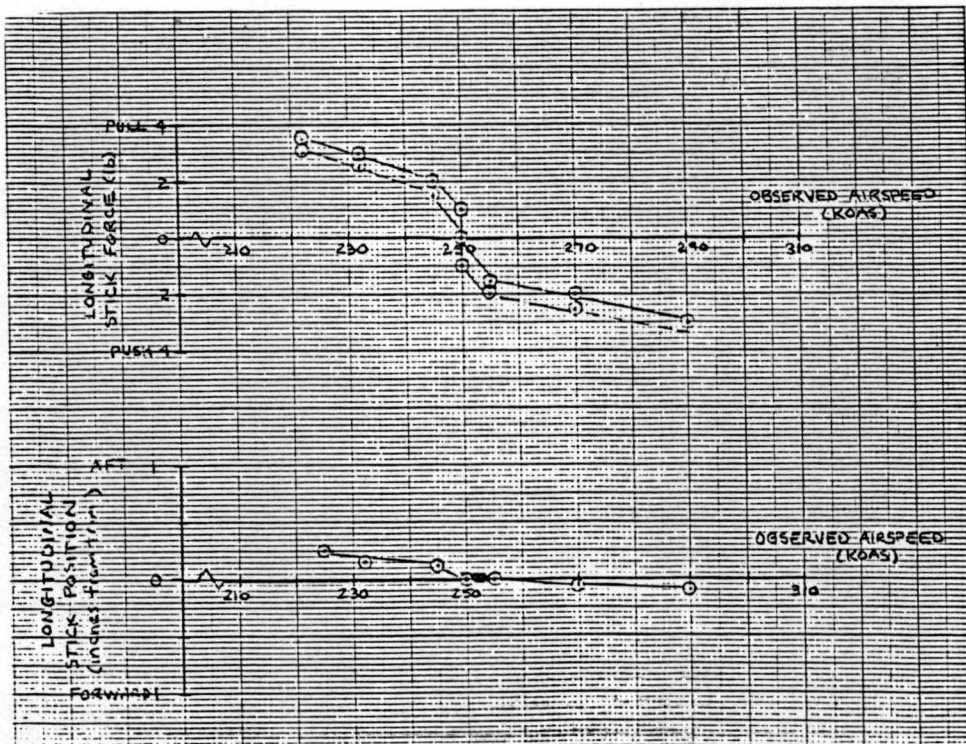


Figure 4

STATIC STABILITY CHARACTERISTICS FOR CONFIGURATION CR

MODEL TA-7C AIRPLANE
BuNo 154407

CONFIGURATION: PA1
LOADING: FAMILIARIZATION
METHOD: STEADY POINT
POWER: THRUST FOR LEVELFLIGHT TRIM

GROSS WEIGHT: 28,000 LB
CENTER OF GRAVITY: 28.4% MAC
PRESSURE ALTITUDE: 10,000FT MSL
AIRSPEED: 143 KOAS

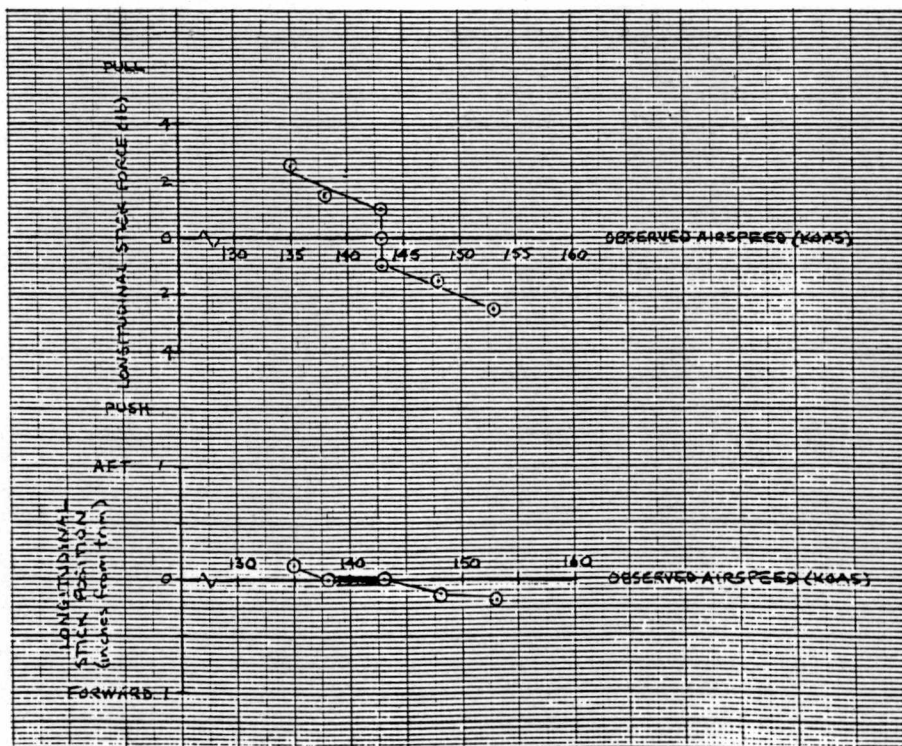


Figure 5

STATIC STABILITY CHARACTERISTICS FOR CONFIGURATION PA1

MODEL TA-7C AIRPLANE
BuNo 154402

CONFIGURATION: PA1
LOADING: FAMILIARIZATION
METHOD: STEADY POINT

GROSS WEIGHT: 22,900 LB
CENTER OF GRAVITY: 27.7% MAC
PRESSURE ALTITUDE: 6000-9000 FT MSL
TRIM AIRSPEED: 132 KOAS

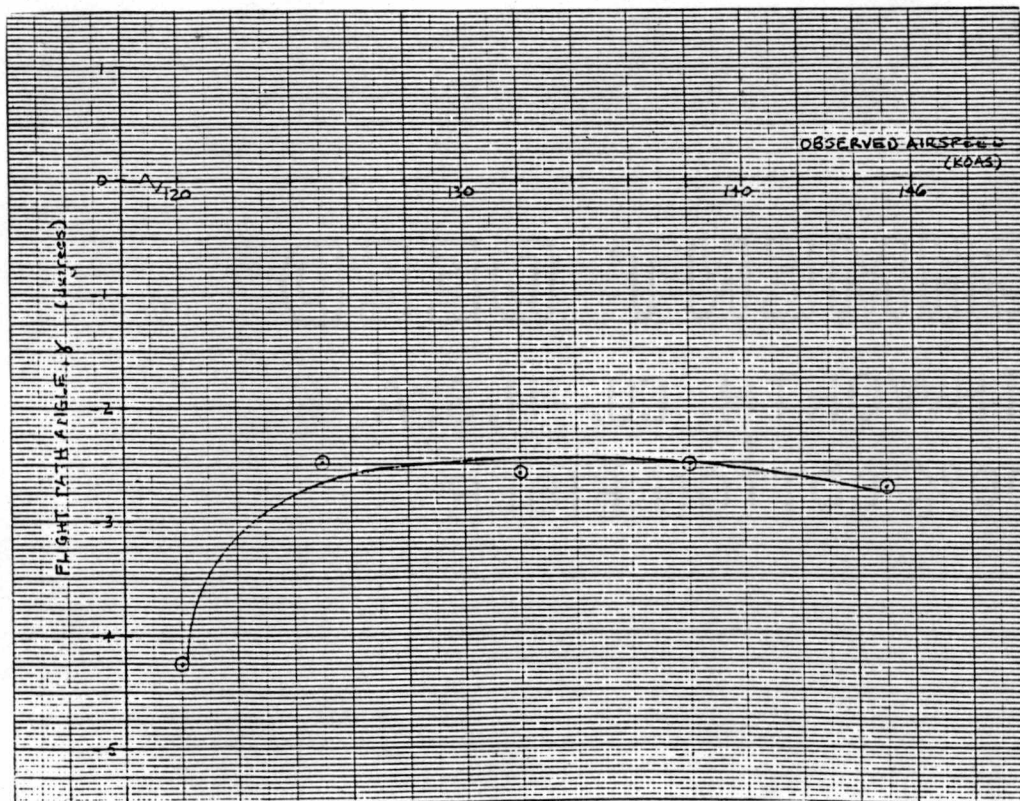


Figure 6

FLIGHT PATH STABILITY CHARACTERISTICS

MODEL TA-7C AIRPLANE
BuNo 154402

CONFIGURATION: POWER
LOADING: FAMILIARIZATION
METHOD: STEADY PULLS,
PUSHOVERS SUDDEN PULLS

GROSS WEIGHT: 25,100 LB
CENTER OF GRAVITY: 29.0% MAC
PRESSURE ALTITUDE: 10,000 FT MSL
TRIM AIRSPEED: 400 KOAS

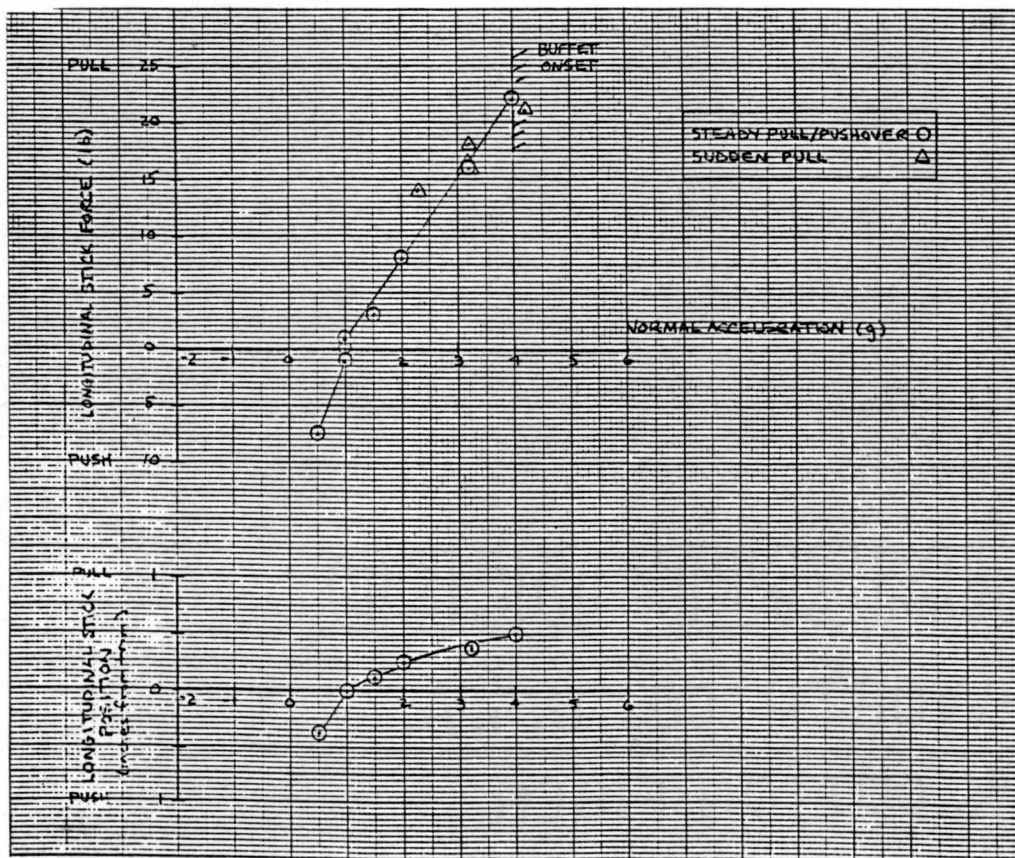


Figure 7

MANEUVERING STABILITY CHARACTERISTICS FOR CONGIFURATION P

MODEL TA-7C AIRPLANE
BuNo 154402

CONFIGURATION: POWER
LOADING: FAMILIARIZATION
METHOD: STEADY PULLS

GROSS WEIGHT: 25,100 LB
CENTER OF GRAVITY: 29.0% MAC
PRESSURE ALTITUDE: 10,000 FT MSL
TRIM AIRSPEED: 400 KOAS

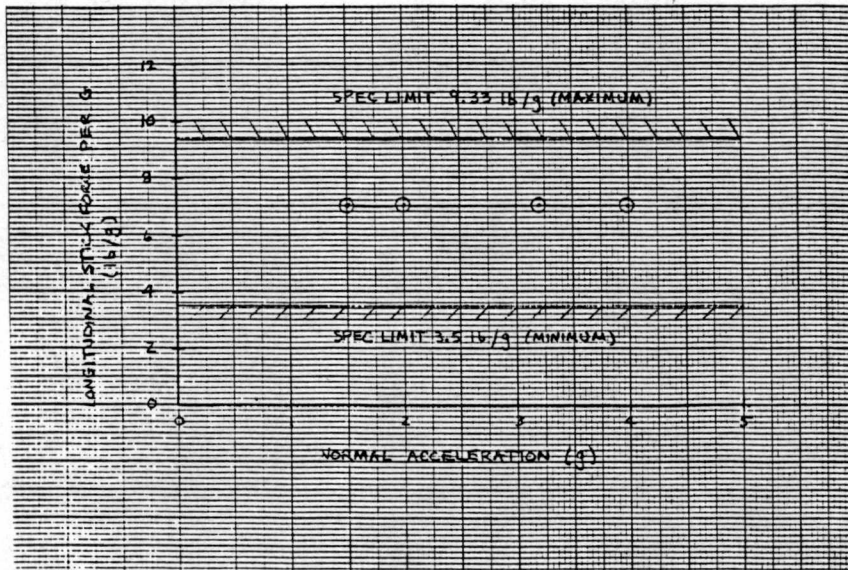


