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Flight Investigation of the Use of a Nose Gear Jump Strut to Reduce Takeoff Ground Roll Distance of STOL Aircraft

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WRIGHT LABORATORY

Preface

The purpose of the jump strut research program was to increase the general knowledge and obtain data on the sudden extension of an aircraft nose gear to reduce the takeoff ground roll distance. The use of stored energy applied to the landing gear oleo strut, termed a "jump strut," to reduce the takeoff roll of the X-29A has been the subject of analytical studies by the Grumman Aircraft Company under contract to the U.S. Air Force Wright Laboratory. The conclusion of this effort in 1983 was that the benefits were large and that the hardware mechanization was simple. These findings fostered additional design and experimental work that culminated in the subject flight investigation. This experiment is a joint effort between the U.S. Air Force Wright Laboratory and the NASA Ames Research Center.

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Nomenclature and Terminology

ALPHA	Angle of attack, degrees
C	Corrected data
CNTR	Data point (counter) number, nondimensional (n.d.)
ELEV	Elevator position, degrees
ENGV	Jump strut control valve activation, n.d.
Initial Pv	Jump strut pneumatic reservoir pressure, psig
JS	Jump strut assisted takeoff
K	Correction factor for runway component of wind to takeoff ground roll distance (ref. 5) , corrected distance = K * (uncorrected distance), n.d.
MAIN LG	Main landing gear strut position, 0 = fully extended, inches
NJS	Unassisted takeoff (no jump strut)
PITCHR	Pitch rate, degrees/second
Pa	Ambient atmospheric pressure, psi
RPM AVG	Engine fan speed, average of four engines during ground roll, RPM
S	Wing Area (S = 600 ft^2 for QSRA), ft^2
STRUT	Nose gear strut position, 0 = fully extended, inches
T valve	Duration of jump strut control valve opening , msec
Target T/W	Planned T/W for data point, n.d.
TEMPC	Ambient atmospheric temperature, degrees celsius
THETA	Pitch attitude, degrees
T/W	Thrust to weight ratio = (total static thrust corrected for ambient conditions and RPM.AVG) / (takeoff gross weight), n.d.
U	Uncorrected, measured data
VCAIRK	QSRA nose boom pitot-static calibrated airspeed, knots
Vcorr	Airspeed corrected for position error, knots
LOAD	Nose gear load, lb
W	Aircraft gross weight at takeoff brake release, lb
W/S	Wing loading = W / (Wing Area), lb/ft^2
Wind	Runway component of wind, Wind = Vcorr – ground speed determined from laser tracker, knots – (tail wind) + (head wind)
X	Distance along runway from point of brake release, ft
Delta X	Correction to measured takeoff distance for T/W variation from target (i.e.: Target T/W – T/W), Corrected takeoff distance = X – (Delta X), feet

Takeoff Distance (ft) Column Heading Code used in Appendix C: a,b,c,d,e,f

a: C = Corrected data
U = Uncorrected data

b: JS = Jump strut assisted takeoff
NJS = Unassisted takeoff (no jump strut)

c: Thrust to Weight ratio (Range: 0.3–0.45)

d*: Initial reservoir pressure/1000, psig (Range: 2–3)

2K = 2000 psig

2.5K = 2500 psig

3K = 3000 psig

e*: Valve timer setting

5 = 80 msec valve open time

8 = 130 msec valve open time

10 = 170 msec valve open time

f*: Wing loading, lb/ft^2 (Range: 77–88)

Examples: C,JS,.4,2.5K, 5 indicates - Corrected data, jumpstrut takeoff, 0.4 T/W, 2500 psig reservoir pressure, 80 msec valve open time

U,NJS,.3,77 indicates - Uncorrected data, unassisted takeoff, 0.3 T/W, 77 lb/ft^2 wing loading

Note: As illustrated in above examples, coding may not include all notation items indicated by "*".

