Library

NASA-TM-56048

NASA Technical Memorandum 56048

DESIGN AND PHYSICAL CHARACTERISTICS OF THE TRANSONIC AIRCRAFT TECHNOLOGY (TACT) RESEARCH AIRCRAFT

Weneth D. Painter and Lawrence J. Caw

January 1979

NASA

NASA Technical Memorandum 56048

DESIGN AND PHYSICAL CHARACTERISTICS OF THE TRANSONIC AIRCRAFT TECHNOLOGY (TACT) RESEARCH AIRCRAFT

Weneth D. Painter and Lawrence J. Caw

Dryden Flight Research Center
Edwards, California

NASA
National Aeronautics and
Space Administration

Scientific and Technical
Information Office

1979

DESIGN AND PHYSICAL CHARACTERISTICS OF THE TRANSONIC AIRCRAFT TECHNOLOGY (TACT) RESEARCH AIRCRAFT

Weneth D. Painter and Lawrence J. Caw
Dryden Flight Research Center

INTRODUCTION

Supercritical airfoil research has been underway since 1964 with successive refinements in concept. The supercritical airfoil potentially offers significant aerodynamic benefits in the transonic region. These benefits include improved aerodynamic efficiency and large gains in drag-divergence Mach number. Exploratory test results indicate that an airplane's maximum range and maximum range cruise may both be increased through use of the supercritical wing.

Two other supercritical wing flight programs were completed before the TACT program. These were the T-2C and F-8 programs. The T-2C program demonstrated through the application of a supercritical airfoil, the ability to increase wing thickness ratio from 12% to 17% with no degradation in airplane performance. Supercritical wing benefits were also demonstrated in the F-8 program, which utilized a wing with a high aspect ratio and a thickness ratio of 9% (average) with a highly blended wing-body junction specifically tailored for a transport-type aircraft, reference 1.

In addition to the aerodynamic benefits, the TACT F-111A supercritical wing offered potential for improved transonic maneuverability. In this regard supercritical airfoil development reached the point where full-scale flight demonstration was necessary to resolve uncertainties and pave the way for further applications.

SYMBOLS

Physical quantities are given in the International System of Units (SI) and parenthetically in U.S. Customary Units. Factors relating the two systems are given in reference 2.

ΔM	Mach number error
M_∞	True Mach number
M'	indicated Mach number
TACT	transonic aircraft technology
Λ	wing sweep angle

PROGRAM DESCRIPTION

The basic purpose of the TACT research program was to provide the data necessary to verify promising aerodynamic concepts, such as the supercritical wing, and to gain the confidence required for the application of such technology to advanced high performance aircraft. Accordingly, an F-111A aircraft was employed as the flight test-bed to provide full-scale data. The data were correlated extensively with predictions based on data obtained from wind-tunnel tests.

The TACT program included an assessment of the improvement afforded at transonic speeds in drag divergence, maneuvering performance, and airplane handling qualities by the use of the supercritical wing. Potential improvements were expected to be reflected in increased cruise speed, range and maneuvering capability. The program also investigated the transonic flight and wind-tunnel testing techniques. The specific research technologies evaluated are summarized in the sections that follow.

Wind-Tunnel Prediction Techniques

Wind-tunnel and flight-test data were correlated in an effort to evaluate the methodology used to predict full-scale flight characteristics on the basis of small-scale model wind-tunnel test results and to define problem areas where either better experimental simulation or improved analytical techniques were required, references 3 through 7.

Supercritical Wing Technology

The TACT supercritical wing and the conventional F-111A wing were evaluated in wind-tunnel tests on a 1/24-scale model to assess the effects of wing configuration. The same evaluation was accomplished in flight using the basic F-111A aircraft and the TACT aircraft.

Wing Pressures

Wind-tunnel wing pressure data were obtained with a 1/12-scale flexible wing and a 1/6-scale semispan model. These data were used to evaluate the capability for predicting full-scale aerodynamic characteristics of a supercritical airfoil from wind-tunnel test data.

In-flight surface pressures were measured on the TACT wing to determine the local flow conditions and aerodynamic loads of a supercritical wing at various wing sweep angles. The general objective was to determine the effectiveness of the supercritical wing configuration in a maneuvering environment.

The wind-tunnel and flight-test data were correlated for various test conditions. Wing and fuselage static pressures from flight test and from 1/12-scale and 1/6-scale wind-tunnel models were compared for the same local angle-of-attack to determine scale effects and variations due to testing techniques. Boundary layer conditions were also studied and compared. Static pressures were correlated and compared using chordwise and spanwise pressure plots and isobar plots, references 8 and 9.

Buffet

Buffet intensity and airplane response were investigated to assess the wing flow separation characteristics and effects in the areas of airframe buffeting, wing separation mapping, and related handling quality difficulties such as wing rock.

Research studies of the unsteady buffet aerodynamics were designed to define the unsteady aerodynamic inputs and structural response characteristics of the wind-tunnel models and the flight vehicle. The goal was to study the TACT models and airplane to produce data considered typical for wings with supercritical airfoils. These data would add to the data base for the determination of an empirical buffet intensity prediction technique, references 10 through 13.

Stability and Control

The existing aerodynamic stability and control design methods and testing technique were evaluated by comparing and correlating full-scale flight data with both wind-tunnel based and analytically derived estimates. This effort included the following task: extraction of linear longitudinal and lateral-directional derivatives from flight-test maneuvers; estimation of the flexible characteristics (increments and ratios) of full-scale aircraft and wind-tunnel models; assessment of the aerodynamic stability and control design procedures by correlation of predicted data with flight data; and evaluation of handling qualities including the comparison of the flight handling qualities parameters of the TACT F-111A and basic F-111A aircraft with requirements from military specification MIL-F-8785B(ASG) (reference 14), comparison of the flight data with estimated characteristics and assessment of the accuracy of the analytical procedures, reference 15 through 17.

Agility

Agility data for the TACT aircraft were compared with data for the basic F-111A aircraft, which were obtained during the baseline program. The evaluation included the effect of wing sweep, load factor and the configuration on the turn capability, degree of precision control, overall handling qualities, and aerodynamic performance. The results showed the advantages and disadvantages of using a supercritical wing in the transonic maneuverability range, reference 18.

Structural Flight Test

Flight-measured structural loads and pressure data were compared with the design and ground proof test results.

Test-Bed Experiments

A number of additional experiments were conducted using the TACT research aircraft as a test-bed. These experiments were as follows:

Base drag - The base drag experiment was conducted on the TACT aircraft in the fuselage closure area between the engines and at the base of the revolution at the top of the vertical fin. This experiment provided valuable information on three-dimensional slopes.

Strip-a-tubing - The evaluation of strip-a-tubing provided a higher level of confidence in this method of measuring pressures on aircraft. This evaluation was conducted at supersonic speeds and various wing sweeps to provide effectiveness and accuracy data.

Afterbody pressure and boundary layer profiles - Afterbody pressure and boundary layer profiles were obtained to determine the validity of predicting the flow characteristics on the aft fuselage of a full-scale aircraft from wind-tunnel test data by defining areas of agreement and disagreement between the model and the flight vehicle.

Local aerodynamic studies - The local aerodynamics of the TACT aircraft were studied to increase the understanding of the relationship of theoretical and experimental data (that is, wind-tunnel and flight data). Local aerodynamics were not studied on any previous program. These data were used to provide insight into the problem of the complex local aerodynamic effects that are common with high subsonic speeds in aircraft design, reference 19.

CONFIGURATION DEVELOPMENT

An F-111A airplane was chosen as the research aircraft because of its variable wing sweep capability, which made it possible to investigate supercritical wing technology for various wing configurations (that is configurations varying in such parameters as leading edge sweep, effective aspect ratio and thickness ratio) over a wide range of Mach numbers with a single research vehicle. The design constraints allowed no alterations to the existing F-111 wing carry-through structure and only minimal redesign of the fuselage fairing in the wing juncture area. The wing design philosophy allowed maximum transonic maneuverability improvements relative to the conventional F-111A airplane. The wing carry-through structure constraints caused design compromises for the vehicles potential performance improvements, but they in no way compromised the research objectives to demonstrate and investigate supercritical wing technology. The supercritical wing incorporated low speed high lift devices that were typically used on operational aircraft, reference.