Figure 8

MANEUVERING STABILITY SPECIFICATION COMPLIANCE

MODEL TA-7C AIRPLANE
BuNo 154402

CONFIGURATION: POWER
LOADING: FAMILIARIZATION
METHOD: STEADY PULLS

GROSS WEIGHT: 25,100 LB
CENTER OF GRAVITY: 29.0% MAC
PRESSURE ALTITUDE: 10,000 FT MSL
TRIM AIRSPEED: 400 KOAS

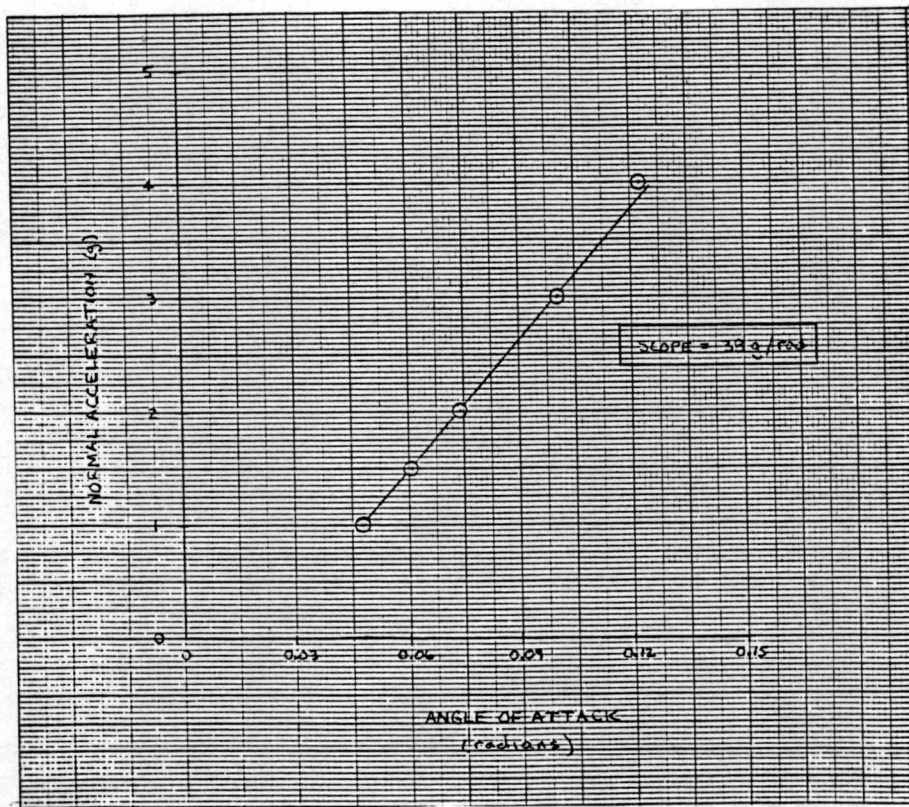


Figure 9

N/α CHARACTERISTICS FOR CONFIGURATION P

MODEL TA-7C AIRPLANE
BuNo 154402

CONFIGURATION: WAVEOFF
LOADING: FAMILIARIZATION
METHOD: STEADY TURN

GROSS WEIGHT: 23,100 LB
CENTER OF GRAVITY: 27.5% MAC
PRESSURE ALTITUDE: 10,000 FT MSL
TRIM AIRSPEED: 160 KOAS

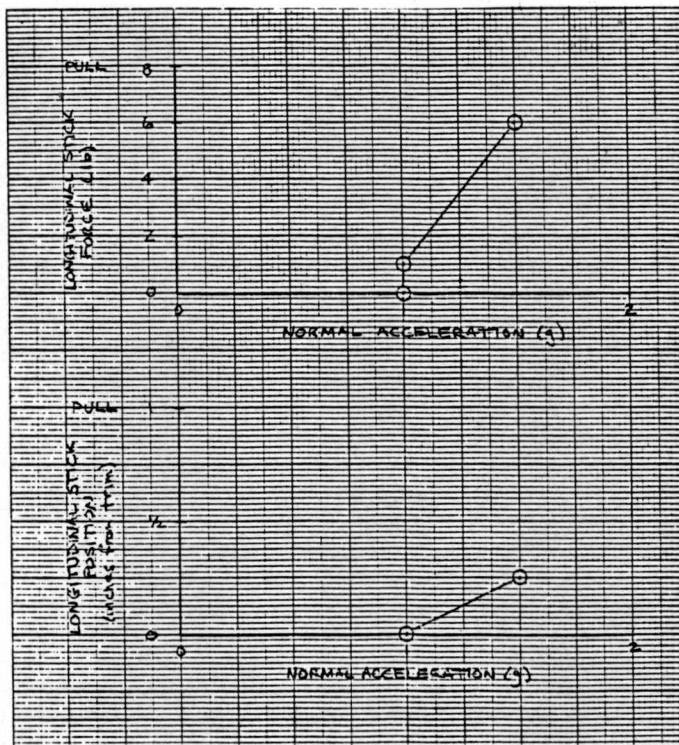


Figure 10

MANEUVERING STABILITY CHARACTERISTICS FOR
CONFIGURATION WO

MODEL TA-7C AIRPLANE
BuNo 154402

CONFIGURATION: WAVEOFF
LOADING: FAMILIARIZATION
METHOD: STEADY TURN

GROSS WEIGHT: 23,100 LB
CENTER OF GRAVITY: 27.5% MAC
PRESSURE ALTITUDE: 10,000 FT MSL
TRIM AIRSPEED: 160 KOAS

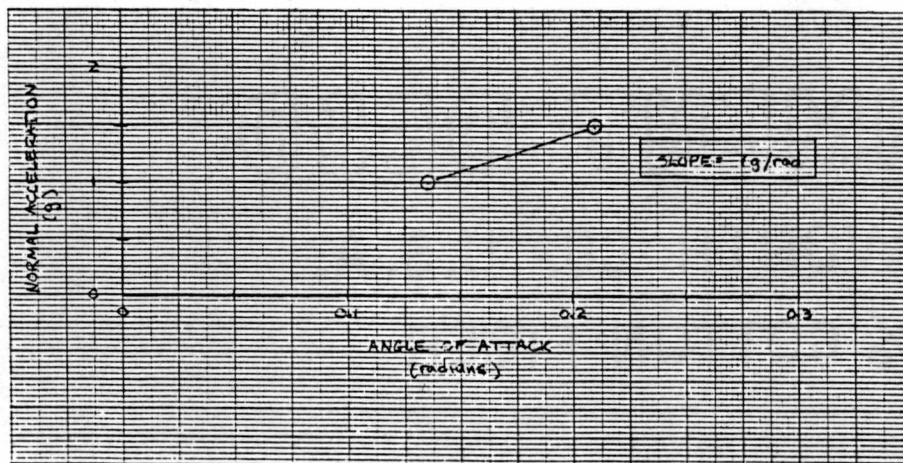


Figure 11

N/α CHARACTERISTICS FOR CONFIGURATION WO

MODEL TA-7C AIRPLANE
BuNo 154402

CONFIGURATION: CL

LOADING: B

CLIMB SCHEDULE: 250 KOAS

TO 10,000 FT, LEVEL

ACCELERATION TO 0.75M, 0.75M

to 25,000 FT MSL

STANDARD GW: 35,199 LB

ENGINE: TF41-A-402D

FUEL: JP-5

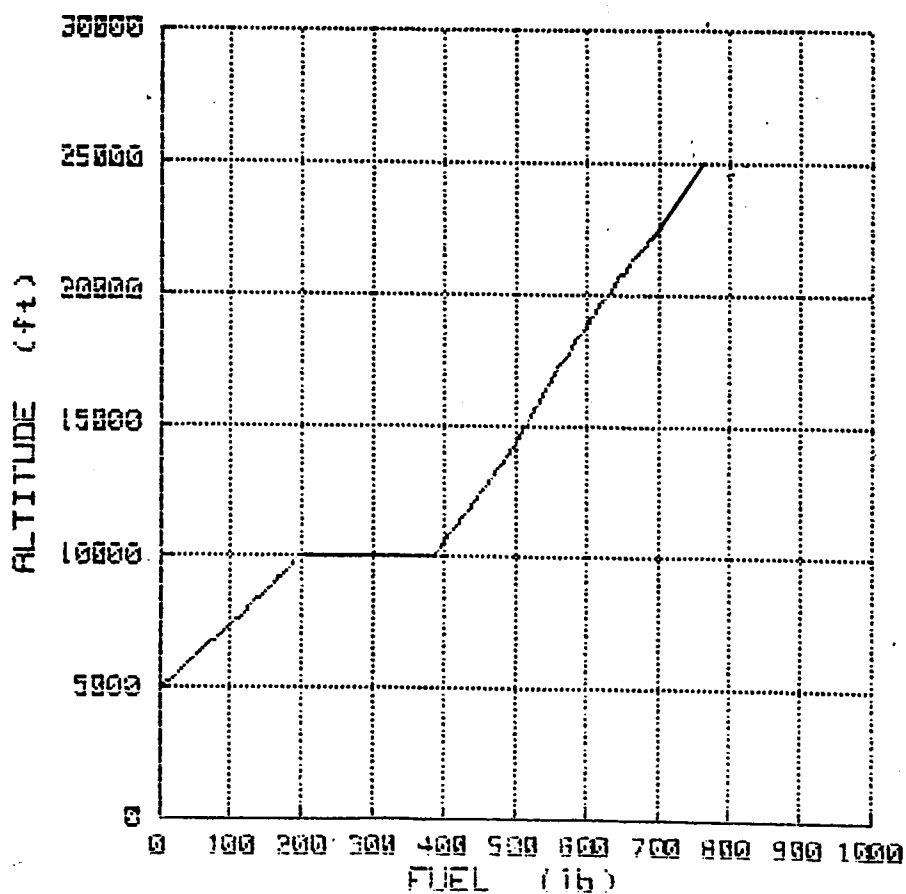


Figure 1

STANDARD DAY FUEL TO CLIMB FOR LOADING B

MODEL TA-7C AIRPLANE
BuNo 154402