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Summary

A series of flight tests was conducted to evaluate the reduction of takeoff ground roll distance obtainable from a rapid extension of the nose gear strut. The NASA Quiet Short-haul Research Aircraft (QSRA) used for this investigation is a transport-size short takeoff and landing (STOL) research vehicle with a slightly swept wing that employs the upper surface blowing (USB) concept to attain the high lift levels required for its low speed, short-field performance. Minor modifications to the conventional nose gear assembly and the addition of a high pressure pneumatic system and a control system provided the extendible nose gear, or "jump strut," capability. The limited flight test program explored the effects of thrust-to-weight ratio, wing loading, storage tank initial pressure, and control valve open time duration on the ground roll distance. The data show that the predicted reduction of takeoff ground roll on the order of 10% was achieved with the use of the jump strut as predicted. Takeoff performance with the jump strut within the range of the parameters examined was also found to be essentially independent of the pneumatic supply pressure and was only slightly affected by control valve open time.

1. Introduction

The minimum takeoff ground roll distance of conventional- and short-takeoff aircraft is influenced by (among other factors) the horizontal tail's effectiveness in rotating to a liftoff pitch attitude at the minimum controllable airspeed. For some configurations, particularly high thrust-line types, the pitch-up tail moment commanded by the pilot is countered by the moment due to engine thrust.

Beginning in 1982, the Flight Dynamic Laboratory of the U.S. Air Force Wright Laboratory investigated a possible approach for reducing the ground roll which involved the use of a pneumatically extendible nose gear, referred to as the jump strut. This joint industry/Department of Defense (DoD) effort resulted in the development of a F-16 jump strut nose gear which was ground tested at Wright Laboratory. In 1985 a T-38 aircraft with a nose gear jump strut was ground-run tested at the Naval Air Test Center, Patuxent River, Maryland. This test provided a database for a subsequent analytical simulation which predicted that a substantial reduction of the takeoff distance of tactical aircraft could be obtained (ref. 1). Wright Laboratory also participated in the Advanced Transport Technology Mission Analysis assessment studies (ref. 2) which showed that the nose wheel jump strut, when used as a rotational aid, produced a significant improvement in takeoff performance for some of the transport aircraft configurations evaluated.

In 1987 a study by Lockheed, Burbank, (ref. 3), funded jointly by Wright Laboratory and NASA Ames Research Center, investigated the takeoff benefits of the jump strut applied to the NASA Quiet Short-Haul Research Aircraft (QSRA) and concluded that, at a thrust to weight ratio of 0.4, reductions of 10–12% of takeoff distance were possible with a two-stage pneumatic jump strut. The QSRA (fig. 1) is a slightly swept high-wing transport-size short takeoff and landing (STOL) research vehicle that employs upper surface blowing (USB) to achieve unusually high lift levels for its low speed capabilities and short-field takeoff and landing performance (ref. 4). The demonstrated low-speed stability of the QSRA makes it an excellent flight test facility to explore the effect of the jump strut on STOL aircraft takeoff performance. Furthermore, the QSRA is an interesting choice for this investigation because the USB presents an adverse nose-down pitching moment due to the high thrust line which diminishes the pitch-up rate during takeoff, thereby increasing the minimum liftoff speed. Authorization to proceed with the experiment was granted in 1989 upon the issuance of a NASA/U.S. Air Force Memorandum of Understanding (MOU) which defined the objective to flight-demonstrate a nose jump strut system on NASA's Quiet Short-Haul Research Aircraft.