AIRCRAFT DESCRIPTION

The TACT F-111A research aircraft (figure 1) is a two-place (side-by-side) fighter aircraft. The supercritical wings were designed and fabricated by the manufacturer of the aircraft, under an Air Force Flight Dynamics Laboratory contract and delivered to the NASA Dryden Flight Research Center (DFRC) where the airplane was modified and supercritical wings were installed. The thrust is provided by two TF30-P-3 axial flow, dual compressor turbofan engines equipped with fully modulating afterburners. The most unique feature of the F-111 series of airplanes is the variable geometry wings. The supercritical wings, which are also variable geometry, are equipped with leading edge Krueger flaps and trailing edge Fowler single-slotted flaps and can be varied in wing sweep, area, and aspect ratio by the selection of any wing sweep between 10° and 58° (figure 2). The physical characteristics of the F-111A and TACT F-111A aircraft are given in table 1.

A forward wing sweep provides the capability for low-speed takeoffs and landings. For these flight regimes the wings are manually swept to the desired angle, which is chosen based on the airspeed, altitude, gross weight configuration, and loading of the airplane.

The cockpit was not modified significantly from that of a standard F-111A airplane. The only changes were the removal of systems that were not necessary for research flights and the addition of several instruments that were necessary for data acquisition.

Unlike the basic F-111A airplane, the TACT F-111A airplane had no wing fuel available. The wings were designed to carry fuel but were not capable of holding fuel during the flight tests, due to the instrumentation in the wings. Therefore, the maximum fuel capacity of the TACT F-111A aircraft was 12,150.0 Kg (27,000 lbs) as compared to 14,400 Kg (32,000 lbs) for the basic F-111A aircraft.

The TACT airplane was designed to fly the same operating envelope as the basic F-111A airplane. The flight envelope is illustrated in figure 3. The airplane was designed with a wide range of performance capability, including Mach 2.2 at 12368.0 M (40,000 ft) and M 1.2 at sea level, with a 7.33 g maneuver capability. The TACT wing was designed for three flight conditions, Mach 0.9 at an altitude of 3090 M (10,000 ft), a wing sweep of 26° and a normal acceleration of 5 g for maneuverability; Mach 0.85 at an altitude of 10815.0 M (35,000 ft) and a wing sweep of 26° cruise; and low-speed takeoff and landings using high lift devices. The airplanes normal flight-test weight ranged from 24,400 Kg (54,000 lbs) when empty to 36,500 Kg (81,000 lbs) when full of fuel.

RESEARCH INSTRUMENTATION

DFRC provided all the research instrumentation except the high frequency pressure transducers which were furnished by the NASA Ames Research Center. The instrumentation provided by DFRC included sensors, wiring, connectors, signal conditioning electronics, recording equipment, telemetry system, tuft cameras, boundary layer probes, wake rakes, and other associated equipment as required. The entire flight-test instrumentation system used during flight tests on the baseline and supercritical wing aircraft was installed and maintained by DFRC.

The flight instrumentation system incorporated a CT-77B flexible airborne pulse code modulation (PCM) system, which is a hard-wired programmable unit capable of multi-plexing 80 channels at a frame rate of 200 frames per second, connecting these channels to a 10-bit (1024-count resolution) digital word at a sampling rate of 200 samples per second. Three of these channels were used for frame synchronization. Four subcommutators were used in conjunction with the prime commutator for the supercritical wing flight tests, whereas only two subcommutators were used during the baseline flight-test program. The subcommutator channels were systematically substituted for the prime commutator channels. The resulting sampling rate for the TACT subcommutators was 20 samples per second. Each subcommutator utilized 8 prime commutator channels. Overall, about 400 parameters of data were recorded on each TACT flight.

During flight, the data from the aircraft instrumentation system were transmitted to the ground receiving station at DFRC by the "L" band UHF transmitter. This 5-watt unit operated at the DFRC assigned frequency of 1441.5 MHz. In addition, a general purpose airborne instrumentation recording system was installed in the airplane to record all the instrumentation parameters on the airplane. A constant bandwidth FM recorder system was used to record high frequency pressure data. Recorder operation during flight was controlled by the pilot; normally the recorders were in operation only during test maneuvers.

The flight-test wing pressure instrumentation was located on the right wing, as shown in figure 4. During the manufacture of the supercritical wing, the contractor made provisions for mounting the pressure sensors, accelerometers, and control position transducers (CPT's) in the wing. In addition the contractor installed all pressure system plumbing and instrumentation wiring to the wing root. NASA and

Air Force technicians installed flight tests and proof test strain-gage instrumentation in the left wing at the contractor's facility. Table 2 is a list of all the instrumentation installed on the TACT aircraft along with ranges and sensitivities.

The airspeed system calibration used in the correction of all air data quantities was obtained using a modified MA-I pitot-static probe mounted ahead of the aircraft on the nose boom (figure 5). The airspeed calibration curves were used to compute true values from the indicated Mach number, indicated static pressure, and indicated altitude. True Mach number ($M_\infty = M' + \Delta M$) has been determined to have an uncertainty of ±0.005.

The altitude calibration between 3048 meter (10,000 ft) and 15,250 meter (50,000 ft) indicated a maximum deviation of -12.2 meters (-40 ft) from the original laboratory calibration that was used in the data reduction process.

Over a pressure range of 7,650 Newton/meter^2 (160 lbs/ft^2) to 57,400 Newton/meter^2 (1198 lbs/ft^2), the altitude and airspeed pressure sensors showed deviations of no more than ±14.35 Newton/meter^2 (±3.0 lb/ft^2).

The angle-of-attack calibration accounted for upwash and the fuselage bending correction to the vane angle-of-attack from flight data. The accuracies were found to be a nominal ±0.25° as determined from the onboard instrumentation and equations. The instrumentation included the pitot-static pressure system, the flow direction sensor, the inertial platform, an instantaneous vertical speed indicator (IVSI), and three longitudinal accelerometers.

The flight path accelerometer (fpa) system was used to obtain an instantaneous measurement of the aircrafts acceleration with respect to the flight air mass. The information, along with the engine performance parameters, was used to obtain the excess thrust characteristics of the aircraft. The acceleration vectors parallel and perpendicular to the flight path were determined by using the inertial platform, thus determining the angle-of-attack of the aircraft. The fpa was capable of measuring the magnitude of acceleration along and perpendicular to the flight path within ±0.001 g, over the range of ±1.0 g along the flight path, and -1.0 g to +7.0 g perpendicular to it provided the proper temperature corrections are taken (reference 20).

REFERENCES

1. Ayers, T.G., and Hallissy, J.B.: Historical Background and Design Evaluation of the TACT Supercritical Wing, Symposium on Transonic Aircraft Technology Paper, August 15, 16, and 17, 1978.

2. Mechtley, E.A.: The International System of Units - Physical Constants and Conversion Factors. Second Revision. NASA SP-7012, 1973.

3. Daugherty, J.C.: Techniques and Procedures Used for Wind-Tunnel Tests in Support of the TACT Correlation Program, Symposium on Transonic Aircraft Technology Paper, August 15, 16 and 17, 1978.

4. Mercer, C.E.: Wind Tunnel-Derived Propulsion Performance Corrections Applicable to the TACT Aircraft, Symposium on Transonic Aircraft Technology Paper, August 15, 16 and 17, 1978.

5. Cooper, J.M., Jr., Rawlings, K., III, and Hughes, D.C.: Flight-Test Lift and Drag Data Methods and Results, Symposium on Transonic Aircraft Technology Paper, August 15, 16 and 17, 1978.

6. Baldwin, W., and Burnett D.: Flight Demonstration of the TACT Supercritical Wing and Correlation with Wind-Tunnel Results, Symposium on Transonic Aircraft Technology Paper, August 15, 16 and 17, 1978.

7. Cooper, James M., Jr., Hughes, Donald L., and Rawlings, Kenneth III: Transonic Aircraft Technology-Flight Derived Lift and Drag Characteristics, Volume I and II. AFFTC Report, AFFTC-TR-77-12, July 1977.

8. Pyle, J.S.: Wing Surface-Static Pressures and Loads Obtained from Flight Measurements on the Transonic Aircraft (TACT) F-111 Airplane, Symposium on Transonic Aircraft Technology Paper, August 15, 16 and 17, 1978.

9. Kinsey, D.W.: Flight-Wind-Tunnel Correlation of Static Pressures, Symposium on Transonic Aircraft Technology Paper, August 15, 16 and 17, 1978.