CONFIGURATION: CL

LOADING: B

CLIMB SCHEDULE: 250 KOAS

TO 10,000 FT, LEVEL

ACCELERATION TO 0.75M, 0.75M

to 25,000 FT MSL

STANDARD GW: 35,199 LB

ENGINE: TF41-A-402D

FUEL: JP-5

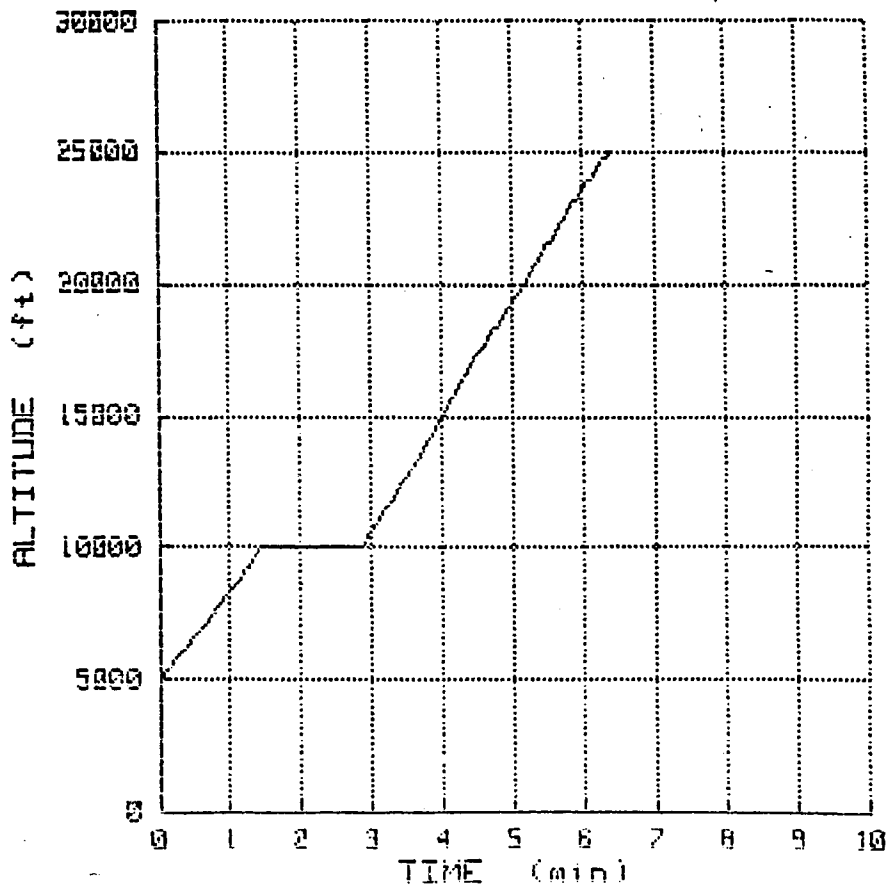


Figure 2

STANDARD DAY TIME TO CLIMB FOR LOADING B

MODEL TA-7C AIRPLANE
BuNo 154402

CONFIGURATION: CL

LOADING: B

CLIMB SCHEDULE: 250 KOAS

TO 10,000 FT, LEVEL

ACCELERATION TO 0.75M, 0.75M

to 25,000 FT MSL

STANDARD GW: 35,199 LB

ENGINE: TF41-A-402D

FUEL: JP-5

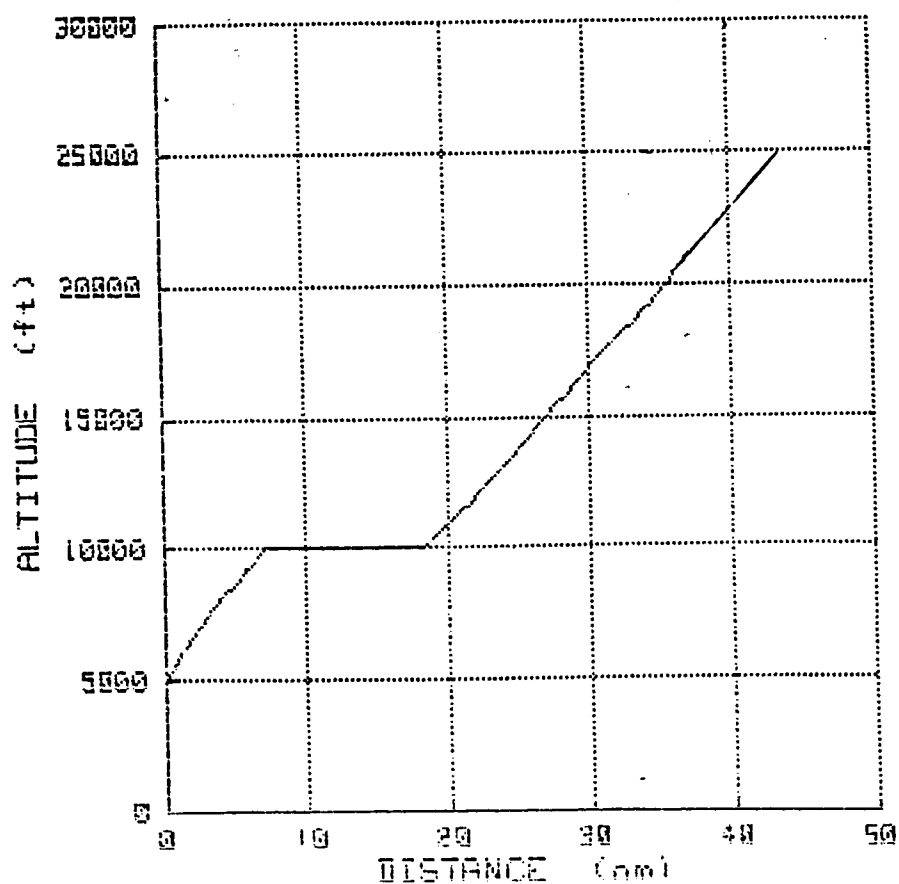


Figure 3

STANDARD DAY DISTANCE TO CLIMB FOR LOADING B

MODEL TA-7C AIRPLANE
BuNo 154361

CONFIGURATION: CL
LOADING: A
CLIMB SCHEDULE: 385 KOAS
UNTIL 0.77M MAINTAIN 0.77M

STANDARD GW: 35,199 LB
ENGINE: TF41-A-402D
FUEL: JP-5

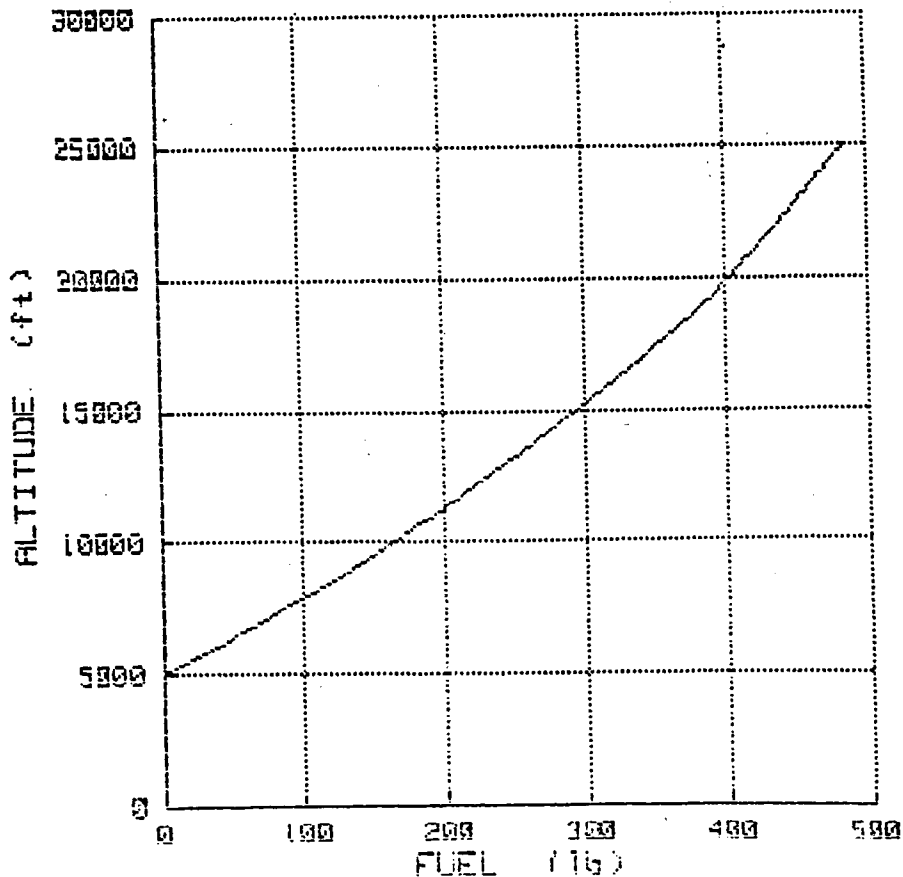


Figure 4

STANDARD DAY FUEL TO CLIMB FOR LOADING A

MODEL TA-7C AIRPLANE
BuNo 154361

CONFIGURATION: CL

LOADING: A

CLIMB SCHEDULE: 385 KOAS

UNTIL 0.77M MAINTAIN 0.77M

STANDARD GW: 35,199 LB

ENGINE: TF41-A-402D

FUEL: JP-5

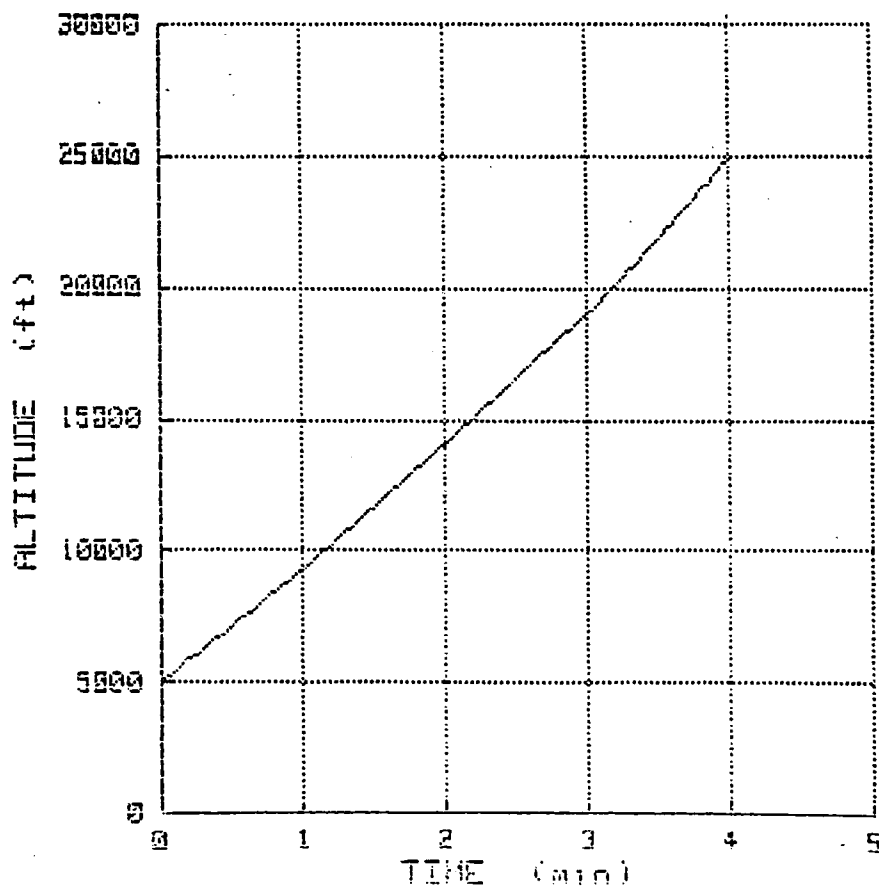


Figure 5

STANDARD DAY TIME TO CLIMB FOR LOADING A

MODEL TA-7C AIRPLANE
BuNo 154361

CONFIGURATION: CL
LOADING: A
CLIMB SCHEDULE: 385 KOAS
UNTIL 0.77M MAINTAIN 0.77M

STANDARD GW: 35,199 LB
ENGINE: TF41-A-402D
FUEL: JP-5

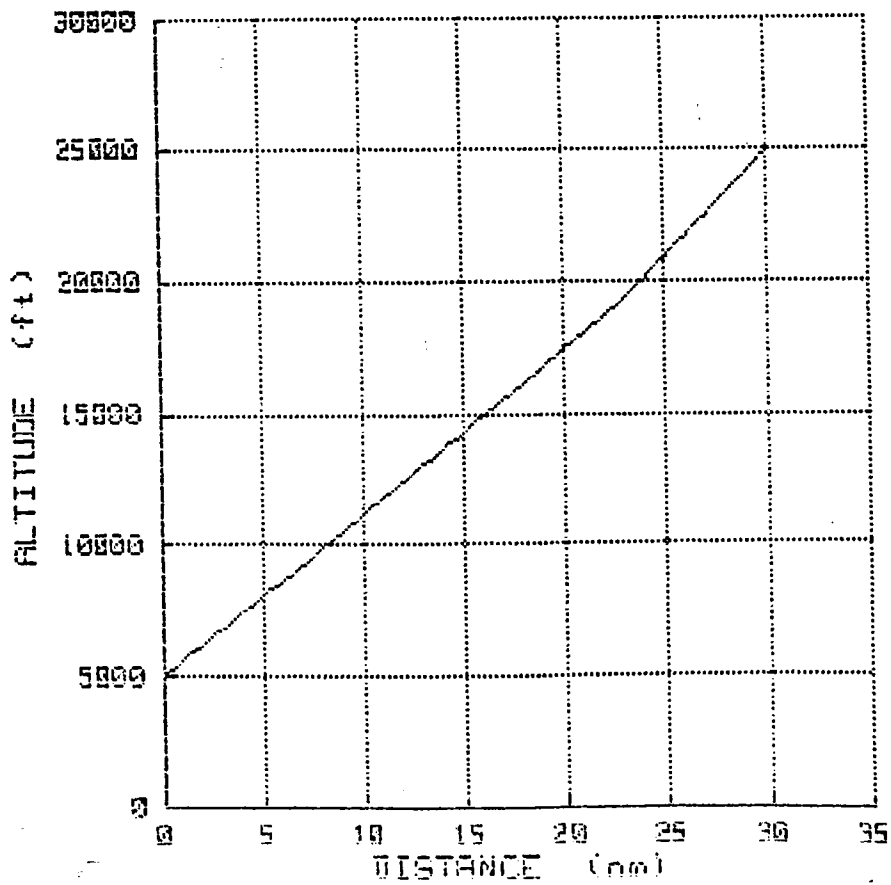


Figure 6