10. Monaghan, Richard C.: Flight Measured Buffet Characteristics of a Supercritical Wing and a Conventional Wing on a Variable-Sweep Airplane, NASA Technical Paper 1244, May 1978.

11. Monaghan, R.C.: Flight Measured Buffet Characteristics, Symposium on Transonic Aircraft Technology Paper, August 15, 16 and 17, 1978.

12. Coe, C.F., and Riddle, D.W.: Buffet Pressures and Forces Measured on the F-111 TACT 1/6-Scale Models and Aircraft, Symposium on Transonic Aircraft Technology Paper, August 15, 16 and 17, 1978.

13. Butler, G.F., and Spavins, G.R.: Wind-Tunnel/Flight-Comparisons of the Level of Buffeting Response Intensity for the TACT F-111 Aircraft, Symposium on Transonic Aircraft Technology Paper, August 15, 16 and 17, 1978.

14. Flying Qualities of Piloted Airplanes. Military Specification MIL-F-8785B (ASG), August 7, 1969.

15. Lash, S., and Sim, A.G.: F-111/TACT Stability and Control Characteristics, Flight, Tunnel and Analytical, Symposium on Transonic Aircraft Technology Paper, August 15, 16 and 17, 1978.

16. Yeager, R.B.: A Comparison of F-111 TACT Estimates and Measured Flying Qualities, Symposium on Transonic Aircraft Technology Paper, August 15, 16 and 17, 1978.

17. Hellmann, G.K.: A Comparison of Estimates and Wind-Tunnel Measured Stability and Control Data for the F-111/TACT, Symposium on Transonic Aircraft Technology Paper, August 15, 16 and 17, 1978.

18. Sakamoto, G.M., and Friend, E.L.: Flight Evaluation of the Transonic Maneuverability Characteristics of the F-111 TACT and F-111A Airplanes, Symposium on Transonic Aircraft Technology Paper, August 15, 16 and 17, 1978.

19. Lux, D.P., and Banner, R.D.: In-Flight Three-Dimensional Boundary-Layer and Wake Measurement from the F-111 TACT Airplane, Symposium on Transonic Aircraft Technology Paper, August 15, 16 and 17, 1978.

20. Final Report Flight Path Accelerometer System AFFTC Report FTC-TR-68-28, December 1968.

TABLE 1. -PHYSICAL CHARACTERISTICS OF THE BASIC F-111A AND F-111A TACT AIRCRAFT

(a) Physical characteristics common to both aircraft

Vertical tail -

Area, M^2 (ft^2)	10.38 (111.7)
Aspect ratio	1.419
Taper ratio	0.411
Sweep at leading edge, deg	0.55
Span, M (in)	2.71 (106.8)
Airfoil section at root	3.2% biconvex
Airfoil section at tip	3.0% biconvex

Rudder -

Area, M^2 (ft^2)	2.72 (29.3)
Span, M^2 (in)	2.43 (95.8)
Root chord, M (in)	1.52 (60.0)
Tip chord, M (in)	0.71 (28.0)
Deflection, maximum, deg	±30.0

Horizontal tail -

Area (exposed), M^2 (ft^2)	16.06 (172.9)
Area (movable, M^2 (ft^2)	14.20 (152.8)
Aspect ratio, M (in)	8.94 (325.0)
Sweep at leading edge, deg	57.5
Root chord (at butt line 1.73 m) (68.2 in)	4.57 (180.1)
Pivot location, fuselage station, M (in)	19.56 (770.25)
Airfoil section (at butt line 1.73M) (68.2 in)	4% biconvex
Airfoil section at tip	3% biconvex
Incidence, deg	1.0
Dihedral, deg	-1.0
Deflection, maximum	
Trailing edge down, deg	15.0
Trailing edge up, deg	30.0

Power plants (two)	TF30-P-3 turbofan engines

Speed brake -

Area (projected planform aft) M^2, (ft^2)	1.58 (17.03)
Deflection, maximum, deg	50.0
Hinge line location, fuselage station, M (in)	12.0 (472.5)

Ventrals, total area, M^2 (ft^2)	2.32 (25.0)

TABLE 1 - PHYSICAL CHARACTERISTICS OF THE BASIC F-111A AND F-111A TACT AIRCRAFT

(b) Physical characteristics that vary with aircraft configuration

PARAMETER	BASIC F-111A AIRCRAFT		F-111A TACT AIRCRAFT	
Wing -				
Area ($\Lambda = 16^{\circ}$), M^2 (ft^2)	47.4	(525.0)	56.10	(604.0)
Aspect ratio ($\Lambda = 16^{\circ}$)	7.56		5.83	
Sweep at leading edge, deg	16.0 to 72.5		10.0 to 58.0	
Root chord, M (in)	3.84	(150.9)	4.03	(158.5)
Tip chord, M (in)	1.25	(49.0)	2.18	(9.89)
Thickness ratio at butt line 2.36M (93 in)			9.89	
Airfoil section at pivot	NACA 64A210.68 (modified)		supercritical	
Airfoil section at tip	NACA 64A209.8 (modified leading edge)		supercritical	
Incidence (jig shape)				
Span station 3.15M (1247 in) deg	-3.15		-3.15	
Span station 9.04M (356 in) deg	-6.70		-6.70	
Dihedral, deg	1		0	
Mean aerodynamic chord, M (in)	2.74	(108.5)	3.19	(125.9)
Span ($\Lambda = 16^{\circ}$), M (ft)	19.40	(63.80)	18.04	(59.33)
Leading edge flaps -				
Type	Slat		Krueger	
No. of sections per wing	4		3	
Total area, M^2, (ft^2)	5.50	(59.2)	5.11	(55.0)
Deflection, deg			45	
Inboard (two)	50			
Outboard (two)	45			
Spoilers (two per side) -				
Type	Fowler, double, slotted		Fowler, single slotted	
Total area, M^2, (ft^2)	10.06	(108.2)	12.54	(135.0)
Deflection, maximum, deg	37.5		30.0	

TABLE 2 RESEARCH INSTRUMENTATION

The prime commutator has a sampling rate of 200 samples per second; the subcommutator, of 20 samples per second

(a) Prime Commutator

Parameter	Type of Sensor	Calibrated range	Sensitivity
Airspeed -			
Digital 13-bit parallel	Precision force balance (linear knots)	0 to 514.4 m/s (0 to 1000 knots)	0.063 m/s/count (0.123 knots/count)
Digital total pressure 13-bit parallel	Precision force (linear natural log total pressure)	12989.5 to 241,314.5 natural log n/m^2a (0.69 to 35 ln psia)	0.000388 natural log n/m^2/count (0.000388 natural log psia/count)
Altitude -			
Digital 13-bit parallel	Precision force balance	sea level to 18288.0 m (sea level to 60,000 ft)	3.35 m/count (11.0 ft/count)
Engine Fuel -			
Left engine fuel flow	Flow meter	25.2 to 612.2 kg/hr (580 to 13,500 lb/hr)	0.00059 kg/count (0.013 lb/count)
Left engine total fuel flow	Flow meter	351.0 to 2632.6 kg/hr (7740 to 58,050 lb/hr)	0.0061 kg/count (0.135 lb/count)
Right engine fuel flow	Flow meter	25.2 to 612.2 kg/hr (580 to 13,500 lb/hr)	0.00059 kg/count (0.013 lb/count)
Rt. engine total fuel flow	Flow meter	351.0 to 2632.6 kg/hr (7740 to 58,050 lb/hr)	0.0061 kg/count (0.135 lb/count)
Accelerations -			
Normal, cockpit	Precision force balance linear accelerometer	-3.0 to 6.0 g	0.01 g/count
Normal, cockpit	" " "	-0.52 to 6.0 g	0.01 g/count
Lateral, cockpit	" " "	-1.0 to 1.0 g	0.002 g/count
Normal, right wing tip	" " "	-4.2 to 14.5 g	0.02 g/count
Normal, left wing tip	" " "	-4.2 to 14.5 g	0.02 g/count
Normal, right wing aft-tip	" " "	-9.0 to 15.0 g	0.03 g/count
Right horizontal tail	" " "	-10.0 to 14.0 g	0.05 g/count

TABLE 2 - Continued.

(a) Continued.