STANDARD DAY DISTANCE TO CLIMB FOR LOADING A

MODEL TA-7C AIRPLANE
BuNo 154402

CONFIGURATION: CL
LOADING: D
CLIMB SCHEDULE: 340 KOAS
UNTIL 0.75M MAINTAIN 0.75M

STANDARD GW: 35,199 LB
ENGINE: TF41-A-402D
FUEL: JP-5

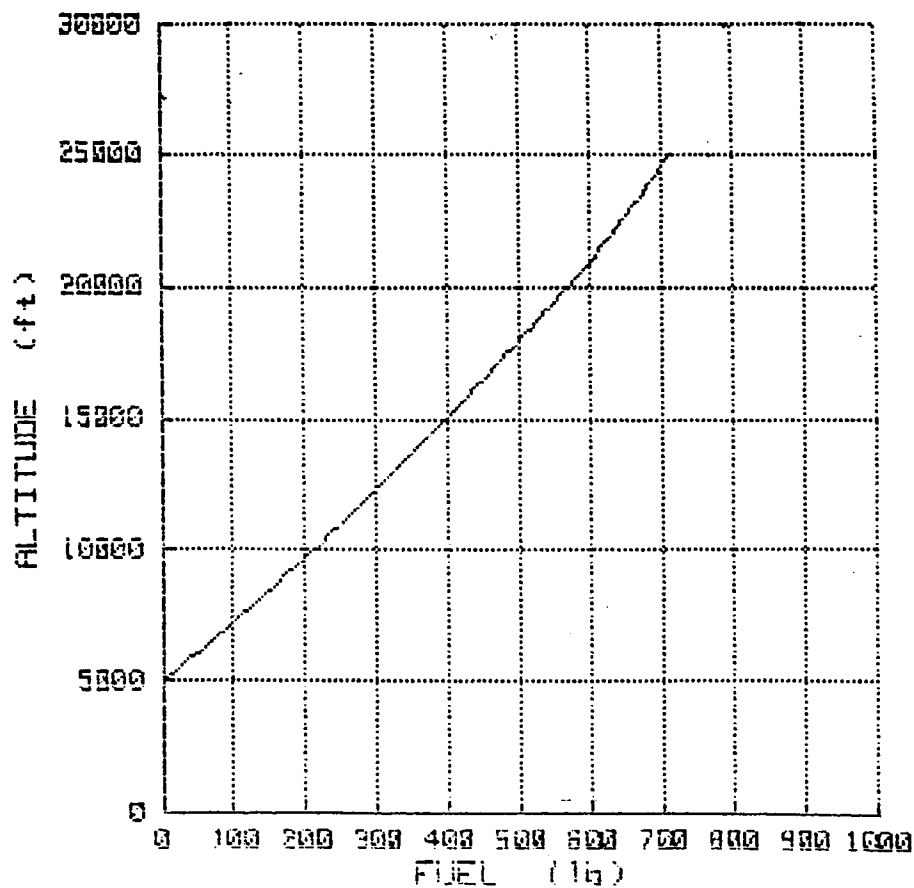


Figure 7

STANDARD DAY FUEL TO CLIMB FOR LOADING D

MODEL TA-7C AIRPLANE
BuNo 154402

CONFIGURATION: CL
LOADING: D
CLIMB SCHEDULE: 340 KOAS
UNTIL 0.75M MAINTAIN 0.75M

STANDARD GW: 35,199 LB
ENGINE: TF41-A-402D
FUEL: JP-5

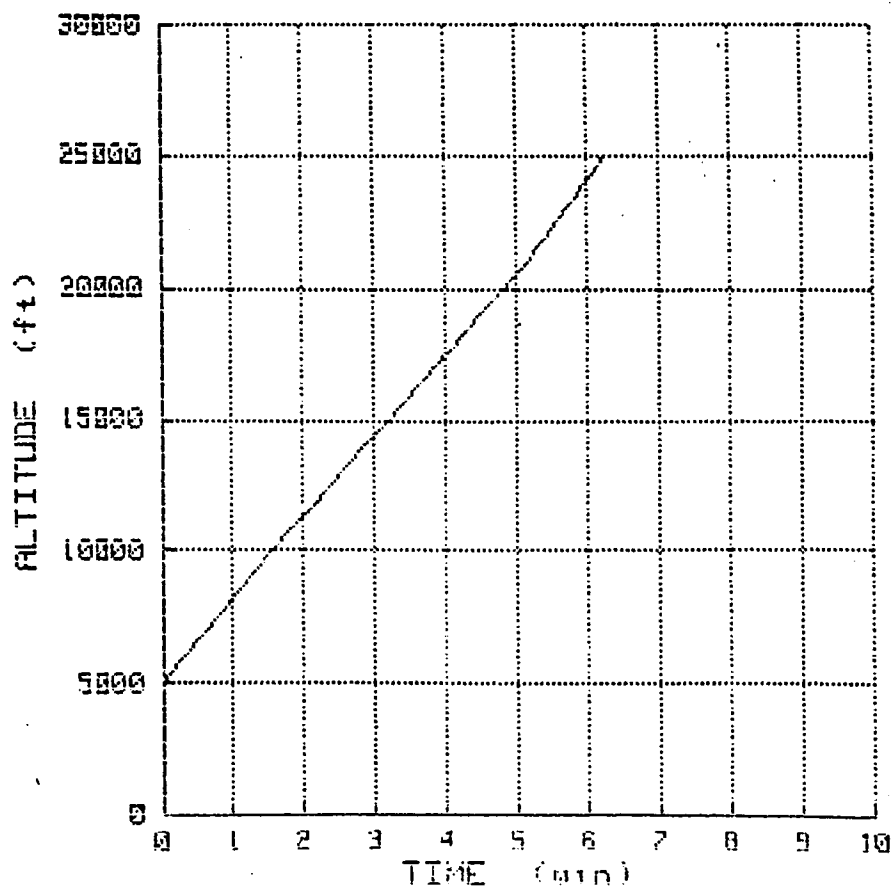


Figure 8

STANDARD DAY TIME TO CLIMB FOR LOADING D

MODEL TA-7C AIRPLANE
BuNo 154402

CONFIGURATION: CL
LOADING: D
CLIMB SCHEDULE: 340 KOAS
UNTIL 0.75M MAINTAIN 0.75M

STANDARD GW: 35,199 LB
ENGINE: TF41-A-402D
FUEL: JP-5

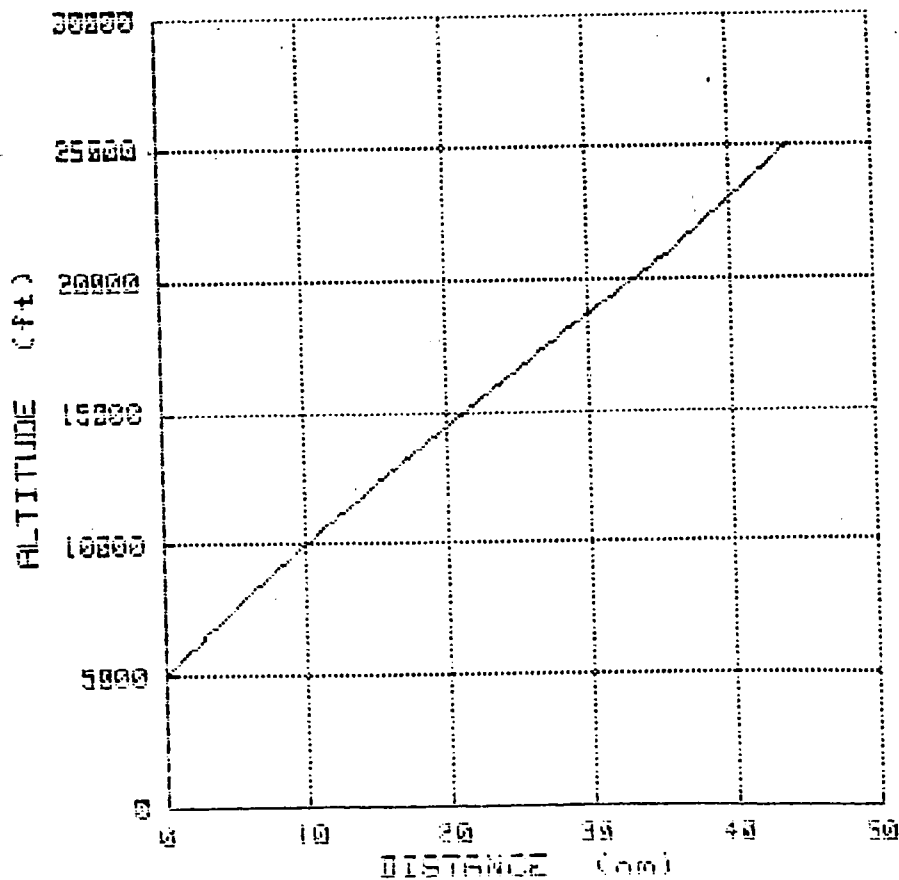


Figure 9

STANDARD DAY DISTANCE TO CLIMB FOR LOADING D

MODEL TA-7C AIRPLANE
BuNo

CONFIGURATION: CR
PRESSURE ALTITUDE: VARIOUS
STANDARD GROSS WGT: 35,199 LB
CONDITION: STANDARD DAY

ENGINE: TF-41-A-402D35,199 LB
FUEL: JP-5
METHOD: CONSTANT ALTITUDE

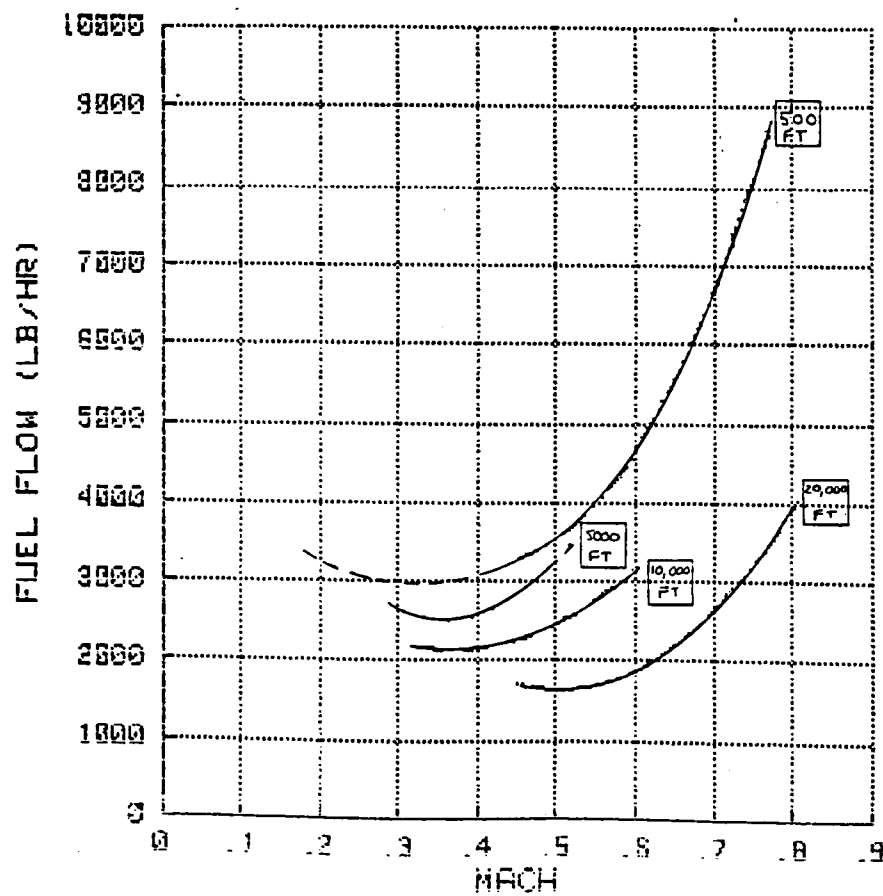


Figure 10

STANDARD DAY FUEL FLOW REQUIRED VS. MACH

MODEL TA-7C AIRPLANE
BuNo 154361, 154402

CONFIGURATION: CR
LOADING: FAMILIARIZATION
METHOD: STABLE POINT

GROSS WEIGHT: 35,199 LBS (STANDARD)
CENTER OF GRAVITY: 25.3-27.8% MAC
PRESSURE ALTITUDE: 500-20,000 FT MSL
TRIM AIRSPEED: N/A

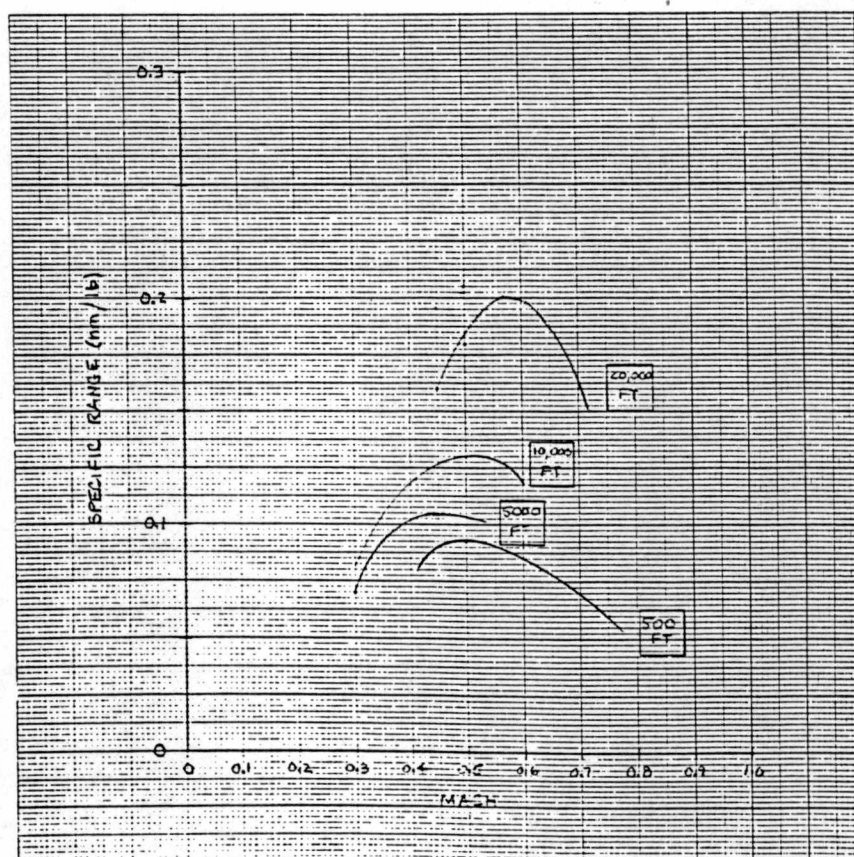


Figure 11

STANDARD DAY SPECIFIC RANGE VS. MACH

MODEL TA-7C AIRPLANE
BuNo 154361, 154402

CONFIGURATION: CR
LOADING: FAMILIARIZATION
METHOD: LEVEL ACCELERATION

GROSS WEIGHT: 35,199 LBS (STANDARD)
CENTER OF GRAVITY: N/A
PRESSURE ALTITUDE: 5,000-20,000 FT MSL
TRIM AIRSPEED: N/A

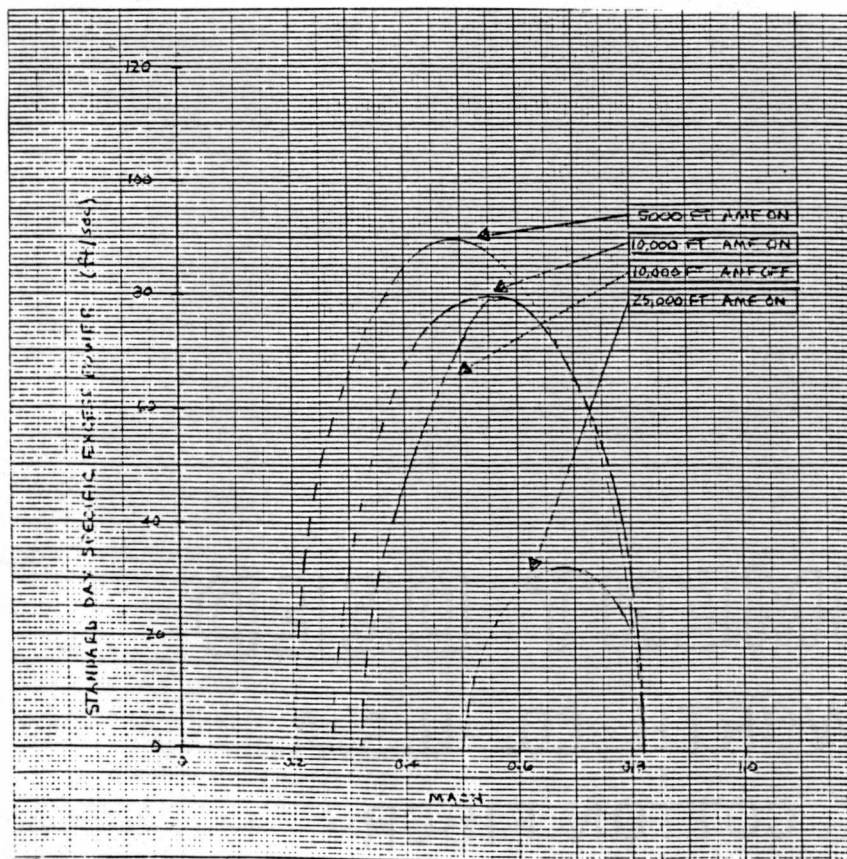


Figure 12

STANDARD DAY SPECIFIC EXCESS POWER VS. MACH

MODEL TA-7C AIRPLANE
BuNo 154402

CONFIGURATION: POWER	STANDARD GW: 35,199 LB
LOADING: A	STANDARD DAY
METHOD: LEVEL ACCELERATION	ALTITUDE: 5,000 FT MSL

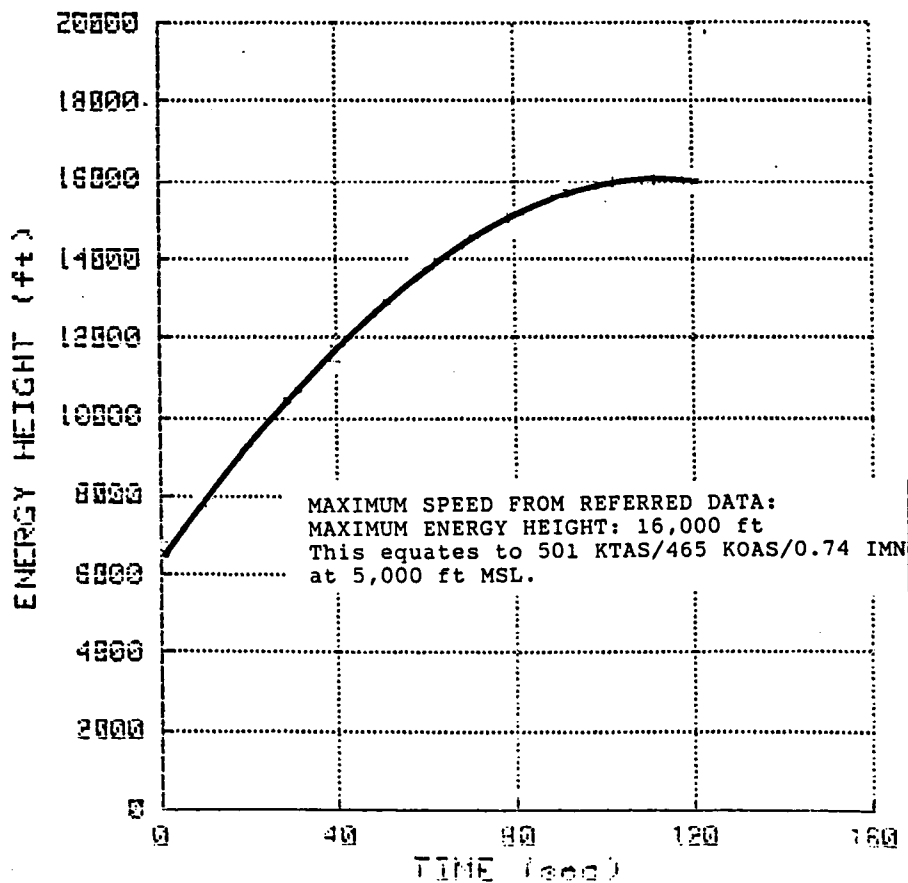


Figure 13
ENERGY HEIGHT VS TIME

MODEL TA-7C AIRPLANE
BuNo 154402

CONFIGURATION: POWER
LOADING: A
METHOD: STEADY TURNS
WIND-UP TURNS

STANDARD GW: 35,199 LB
STANDARD DAY
ALTITUDE: 5,000 FT MSL

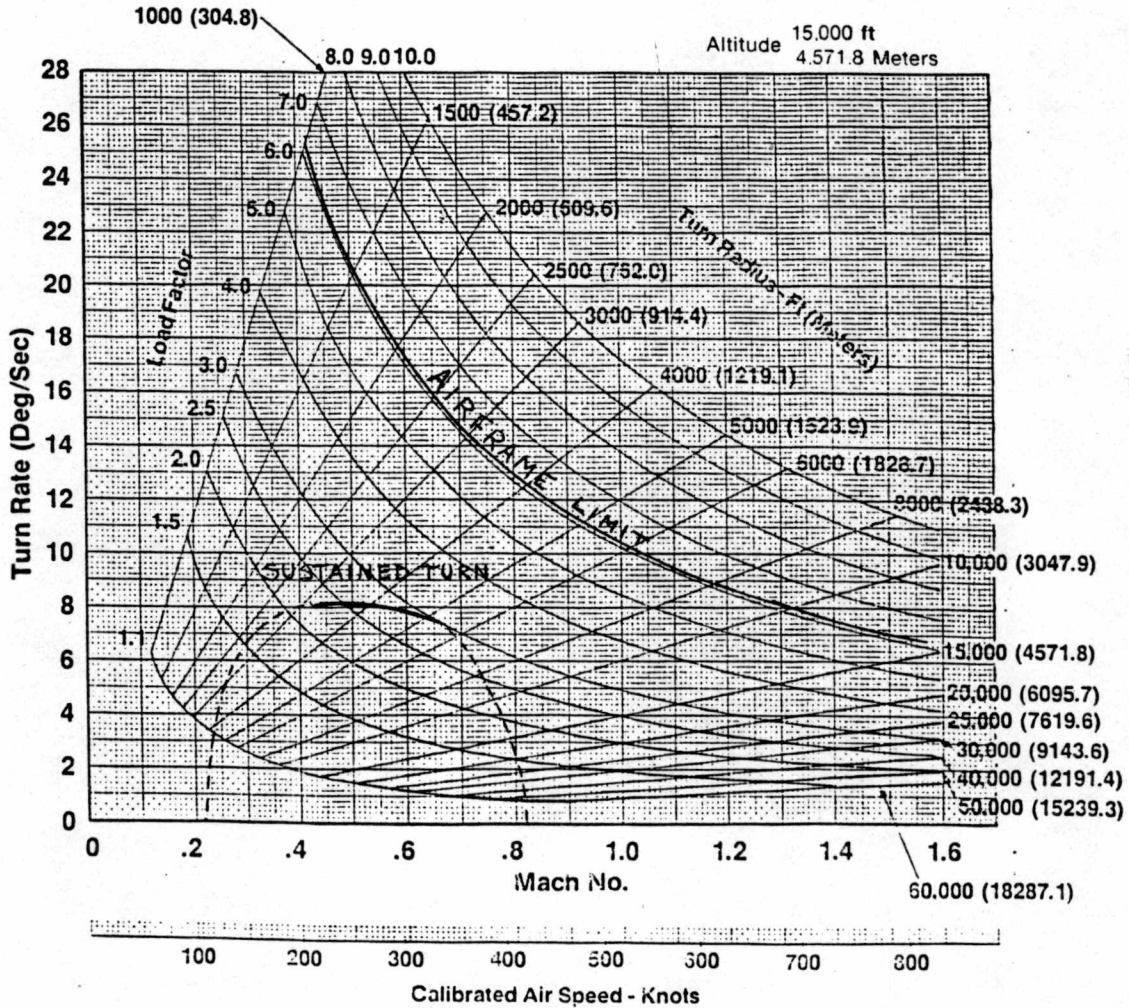


Figure 14

SUSTAINED TURN PERFORMANCE

MODEL TA-7C AIRPLANE
BuNo 154402

CONFIGURATION: POWER
LOADING: A
METHOD: STEADY TURNS
WIND-UP TURNS

STANDARD GW: 35,199 LB
STANDARD DAY
ALTITUDE: 10,000 FT MSL

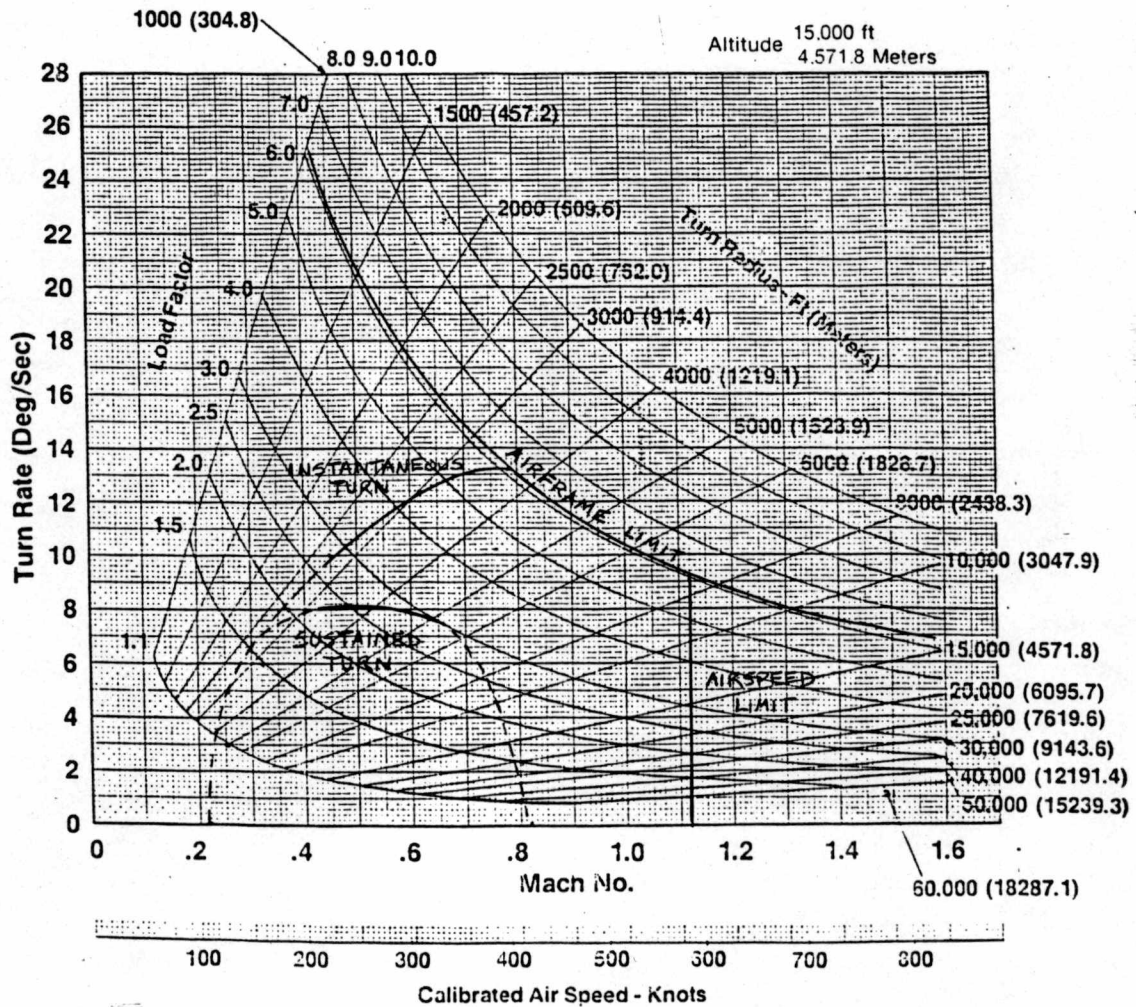


Figure 15

SUSTAINED AND INSTANTANEOUS TURN PERFORMANCE

MODEL TA-7C AIRPLANE
BuNo 154402

CONFIGURATION: DE 1
LOADING: FAMILIARIZATION
DECENT SCHEDULE: 250 KOAS

STANDARD GW: 35,199 LB
ENGINE: TF41-A-402D
FUEL: JP-5

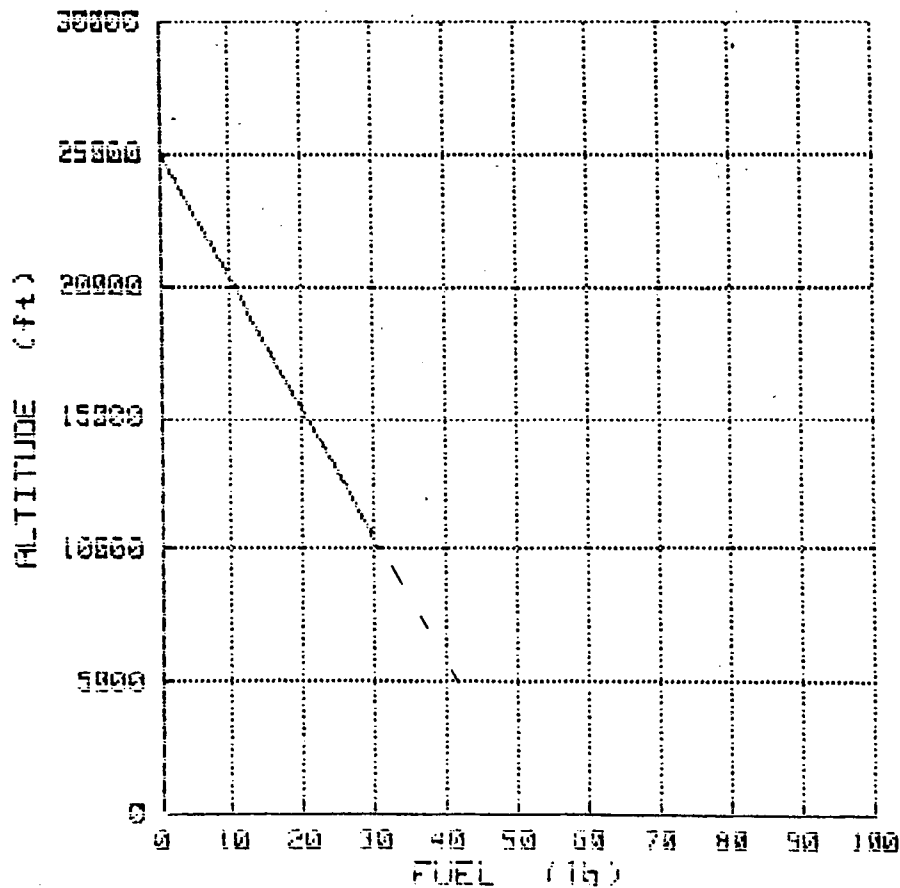


Figure 16

STANDARD DAY FUEL TO DESCEND FOR CONFIGURATION DE 1

MODEL TA-7C AIRPLANE
BuNo 154402

CONFIGURATION: DE 1
LOADING: FAMILIARIZATION
DECENT SCHEDULE: 250 KOAS

STANDARD GW: 35,199 LB
ENGINE: TF41-A-402D
FUEL: JP-5

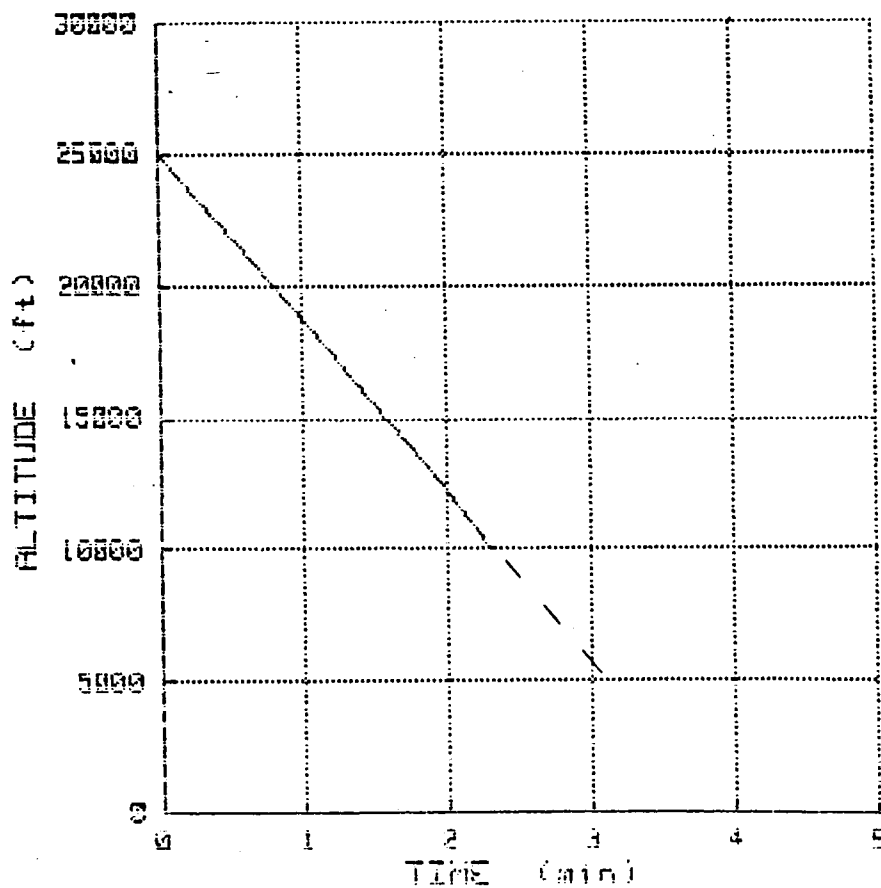


Figure 17

STANDARD DAY TIME TO DESCEND FOR CONFIGURATION DE1

MODEL TA-7C AIRPLANE
BuNo 154402

CONFIGURATION: DE 1
LOADING: FAMILIARIZATION
DECENT SCHEDULE: 250 KOAS

STANDARD GW: 35,199 LB
ENGINE: TF41-A-402D
FUEL: JP-5

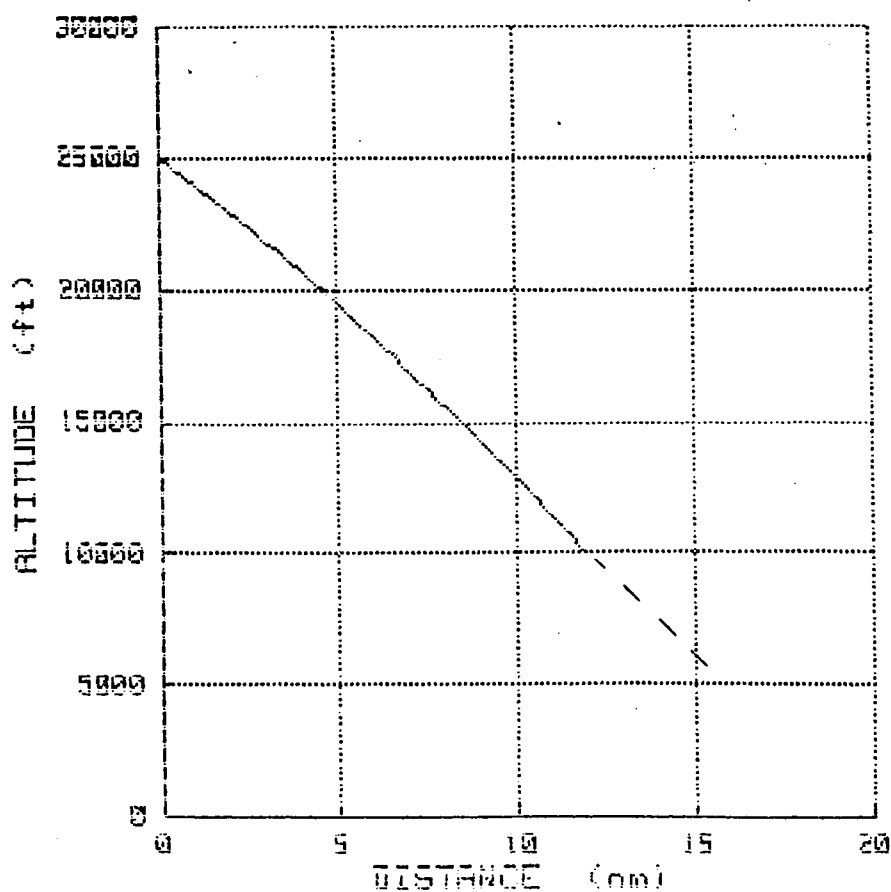


Figure 18

STANDARD DAY DISTANCE TO DESCEND FOR CONFIGURATION DE1