Parameter	Type of Sensor	Calibrated range	Sensitivity
Pressures -			
Wing references pressure (backup)	Diaphragm type (monitor backside of wina differential transducer)	0 to 99878.2 Newton/Meter^2 (0 to 2086 lbs/ft^2) absolute	1963 Newton/Meter^2(4.1 lb/ft^2) obsolute/count
Scanivalve #1 pressure	1/2-inch flush diaphragm strain gage sensor	-52668.3 to 49891.2 N/M^2 (-11 00.0 to 1042.0 lb/ft^2)	100.55 N/M^2/count (2.1 lb/ft^2) per count)
Base drag scanivalve #2	" " "	-2824.9 to 26334.1	52.67 N/M^2/count (1.1 lb/ft^2 per count)
Scanivalve, port identification	Digital Code		
Loads -			
Left Wing, Station I,* shear	Strain gages	±711,680.0 Newton (±160,000.0 lbs)	±3.0% error tolerance
Left wing, station I, bending moment	Strain gages	±1,242.771.2 M-N (±11,000,000.0 in-lbs)	±2.0% error tolerance
Left wing, Station I, torque moment	Strain gages	±451916.8 M-N (±4,000,000.0 in-lbs)	±5.0% error tolerance
Right wing, Station I, bending moment	Strain gages	±1,242,771.2 M-N (±11,000,000.0 in-lbs)	±2.0% error tolerance
Right wing, Station I, torque moment	Strain gages	±451916.8 M-N (±4,000,000 in-lbs)	±5.0% error tolerance
Left horizontal stabilizer shear	Strain gage	±311,500 Newton (±70,000 lbs)	±3.0% error tolerance
Left horizontal stabilizer bending moment	Strain gage	±338937.6 M-N (±3,000,000 in-lbs)	±2.0% error tolerance
Left horizontal stabilizer torque moment	Strain gage	±135575.0 M-N (±1,200,000 in-lbs)	±5.0% error tolerance
Right horizontal stabilizer shear	Strain gage	±7908.5 M-N (±70,000 in-lbs)	±3.0% error tolerance

TABLE 2 - Continued.

(a) Continued.

Parameter	Type of Sensor	Calibrated range	Sensitivity
Right horizontal stabilizer bending moment ----------	Strain gage	±338937.6 M-N (±3,000,000 in-lbs)	±2.0% error tolerance
Right horizontal stabilizer torque moment -----------	Strain gage	±135575.0 M-N (±1,200,000 in-lbs)	±5.0% error tolerance
Right wing, station I dynamic moment-----------	Semiconductor " "	±51,980.0 M-N (±460,000 in-lbs)	±10% error tolerance
Left wing, station I dynamic moment-----------	" "	±51,980.0 M-N (±460,000 in-lbs)	±10% error tolerance
Right wing, station I dynamic torsion----------	" "	±35,030.0 M-N (±310,000 in-lbs)	±10% error tolerance
Left wing, station I dynamic torsion----------	" "	±35,030.0 M-N (±310,000 in-lbs)	±10% error tolerance
Left trailing edge flaps #4, Stress---------------	Strain gage	±723,949,800.0 N/M^2 (±105,000 lb/in^2)	±2% error tolerance
Left trailing edge flap #5, Stress---------------	Strain gage	±413,685,600.0 N/M^2 (±60,000 lb/in^2)	±2% error tolerance

*Station I is located a Span Station 2.07 meters (81.5 inches)

TABLE 2 Continued.

(b) Subcommutator No. 1

Parameter	Type of Sensor	Calibrated range	Sensitivity
Angles -			
Angle of attack (sensitive)	Synchro	-5 to 10°	0.02 deg/count
Angle of attack-----------	"	-5 to 24°	0.05 deg/count
Angle of attack-----------	"	-5 to 28.5°	0.06 deg/count
Angle of sideslip---------	"	-5 to 4.7°	0.01 deg/count
Angle of sideslip---------	"	-15 to 15°	0.03 deg/count
Pitch angle (sensitive)	Aircraft computer	-10 to +10°	0.02 deg/count
Pitch angle---------------	" "	-30 to 30°	0.06 deg/count
Roll angle----------------	" "	-70 to 70°	0.11 deg/count
Rates -			
Pitch rate (filtered sensitive)--------------	Precision gyro package	±10 deg/sec	0.02 deg/sec/count
Pitch rate----------------	" " "	±40 deg/sec	0.08 deg/sec/count
Roll rate (sensitive)-----	" " "	±40 deg/sec	0.08 deg/sec/count
Roll rate-----------------	" " "	±200 deg/sec	0.40 deg/sec/count
Yaw rate------------------	" " "	±40 deg/sec	0.08 deg/sec/count
Acceleration -			
Normal, center of gravity (passive)---------------	Precision force balance linear accelerometer	0 to 6.0g	0.006g/count
Lateral, center of gravity (passive)---------------	" " "	±1.0g	0.002g/count
Longitudinal, center of gravity (sensitive)-----	" " "	±0.28g	0.0006g/count
Longitudinal, center of gravity	" " "	±1.0g	0.002g/count
Lateral, center of gravity	" " "	-2.7 to 5.7g	0.008g/count
Longitudinal boom---------	" " "	±0.57g	0.001g/count
Flight path, longitudinal (filtered)--------------	" " "	±0.63g	0.001g/count
Flight path, normal (filtered)--------------	" " "	±6.6g	0.013g/count
Normal, center of gravity (filtered)--------------	" " "	0 to 6.0g	0.006g/count
Longitudinal, flight paths	" " "	±0.25g	0.005g/count
Normal, flight path-------	" " "	±2.0g	0.0035g/count

TABLE 2 Continued.

(b) Continued.

Parameter	Type of Sensor	Calibrated range	Sensitivity
Positions -			
Horizontal stabilizer, right-	Synchro	-31.5 to 15.8°	0.05 deg/count
Horizontal stabilizer, left--	Synchro	-31.0 to 16.0°	0.05 deg/count
Inboard spoiler, right-------	linear potentiometer	0 to 42.4°	0.05 deg/count
Inboard spoiler, left--------	" "	0 to 45.6°	0.05 deg/count
Outboard spoiler, right------	" "	0 to 45.0°	0.05 deg/count
Outboard spoiler, left-------	" "	0 to 43.6°	0.05 deg/count
Rudder----------------------	Synchro	±30°	0.07 deg/count
Trailing edge flap, right----	Potentiometer	0 to 33°	0.035 deg/count
Leading edge flap, right-----	Synchro	0 to 132.9°	0.20 deg/count
Wing sweep------------------	Wire-pull potentiometer	10 to 58°	0.05 deg/count
Longitudinal stick-----------	Synchro	-6 to 10cm (-15.2 to 25.4in)	0.02 cm/count (0.051 in/count)
Lateral stick----------------	Synchro	±5 cm (±12.7 in)	0.01 cm/count (0.025 in/count)
Rudder pedal----------------	Synchro	±Full travel	0.2%/count
Elevator servo--------------	Ship's system	-14 to 13°	0.027 deg/count
Aileron servo---------------	" "	-15.8 to 15.9°	0.03 Deg/count
Rudder servo----------------	" "	-21 to 14°	0.05 Deg/count
Elevator, series trim--------	" "	-14 to 5.1°	0.037 Deg/count
Elevator, parallel trim------	" "	-9 to 15.3°	0.03 deg/count
Aileron trim----------------	" "	-11 to 12.5°	0.1 deg/count
Pitch gain------------------	" "	0 to 100 %	0.32 % gain/count
Roll gain-------------------	" "	0 to 100 %	0.34 % gain/count
Forces -			
Longitudinal stick forces----	Strain gage	±222.5 newton (±50 lbs)	2.23 newton/count (0.5 lb/count)
Lateral stick forces---------	" "	±142.4 newton (±32 lbs)	2.50 newton/count (0.56 lb/count)
Vertical velocity------------	Inertial indicator	±914.4 meter/min (±3000 ft/min)	2.13 meter/min/count (7.0 ft/min/count)
Pressures -			
Wing reference (Prime)	Variable capacitor diaphram	0 to 105,000.0 N/M^2 (0 to 2193 lb/ft^2 absolute)	201.1 N/M^2 absolute/count (4.2 lb/ft^2 absolute/count)
Fuselage base, high range	Strain gage pressure transducer	±10342.14 N/M^2 diff (±1.5 lb/in^2 differential)	20.7 N/M^2 diff/count (0.003 lb/in^2 diff/count)

TABLE 2 Continued.