MODEL TA-7C AIRPLANE
BuNo 154402

CONFIGURATION: DE 2
LOADING: FAMILIARIZATION
DECENT SCHEDULE: 14 UNITS
ANGLE OF ATTACK

STANDARD GW: 35,199 LB
ENGINE: TF41-A-402D
FUEL: JP-5

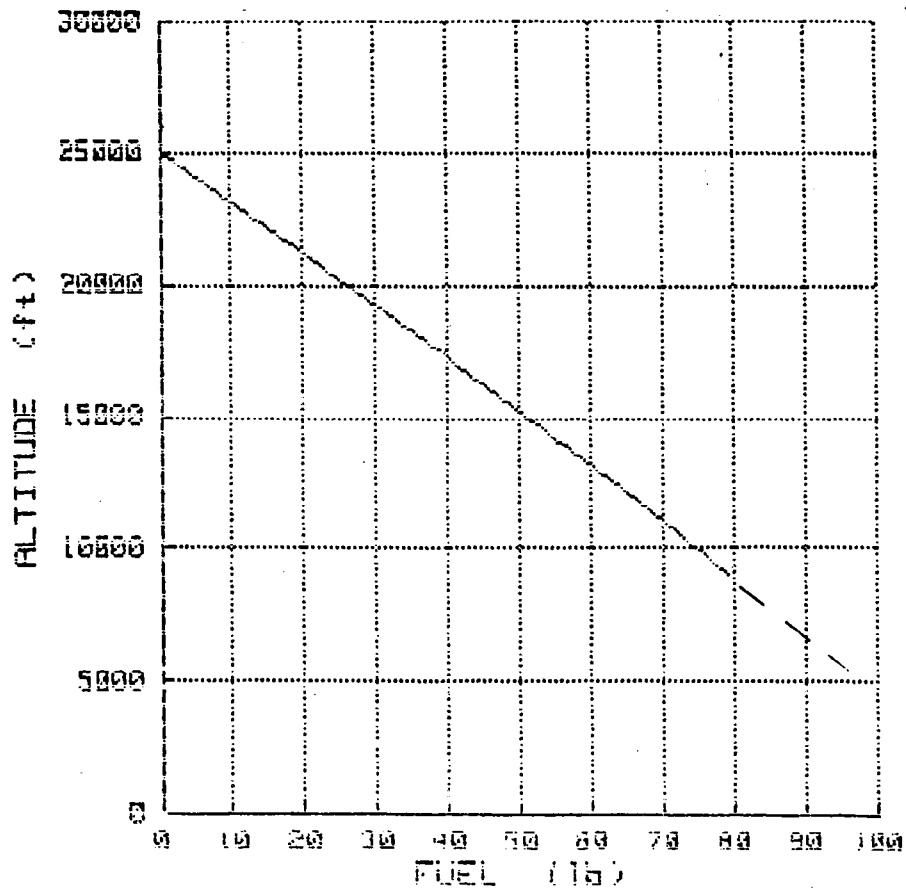


Figure 19

STANDARD DAY FUEL TO DESCEND FOR CONFIGURATION DE2

MODEL TA-7C AIRPLANE
BuNo 154402

CONFIGURATION: DE 2
LOADING: FAMILIARIZATION
DECENT SCHEDULE: 14 UNITS
ANGLE OF ATTACK

STANDARD GW: 35,199 LB
ENGINE: TF41-A-402D
FUEL: JP-5

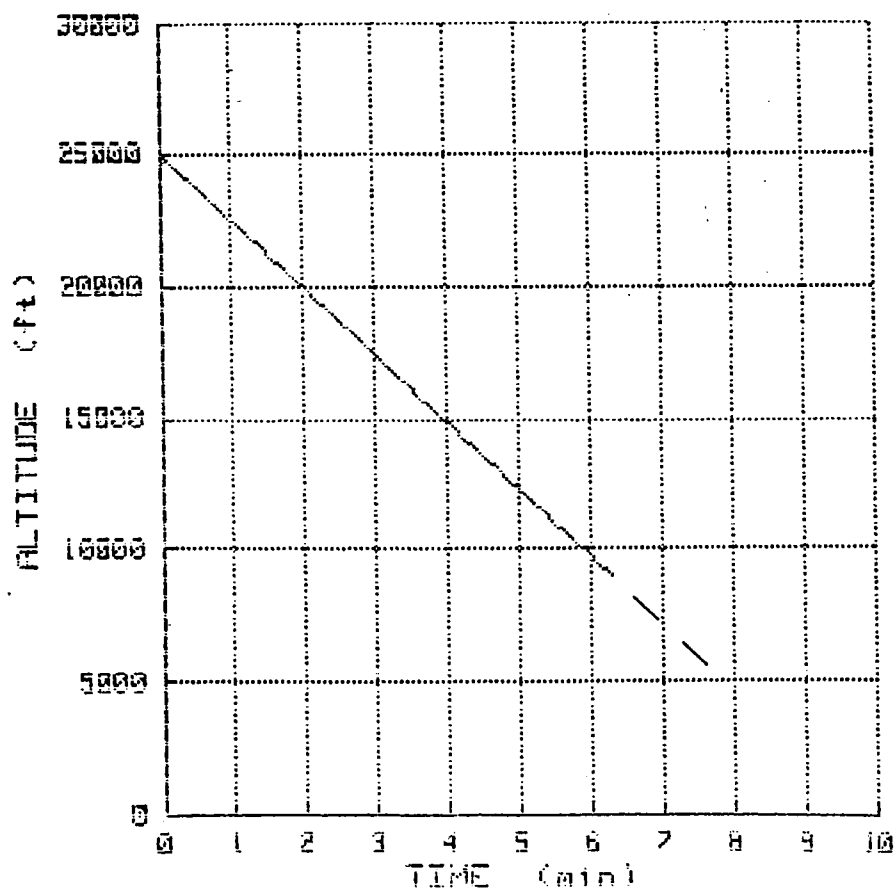


Figure 20

STANDARD DAY TIME TO DESCEND FOR CONFIGURATION DE2

MODEL TA-7C AIRPLANE
BuNo 154402

CONFIGURATION: DE 2
LOADING: FAMILIARIZATION
DECENT SCHEDULE: 14 UNITS
ANGLE OF ATTACK

STANDARD GW: 35,199 LB
ENGINE: TF41-A-402D
FUEL: JP-5

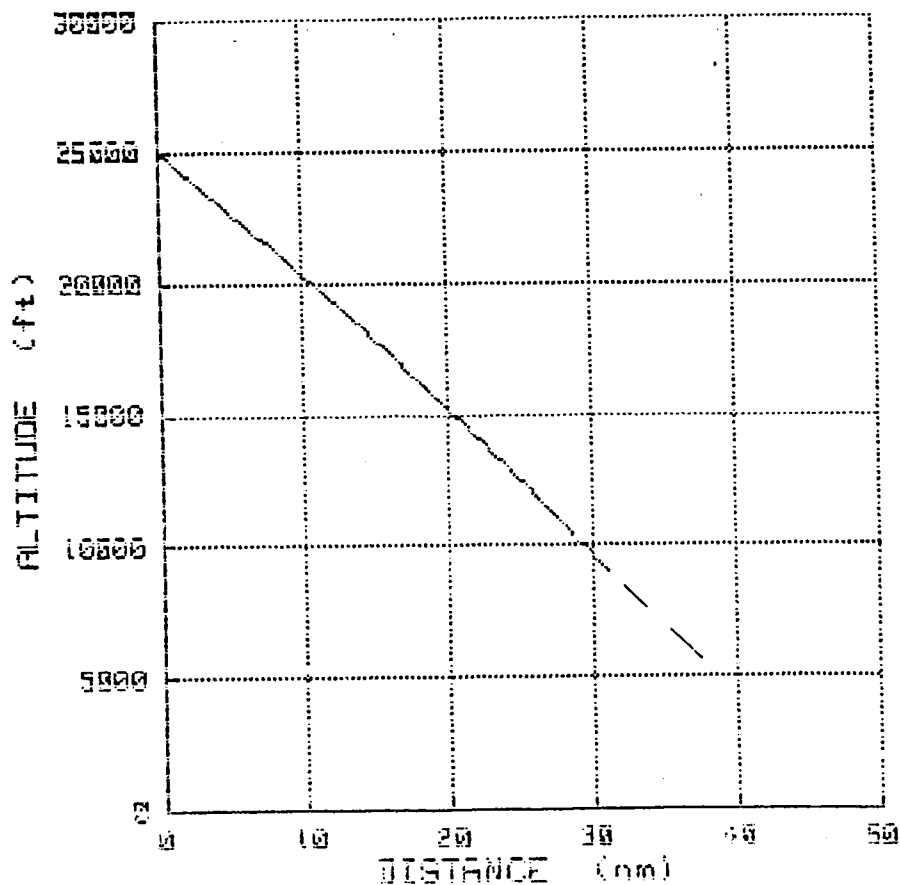


Figure 20

STANDARD DAY DISTANCE TO DESCEND FOR CONFIGURATION DE2

TABLE I
MISSION PROFILE

MISSION TASK	TIME (min)	FUEL USED (lb)	DISTANCE (NM)
Start, taxi, takeoff, acceleration to climb speed	-	770	4
Climb on course to 20,000 ft cruise altitude	6	700	43
Cruise at 20,000 ft at maximum range speed	37	1125	225
Descend to sea level	3	-	-
Run in 200 NM at sea level at speed for maximum range	35	2200	200
Fuel allowance of 5 min at maximum Power (sea level)	-	800	-
Drop bombs, climb on course to 20,000 ft	4	480	30
Cruise at 20,000 ft at maximum range speed	70	2125	425
Descend to sea level	3	-	-
Arrive overhead with 3000 lb/ including reserve fuel (5% initial fuel plus 20 min at sea level maximum endurance	-	(1500 lb reserve)	-
TOTAL	2 hr 38 min	10,200 lb	927NM

$$P_s = \frac{V}{W} (T-D)$$

Assuming: Weight is constant @ 35,000 lb

Velocity is constant

Drag remains constant for given weight and velocity

PRESENT ENGINE

$$P_{s1} = \frac{V}{W} (T_1 - D)$$

NEW ENGINE

$$P_{s2} = \frac{V}{W} (T_2 - D)$$

$$P_{s2} - P_{s1} = \frac{V}{W} (T_2 - D) - (T_1 - D)$$

$$P_s = \frac{V}{W} T_2 - T_1$$

Substituting values for contractor recommended climb