(b) Continued.

Parameter	Type of Sensor	Calibrated range	Sensitivity
Fin tip base, low range	Strain gage pressure tranducer	$\pm$ 6894.76 N/M^{2}d.ff.($\pm$ 1.0 lb/in^2 differential)	20.7 N/M^2/count (1.1 lb/ft^2/count)
Wing (4 ea supper surface at span station 2.03 M (80 inches)	" " " "	-27,004.3 to 27,291.6 N/M^2 (-564 to 570 lb/Ft^2)	52.7 N/M^2/count (1.1 lb/ft^2/ count)
Body of revolution, pitot probe	" " " "	0 to 68,947.6 N/M^2 diff (0 to 10 lb/in^2 differential)	68.9 N/M^2/count (0.01 lb/in^2/ count)
Fuselage base pressure	Variable capacitor diaphragm Strain gage pressure transducer	$\pm$ 6894.76 N/M^2 ($\pm$ 1.0 lb/in^2)	20.7 N/M^2/count (0.003 lb/in^2 /count)
Base drag reference	Force balance - analog	0 to 105,336.0 N/M^2 absolute (0 to 2200 lb/Ft^2 absolute)	100.5 N/M^2 absolute/count (2.1 lb/Ft^2 absolute/count)
Data package temperature	Resistance element	0 to 200^{0}F	0.2^{0}F/count
Flight path accelerometer	" "	-70 to 230^{0}F	0.56^{0}F/count
Base drag scanivalve temperature	" "	-50 to 200^{0}F	0.2^{0}F/count
Rotating rake position trailing edge	Potentiometer	0 to 359^0	0.44 deg/count
Right engine power lever angle	Synchro	0 to 120^0	0.11 deg/count
Left engine power lever angle	Synchro	0 to 120^0	0.11 deg/count

TABLE 2 Continued.
(b) Continued.

Parameter	Type of Sensor	Calibrated range	Sensitivity
Fuel quantity, forward	Ship's system monitor	0 to 9,080 Kg (0 to 20,000 lbs)	19.1 Kg/count (42.0 lb/count)
Fuel quantity, aft tank	Ship's system monitor	0 to 4,540 Kg (0 to 10,000 lbs)	9.1 Kg/count (20.0 lb/count)
Fuel quantity, total	Ship's system monitor	0 to 14,982 Kg (0 to 33,000 lbs)	33.6 Kg/count (74.0 lb/count)
N_1, right engine rpm	Freq. to D.C. voltage converter	4 to 13000 rpm	25 rpm/count
N_2, right engine rpm	Freq. to D.C. voltage converter	8 to 20,000 rpm	40 rpm/count
N_1, left engine rpm	Freq. to D.C. voltage converter	4 to 13,000 rpm	25 rpm/count
N_2, left engine rpm	Freq. to D.C. voltage converter	6 to 18,000 rpm	37 rpm/count
Left engine total fuel rate	Freq. to D.C. voltage converter	0 to 36,320 Kg/hr (0 to 80,000 lb/hr)	35.4 Kg/hr/count (78 lb/hr/count)
Right engine total fuel rate	Freq. to D.C. voltage converter	0 to 36,320 Kg/hr (0 to 80,000 lb/hr)	35.4 Kg/hr/count (78 lb/hr/count)
Left engine burner static pressure	1/2-in flush diaphram strain gage transducer	137,895.24 to 4136,857.2 N/M^2 (20 to 600 lb/in^2)	6894.8 N/M^2 absolute/count (1.0 lb/in^2 absolute/count)
Right engine burner static pressure	1/2-in flush diaphram strain gage transducer	68,947.6 to 413,857.2 N/M^2 (10 to 600 lb/in^2)	6205.3 N/M^2 absolute/count (0.9 lb/in^2 absolute/count)
Left engine total temperature station 5 (TT5)	Cockpit indicator	0 to1495°C	1.5°C/count
Right engine total temperature station 5 (TT5)	Cockpit indicator	0 to 1475°C	1.4°C/count

TABLE 2 Continued.

(c) Sub commutator no. 2

Parameter	Type of Sensor	Calibrated range	Sensitivity
Left engine fuel temperature	Resistantance temperature probe	253 to 339°K	0.1°K/count
Left engine total fuel temperature	Resistantance temperature probe	259 to 334°K	0.09°K/count
Propulsion static pressure	1/2-inch flush diaphram pressure transducer	-6205. to 103421.4 N/M^2(0.9 to 15.0 lb/in^2) absolute	103.4 N/M^2/count(0.015 lb/in^2 count) absolute
Right Nozzle base 20°	" " "	±27.579.0 N/M^2 differential (±4.0 psid)	55.2 N/M^2 diff/count(0.008 psid/count)
Right Nozzle base 140°	" " "	±27,579.0 N/M^2 differential (±4.0 psid)	48.3 N/M^2 diff/count(0.007 psid/count)
Right Nozzle base 260°	" " "	±28,958.0 N/M^2 differential (±4.2 psid)	62.1 N/M^2 diff/count(0.009 psid/count)
Left int. sec. noz. sta. 90°	" " "	±24,821.1 N/M^2 differential (±3.6 psid)	55.2 N/M^2 diff/count(0.008 psid/count)
Left sec. noz. sta. 210°	" " "	±27,579.0 N/M^2 differential (±4.0 psid)	55.2 N/M^2 diff/count(0.009 psid/count)
Left sec. noz. sta. 330°	" " "	±30,336.9 N/M^2 differential (±4.4 psid)	62.1 N/M^2 diff/count(0.009 psid/count)
Left Nozzle base 100°	" " "	±27,579.0 N/M^2 differential (±4.0 psid)	55.2 N/M^2 diff/count(0.008 psid/count)
Left Nozzle base 220°	" " "	±28,958.0 N/M^2 differential (±4.2 psid)	62.1 N/M^2 diff/count(0.009 psid/count)
Left Nozzle base 340°	" " "	±27,579.0 N/M^2 differential (±4.0 psid)	55.2 N/M^2 diff/count(0.008 psid/count)

TABLE 2 Continued.
(c) Sub commutator no.2

Parameter	Type of sensor	Calibrated range	Sensitivity
Right engine nozzle area	Potentiometer on linkage	0.328 to 0.665 M^2(508.4 to 1030.8 in^2)	0.0004 M^2/count(0.62 in^2/count
Left engine nozzle area	" " "	0.346 to 0.659 M^2 (536.3 to 1021.5 in^2)	0.0004 M^2/count(0.62 in^2/count
Secondary air static 100°	Strain gage pressure transducer	-79289.7 to 81358.2 N/M^2 (-11.5 to 11.8 psid)	206.8 N/M^2/count(0.03 psid/count)
Secondary air static 220°	" " "	$\pm$ 73084.5 N/M^2 ($\pm$ 10.6psid)	206.8 N/M^2/count(0.03 psid/count)
Secondary air static 340°	" " "	- 71705.5 to 68671.8 N/M^2 (-10.4 to 9.96 psid)	137.9 N/M^2/count(0.02 psid/count)
Kidney exit static 58° 55'	" " "	- 78600.3 tp 73084.5 N/M^2 (-11.4 tp 10.6 psid)	206.8 N/M^2/count(0.03 psid/count)
Kidney exit total 61° 45'	" " "	0 to 137895.2 N/M^2 (0 to 20 psia)	206.8 N/M^2/count(0.03 psid/count)
Kidney exit static 83° 55'	" " "	$\pm$ 68947.6 N/M^2 ($\pm$ 10 psid)	206.8 N/M^2/count(0.03 psid/count)
Kidney exit total 86° 45'	" " "	0 to 137895.2 N/M^2 (0 to 20 psia)	206.8 N/M^2/count(0.03 psid/count)
Kidney exit total static 114° 10'	" " "	$\pm$68947.6 N/M^2 ($\pm$ 10 psid)	206.8 N/M^2/count(0.03 psid/count)
Kidney exit total 117° 0'	" " "	0 to 137895.2 N/M^2 (0 to 20 psia)	275.8N/M^2/count (0.04 psia/count)
Kidney exit static 254° 25'	" " "	$\pm$68947.6 N/M^2 ($\pm$10 psid)	206.8 N/M^2/count (0.03 psid/count)
Kidney exit total 297° 15'	" " "	0 to 137895.2 (0 to 20 psia)	206.8 N/M^2/count (0.03 psid/count)
Kiel probe 100°	" " "	0 to 137895.2 N/M^2 (0 to 20 psia)	206.8 N/M^2/count (0.03 psia/count)
Kiel probe 220°	" " "	0 to 137895.2 N/M^2 (0 to 20 psia)	206.8 N/M^2/count (0.03 psia/count)
Kiel probe 340°	" " "	0 to 137895.2 N/M^2 (0 to 20 psia)	206.8 N/M^2/count (0.03 psia/count)

TABLE 2 Continued.
(c') Sub cummutator no.2

Parameter	Type of sensor	Calibrated range	Sensitivity
Left vent exit total 100°	Strain gage pressure transducer	±25510.6 N/M^2 (±3.7 psia)	55.2 N/M^2/count (0.008 psid/count)
Left vent exit total 220°	" " "	-28475.4 to 27579.0 N/M^6 (-4.13 to 4.0 psid)	55.2 N/M^2/count (0.008 psid/count)
Left vent exit total 340°	" " "	±27579.0 N/M^2(±4.0 psid)	137.9 N/M^2 count (0.02 psid/count)
Left engine P_t7	" " "	0 to 137895.2 N/M^2 (0 to 20 psid)	137.9 N/M^2 count (0.02 psid/count)
Right engine P_t7	" " "	0 to 137895.2 N/M^2 (0 to 20 psid)	137.9 N/M^2 count (0.02 psid/count)
Left engine hub. P_t2	" " "	±34473.8 N/M^2 (±5.0 psid)	68.9 N/M^2 count (0.01 psid/count)
Right engine hub. P_t2	" " "	±34473.8 N/M^2 (±5.0 psid)	68.9 N/M^2 count (0.01 psid/count)
Propulsion reference pressure	Precision variable capacitor diaphram type	0 to 137895.2 N/M^2 (0 to 20 psia)	206.8 N/M^2 count (0.03 psia/count)
Total temperature	Variable resistance temperature probe	-50 to 180° C	0.3° C/count
Left overwing fairing Position	Cable pull control position transducer	2.54 to 35.6CM (1 to 14 in.)	0.14 cm/count (0.055 in/count)
Right overwing fairing position	Cable pull control position transducer	2.54 to 33.02 CM (1 to 13 in.)	0.10 CM/count (0.04 in/count)
Right pivot plate stress (12 ea.)	STRAIN GAGE	±489,527,960.0 to ±1,034,214,000.0 N/M^2 (71x10^3 to 150x10^3 psi)	±2.0 %
Right horz. stab. shear	" "	±311,500 Newton (±70x10^3 lbs)	±3.0 %
Left horz. stab. shear	" "	±311,500 Newton (70x10^3 lbs)	±3.0 %

TABLE 2 Continued.

(c) Sub cummutator no. 2

Parameter	Type of sensor	Calibrated range	Sensitivity
Left wing pivot shear	STRAIN GAGF	±694.200 Newton (156×10^3 lbs)	±3.0 %
Left wing pivot bend moment	" "	±2034 M-N ($\pm 18 \times 10^6$ in-lb)	±2.0 %
Left wing pivot torque	" "	±1695 M-N ($\pm 15 \times 10^6$ in-lb)	±5.0 %

(d) Sub commutator no. 3

Parameter	Type of sensor	Calibrated range	Sensitivity
79 Static pressure sensors from right wing surface	Strain gage pressure transducers	±24,131.7 N/M^2 (±3.5 psi), 34,473.8 (±5.0 psi) ±48.263.3 N/M^2 (±7.0 psi) and 68.947.6 N/M^2(±10 psi)	71.8 N/M^2/count (0.0104 psi/count) to 153.2 N/M^2/count (0.0225 psi/count)

(e) Sub cummutator no. 4

Parameter	Type of sensor	Calibrated range	Sensitivity
79 Static pressure sensor from right wing	Strain gage pressure transducers	±24,131.7 N/M^2 (±3.5 psi) 34,473.8 (±5.0 psi) ±48,263.3 N/M^2 (±7.0 psi) & 68,947.6 N/M^2(±10 psi)	71.8 N/M^2/count (0.0104 psi/count) to 153.2 N/M^2/ count (0.0225 psi/count)

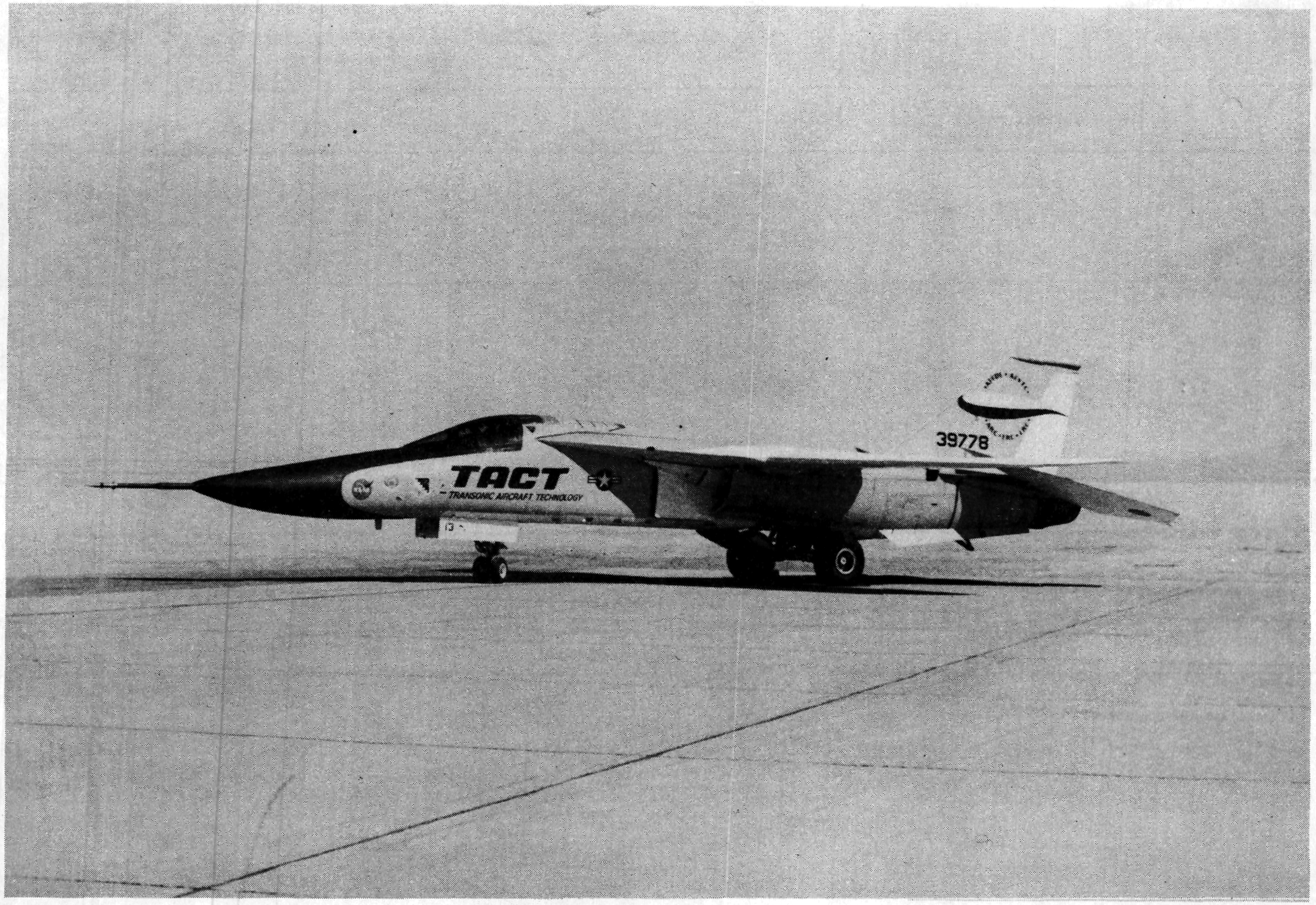

Figure 1(a) Photograph of the F-111A TACT airplane.

Figure 1(b) Photograph of the F-111A TACT airplane in flight with external stores.