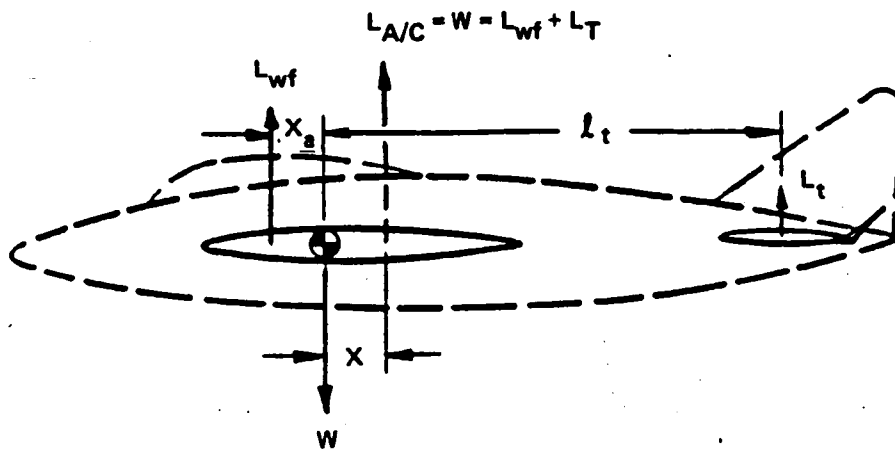
$$P_s \frac{385 \text{ kts}}{35000 \text{ lb}} T_2 - T_1 = \frac{385 \text{ nm}}{\text{hr}} \times \frac{6000 \text{ ft}}{\text{nm}} \times \frac{1 \text{ hr}}{3600 \text{ sec}} T_2 - T_1$$

Military Rated Thrust $P_s = (0.01833) 17,000 - 15,300 = 31.16 \text{ ft/sec}$

Maximum Thrust $P_s = (0.01833) 28,600 - 15,300 = 243.79 \text{ ft/sec}$

Figure 1

SPECIFIC EXCESS POWER CALCULATIONS



L_{wf} = Lift of wings and fueslage
 L_t = Lift of tail
 $L_{a/c}$ = Total lift of airplane
 W = Weight

LEX EFFECT

The depiction above illustrates the original aircraft configuration. With the LEX added L_{wf} will move toward the nose and the distance X_a will increase. With no change in center of gravity this acts to move $L_{a/c}$ forward reducing the distance X . This will result in reduced static stability.

CENTER OF GRAVITY REPOSITIONING

Since $L_{a/c}$ has moved forward reducing the distance X , we can move the center of gravity forward to increase the distance X sufficiently to assure adequate static stability characteristics.

Figure 2

DEPICTION OF PROPOSED CENTER OF GRAVITY REPOSITIONING
 WITH LEX INCORPORATED

ASSUMPTIONS:

Additional 10% wing area (LEX)
 C_{lmax} of new wing = 1.3 C_{lmax} of old wing
Load factor maximum 6.2
Constant weight

SUBSCRIPTS:

1 - Old wing
2 - New wing

$$L_1 = n_z W = L_2$$

$$\frac{1}{2} \rho V_1^2 S_1 C_{lmax1} = \frac{1}{2} \rho V_2^2 S_2 C_{lmax2}$$

$$V_1^2 S_1 C_{lmax1} = V_2^2 S_2 C_{lmax2}$$

$$V_1^2 (S_1/S_2) (C_{lmax1}/C_{lmax2}) = V_2^2$$

$$V_1^2 (1.0/1.1) (1.0/1.3) = V_2^2$$

$$V_1 \sqrt{(1/1.463)} = V_2$$

$$0.8267 V_1 = V_2$$

AT CURRENT 400 KT CORNER SPEED

$$\text{New corner speed} = 0.8267 (400) = 330 \text{ kts}$$

Figure 3

APPROXIMATION OF NEW CORNER SPEED WITH LEX INCORPORATED

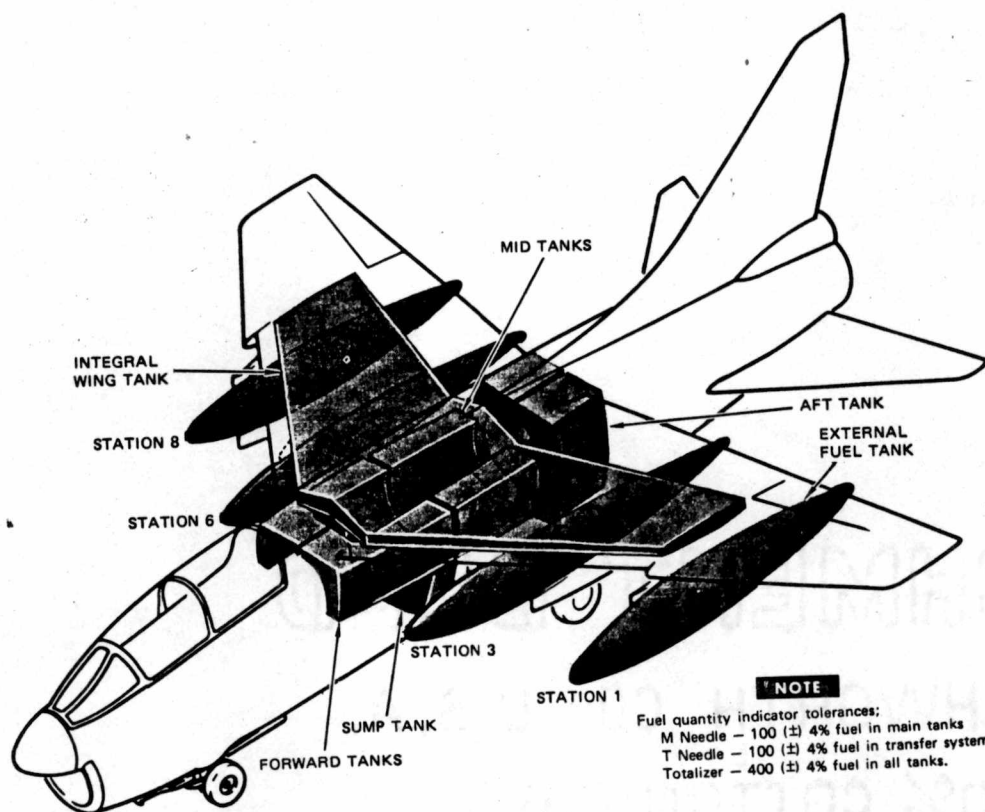


Figure 4
CURRENT FUEL TANK ARRANGEMENT

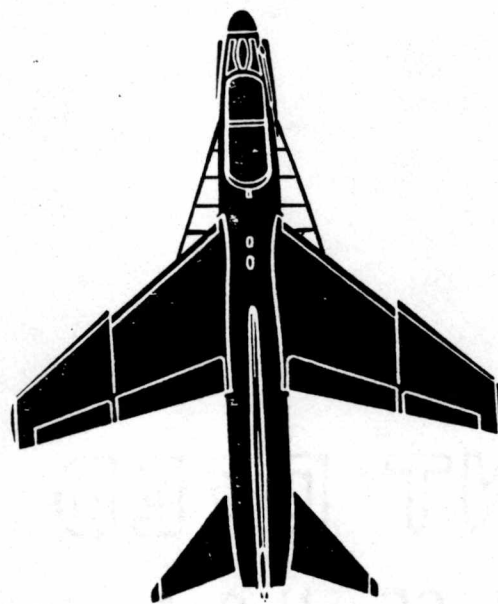
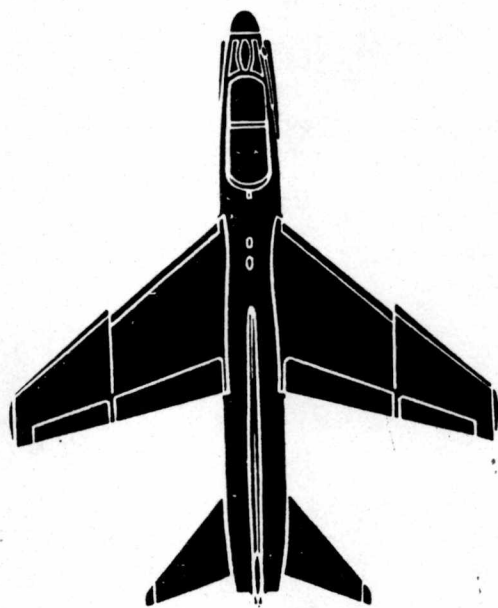