WING PARAMETER	BASIC	TACT
Area, M^2(+2)	56(604)	48.6(525)
Mean aerodynamic chord, cm(in.)	319.5(125.8)	275.6(108.5)
Aspect ratio	5.83	7.56

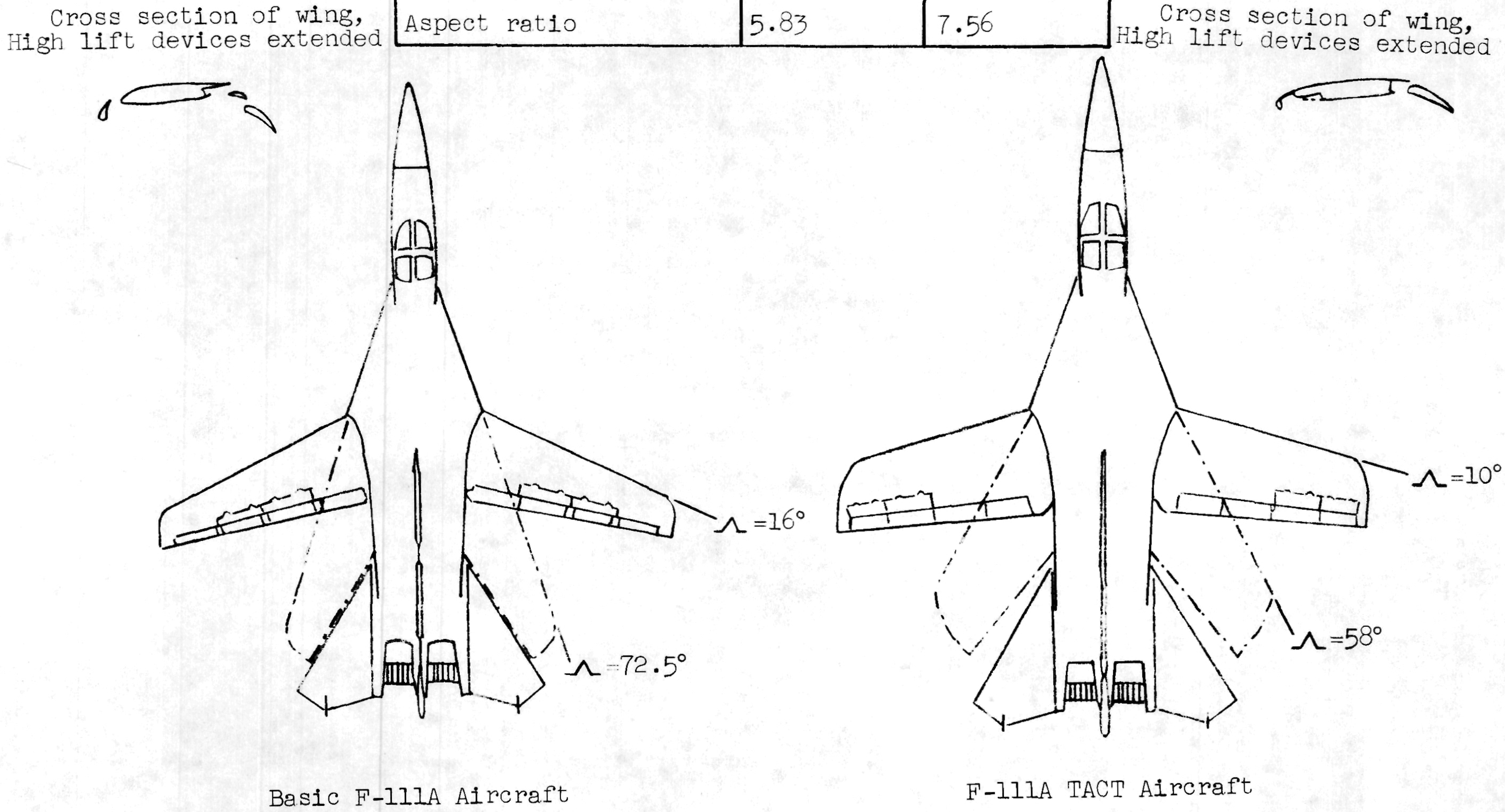

Figure 2.- Comparison of basic F-111A and TACT F-111A aircraft

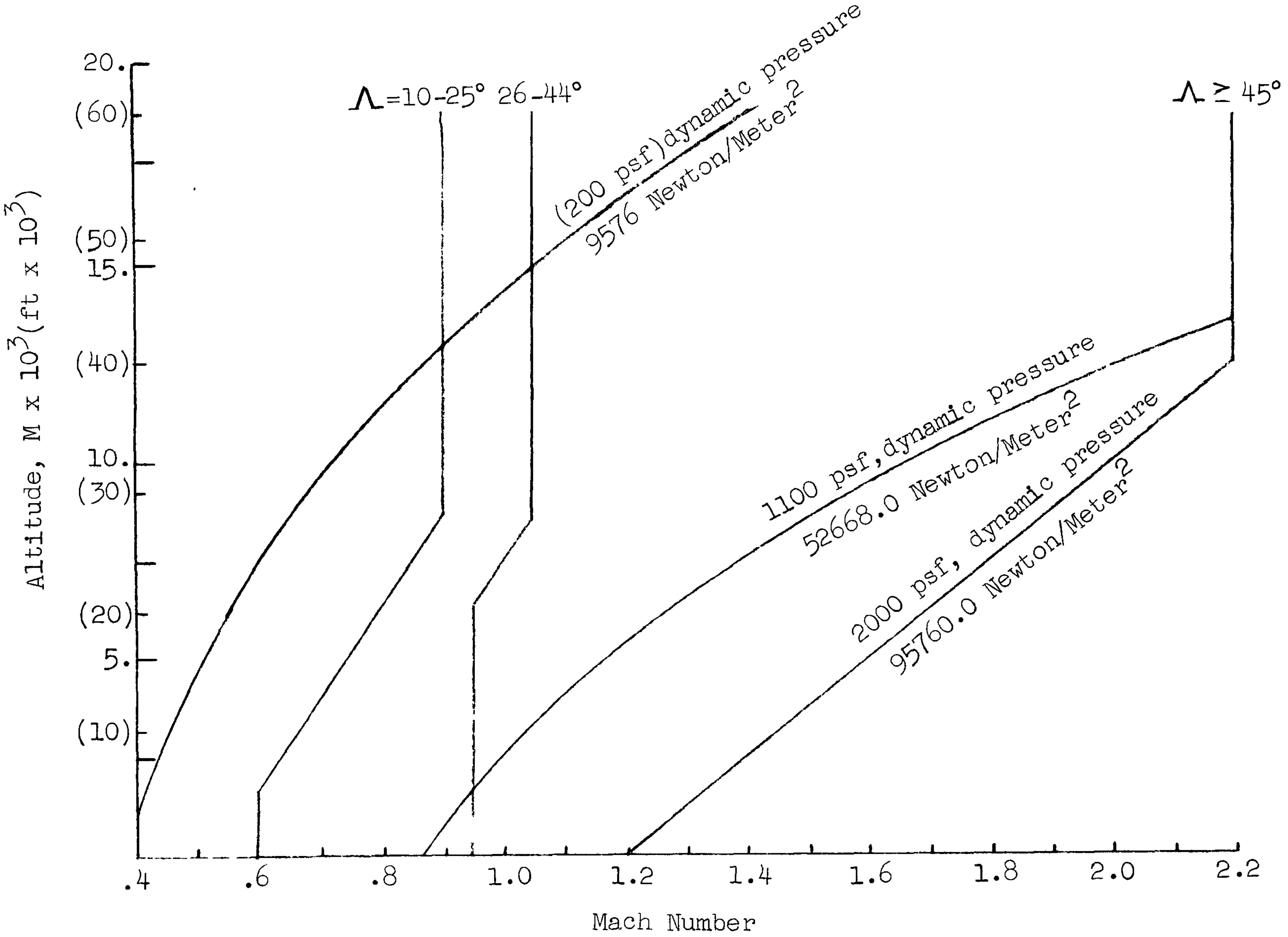

Figure 3. Flight envelope for TACT F-111A aircraft

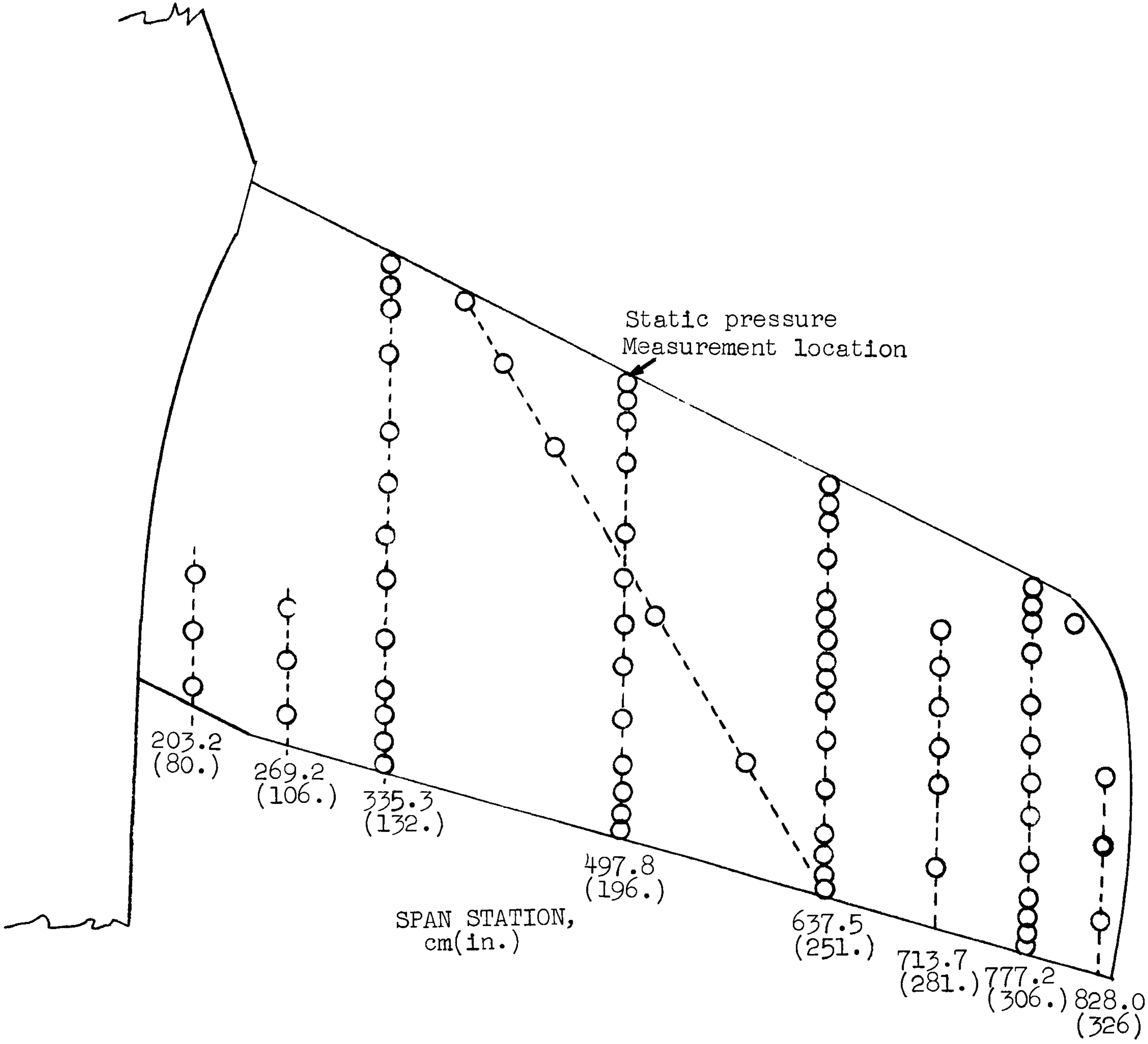

Figure 4. Wing pressure orifice locations

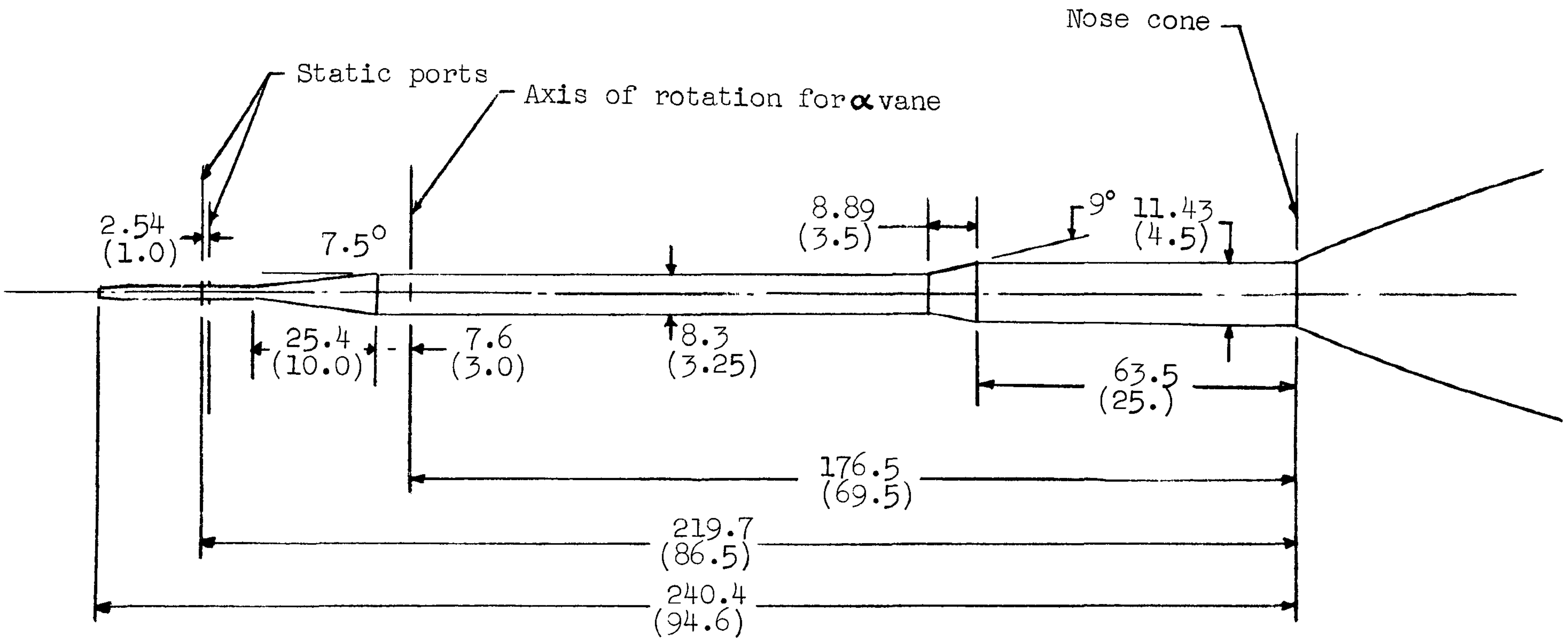

Figure 5. Pitot probe and nose boom installation for the F-111A TACT aircraft. Dimensions are in centimeters (inches).

1 Report No NASA TM-56048	2 Government Accession No	3 Recipient's Catalog No

4 Title and Subtitle DESIGN AND PHYSICAL CHARACTERISTICS OF THE TRANSONIC AIRCRAFT TECHNOLOGY (TACT) RESEARCH AIRCRAFT	5 Report Date January 1979 6 Performing Organization Code H-976
7 Author(s) Weneth D. Painter and Lawrence J. Caw	8 Performing Organization Report No
9 Performing Organization Name and Address NASA Dryden Flight Research Center P O Box 273 Edwards, California 93523	10 Work Unit No 505-11-44 11 Contract or Grant No
12 Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D. C. 20546	13 Type of Report and Period Covered Technical Memorandum 14 Sponsoring Agency Code

15 Supplementary Notes

16 Abstract

The supercritical wing offered potential for improved transonic aerodynamic benefits. The Transonic Aircraft Technology (TACT) Program evaluated the transonic maneuverability of the supercritical wing. The full-scale flight demonstration of this wing was necessary to resolve uncertainties and pave the way for further application of these technologies.

17 Key Words (Suggested by Author(s)) Supercritical wing Flight test techniques Wind tunnel to flight correlation In-flight wing pressure distribution Flight measured lift and drag values	18 Distribution Statement Unclassified—Unlimited STAR category: 02

19 Security Classif (of this report) Unclassified	20 Security Classif (of this page) Unclassified	21 No of Pages 33	22 Price* $3.75

*For sale by the National Technical Information Service, Springfield, Virginia 22161