Figure 5

PROPOSED INSTALLATION OF LEADING EDGE EXTENSION

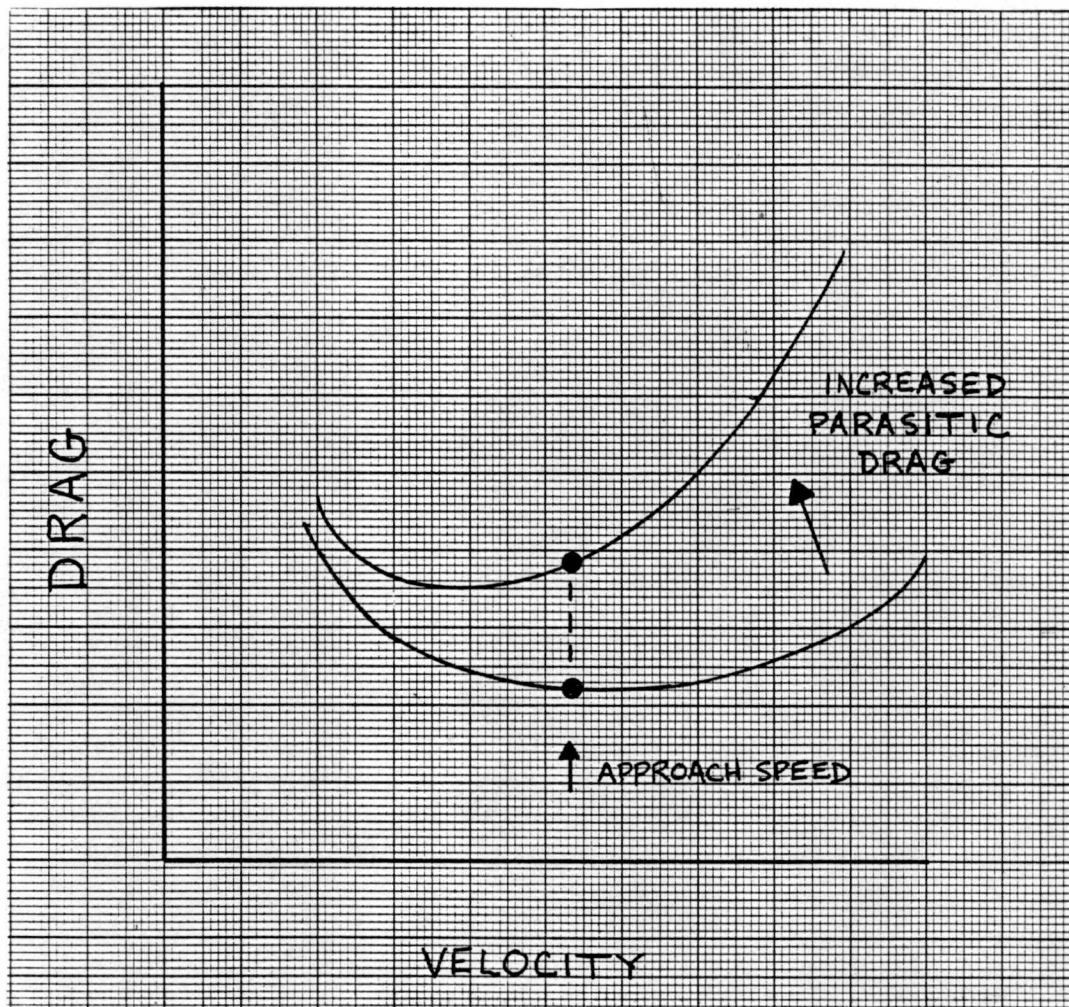
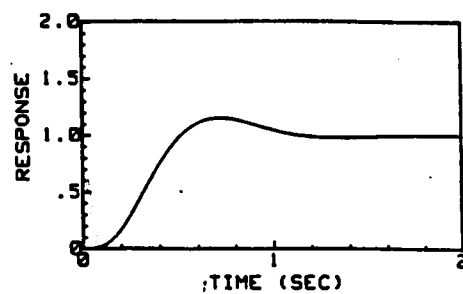
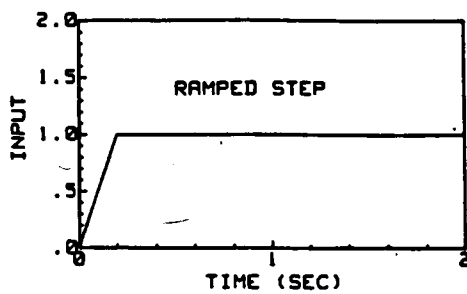
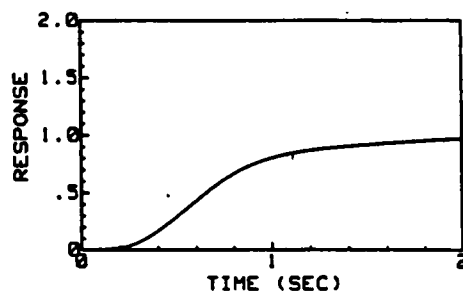
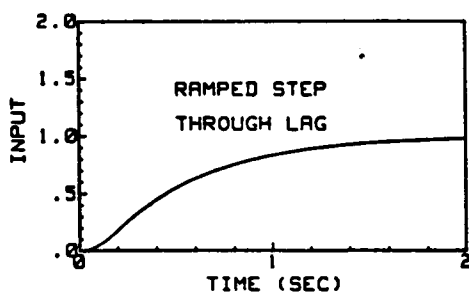


Figure 6

EFFECT OF PARASITIC DRAG INCREASE IN APPROACH PHASE



INPUT AND SECOND ORDER RESPONSE



INPUT AFTER FIRST ORDER LAG AND RESULTANT RESPONSE

Figure 7

EFFECT OF LAG PREFILTER INPUT AND RESPONSE

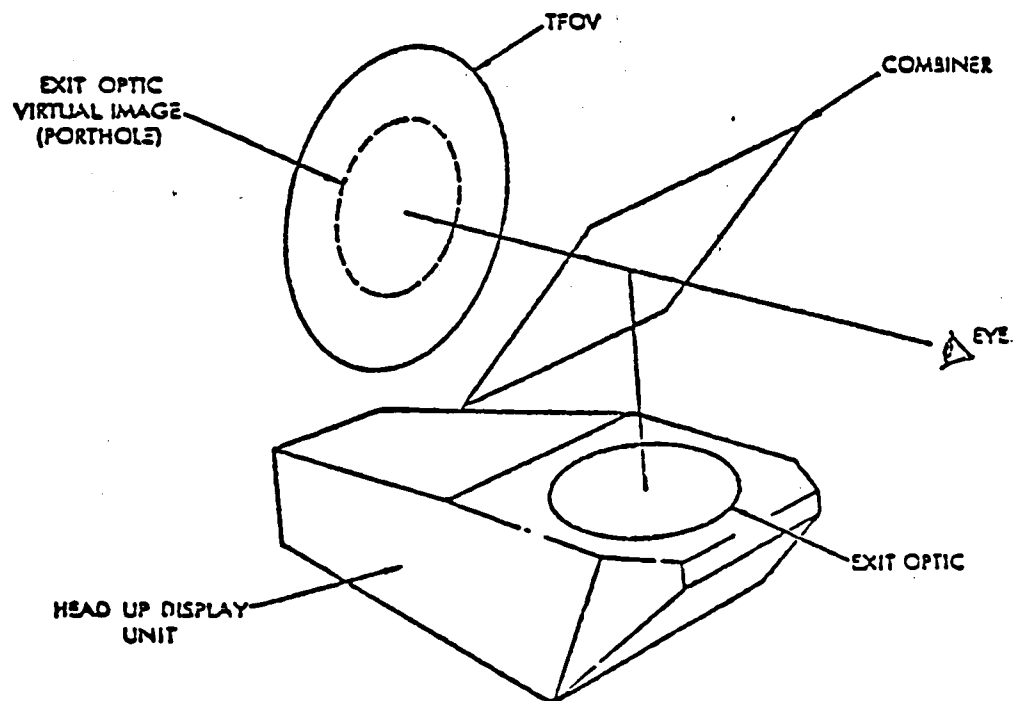


Figure 8

HEADS UP DISPLAY TOTAL AND INSTANTANEOUS FIELD OF VIEW

GLOSSARY OF TERMS

AERODYNAMIC CENTER. That point on a wing or aircraft body at which the total lift may be assumed to act.

ANTHROPOMETRIC MEASUREMENTS. A person's physical measurements (i.e. total sitting height, sitting eye height, functional reach, etc.) as compared to a data base. For the purpose of this thesis, the data base was a sampling of Naval Aviators compiled by the U.S. Navy Aviation Physiology Department.

BREAKOUT PLUS FRICTION. The sum of the pre-loaded flight control force (breakout) and the friction, this is the maximum force exerted by the pilot before movement of the flight control from trim.

COMBAT RADIUS. The total distance that the aircraft can fly and still have enough fuel to perform the mission upon reaching the target and adequate fuel reserve upon return.

CONTROL AUGMENTATION. Flight control system design which contributes aerodynamic and inertial feed back into the mechanical flight controls to enhance airplane handling.

CONTROL CENTERING. Positive centering is the tendency for a flight control to return to a trimmed position following displacement. Absolute centering occurs when the control stick or rudder returns to the exact position from which it was displaced.

CONTROL FORCE GRADIENT. The force required per increment of control displacement once a flight control has been displaced from trim. The average gradient is the slope of the average variation of force versus displacement.

CONTROL OSCILLATIONS. The resultant motion of a flight control following a release from a given amount of displacement.

CONTROL SENSITIVITY. The angular acceleration of aircraft response generated by a specific amount of flight control input.

DESIGN EYE POSITION. The point in space located at the sitting eye height dimension of the "average" aviator (50th percentile - 31.5 in. above the seat). Design eye position is the source of measurement for control reach, display visibility, cockpit space accommodation, etc.

FIELD OF VIEW. Binocular field of regard of the human eyes focused at infinity.

FREEPLAY. The lost motion that exists between a cockpit control and the corresponding aircraft control surface.

HANDLING QUALITIES RATING. A subjective conclusion reached as to the performance or desirability of a handling feature with regard to the pilot's ability to perform a task within certain tolerances.

GLOSSARY OF TERMS (Con't)

HEADS UP DISPLAY. An optical device mounted near the windscreen which provides airplane heading, altitude, speed and weapon release information to the pilot. Allows the pilot to monitor airplane and weapon system performances while continuing to monitor the external environment.

HUD INSTANTANEOUS FIELD OF VIEW. A "snapshot" view of HUD information. Size of instantaneous field of view is dependent on exit optic size, distance from eyes to HUD, lateral and vertical position of eyes relative to HUD.

INDICATED AIRSPEED. The aircraft velocity value corrected for instrument error, but not for position, compressibility, or air density errors.

INSTRUMENT METEOROLOGICAL CONDITIONS. Meteorological conditions under which the pilot must rely solely upon aircraft instruments to maintain aircraft attitude and position.

IRREVERSIBLE FLIGHT CONTROL SYSTEM. A system which transmits pilot commands to the aircraft control surfaces via the flight controls, but which does not allow any control surface loads to be felt by the pilot.

MANEUVERING STABILITY. An evaluation of static longitudinal stability in other than 1 g flight. Maneuvering stability is evaluated by measuring control stick force and displacement versus load factor variations.

MEAN SEA LEVEL ALTITUDE. Airplane altitude referenced to the average level of the ocean.

NORMAL ACCELERATION. That acceleration present in the airplane along the aircraft vertical axis. Often quantified as 'g' level or load factor.

PRESSURE ALTITUDE. The altitude measured when the barometric altimeter is set to standard day pressure conditions (29.92 in. Hg).

RADAR ALTITUDE. Height of the aircraft above the ground as determined by an onboard system which transmits a radar signal towards the ground, measures the time for the signal to return, and thereby computes aircraft altitude.

REAR QUARTER ATTACK. An offensive maneuver against an airplane in which the attacker approaches and fires weapons from behind the target.

RECTILINEAR TOTAL VISION PLOT. A compilation of the forward, side, and rear fields of view as measured from the design eye position. Includes information on obstructions for 180 degrees vertically and 360 degrees side to side with axes referenced to the nose of the aircraft (side-to-side) and the cockpit floor (vertically).

GLOSSARY OF TERMS (Con't)

ROLL MODE TIME CONSTANT. The time required for the roll rate to reach 63.2 percent of the steady state roll rate following a step input of lateral control.

SIDESLIP. Condition at which the relative wind to the airplane is not perpendicular to the lateral axis.

SPECIFIC EXCESS POWER. Defined by the equation, $P_s \frac{V(T-D)}{W}$.

STANDARD DAY. Standard day sea level conditions defined as temperature = 59 deg F, air pressure = 29.92 in. hg, and air density = 0.0023769 slugs per cubic foot.

STATIC MARGIN. The distance between the actual center of gravity and the neutral point of the airplane usually expressed as a percentage of the mean aerodynamic chord.

STEADY PULL UPS. A maneuvering stability test technique designed to momentarily increase aircraft load factor by smoothly applying control stick.

STEADY PUSH OVERS. A maneuvering stability test technique designed to momentarily decrease aircraft load factor by smoothly applying forward control stick.

STEADY TURNS. A constant normal acceleration and airspeed turn.

STEP INPUT. A rapid, precise flight control input of a specific magnitude, maintained for some finite period of time in order to examine aircraft response.

SUDDEN PULLUPS. A maneuvering stability test technique designed to momentarily increase aircraft load factor by rapidly applying a step input to the control stick.

TAPER RATIO. The ratio of the wing tip chord length to the wing root chord length.

TRIMMED FLIGHT CONTROL POSITIONS. Flight control positions measured while in a stabilized flight condition.

TRUE AIRSPEED. The aircraft velocity value corrected for instrument, position, compressibility, and air density errors.

UNREFERRED DATA. The process by which referred data is applied to a set of specific ambient conditions and engine variables.

VERTIGO. A state of disorientation.

VISCOUS DAMPER. A mechanical unit designed to provide an opposing force proportional to rate of motion. Viscous dampers can be utilized to resist rapid control inputs.

VISUAL METEOROLOGICAL CONDITIONS. Meteorological conditions under which the pilot may rely upon outside references to maintain aircraft attitude and position.

LIST OF ABBREVIATIONS

AFCS	Automatic flight control system
AGL	Above ground level
BO+F	Break out plus friction
BuNo	Aircraft bureau number
Cdo	Coefficient of parasite drag
CG	Center of gravity
Clmax	Maximum coefficient of lift
deg	Degree
DEP	Design eye position
FOV	Field of view
ft	Foot
IFF	Identification, Friend or Foe
g	Normal acceleration due to gravity
Hg	Mercury
HQR	Handling qualities rating
hr	Hour
IMC	Instrument meteorological conditions
in.	Inch
KOAS	Knots observed airspeed
kt	Knot
lb	Pound
Lmax	Maximum lift
min	Minute
MSL	Mean sea level
nmi	Nautical mile
Nz	Normal acceleration
Ps	Specific excess power
psi	Pounds per square inch
RPM	Revolutions per minute
sec	Second
STD	Standard
TACAN	Tactical Air Navigation
UFC	Up front control
USNTPS	United States Naval Test Pilot School
VMC	Visual meteorological conditions
Vmax	Maximum level flight airspeed
%	Percent

VITA

Thomas Cropper was born in Leonardtown, Maryland on June 20, 1959. He attended Haverford High School in Havertown, Pennsylvania where he graduated in 1977. He studied at Iowa State University receiving a Bachelor of Science degree in Engineering Operations in 1981.

Upon graduation he was commissioned an officer in the U.S. Navy and attended flight training in Pensacola, Florida and Kingsville, Texas. After designation as a naval aviator in November 1982, he spent four years as an A-6E attack pilot with VA-34, embarked in USS America and homeported in Virginia Beach, Virginia. He was selected to attend the United States Naval Test Pilot School in 1986. Following graduation from the School in December 1987 he was assigned to the Strike Aircraft Test Directorate at the Naval Air Test Center, Patuxent River, Maryland. There he served as an engineering test pilot in A-4, A-6E, and EA-6B aircraft conducting carrier suitability, ordnance separation, and engine airstart testing. He is currently assigned as a flight instructor at the United States Naval Test Pilot School. He enrolled in the Graduate School of the University of Tennessee, Knoxville in December 1987. Thomas Cropper will continue his career in naval Aviation upon graduation.