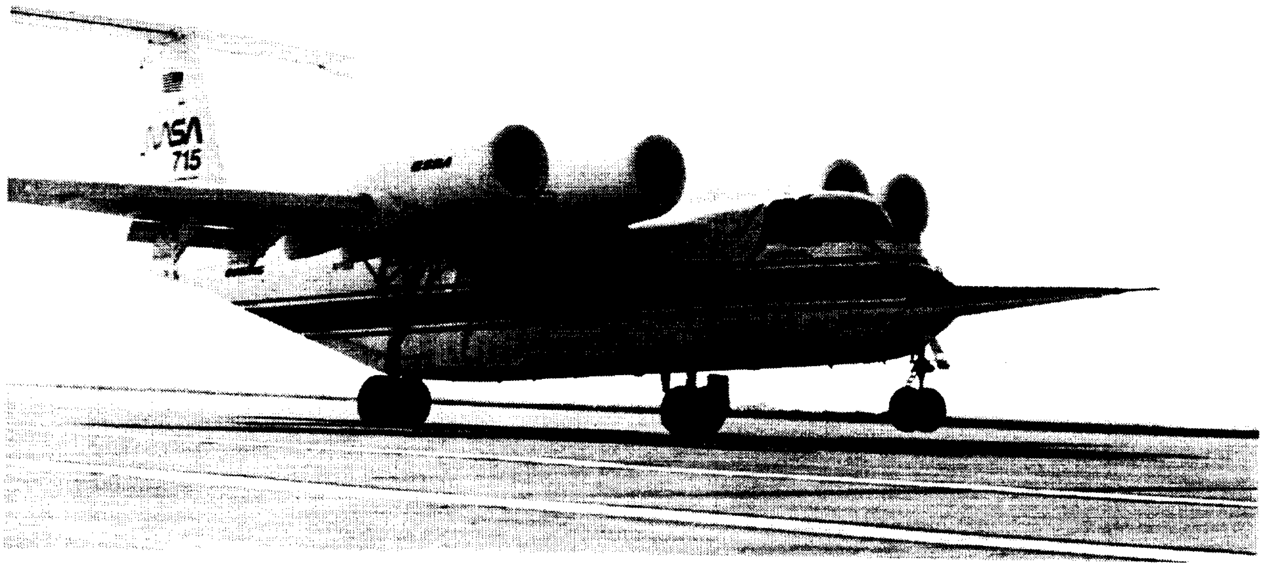


Figure 1. QSRA in the takeoff configuration.

The authors thank the QSRA Flight Test Team for their assistance and suggestions in conducting this experiment. We are particularly indebted to the support of Bill Hindson, Test Pilot, and to the ground crew: Richard Young, Crew Chief, Dave Walton, Inspector, John Lewis, Instrumentation Engineer, Benny Cheung, Electronic Systems Engineer, and Marty Maisel, Acting Chief, Flight Experiments Branch at NASA Ames Research Center. A special thank you is given to William Luce, Menasco Aerosystems Division for the development of the jump strut hardware and to J. Greer McClain, U.S. Air Force Wright Laboratory for conducting the dynamic validation tests.

2. Approach

Project management of the QSRA/Jump Strut investigation was assigned to Ames Research Center, Moffett Field, California. NASA provided technical direction, contract monitoring, the QSRA aircraft, the engineering and technical staff, and the operations infrastructure required for the development and test of the flight hardware. The U.S. Air Force was responsible for technical coordination with NASA, contract funding, and landing gear assembly laboratory performance testing. The Air Force also shared in the costs of the flight test.

Modifications to the QSRA included replacing the original nose gear with a jump strut nose gear, and installing a pressure reservoir, a pneumatic system, a control system, and the required instrumentation. A Failure Modes and Effects Analysis was performed to ensure safe operation. A summary of the key findings is presented in appendix A.

A nonserviceable QSRA nose gear was restored to flightworthy condition and modified by Menasco Industries to provide the jump strut, or pneumatic extension capability. The reworked nose gear represented a low cost, low complexity system which operates as a normal nose gear after its use as a jump strut. Preliminary functional tests were performed by Menasco, and gear validation tests were conducted at Wright Laboratory.

After installation of the jump strut system on the QSRA a series of static tests was conducted to verify the performance of the electrical and pneumatic systems and to calibrate the new instrumentation. Following these static tests, the flight program was initiated. The first phase of flight testing performed at NAS Moffett Field, California, focused on operational (piloting) techniques. The subsequent data-flight tests were conducted at NALF Crows Landing, California.

3. Test Objectives

The primary goal of this program is to experimentally determine the effect of using a nose gear jump strut on takeoff ground roll distance. Associated with this overall objective the following specific objectives were targeted:

- Determine the influence of jump strut parameters (initial pneumatic reservoir pressure and valve-open time) on takeoff ground roll distance.

- Determine the influence of aircraft parameters (thrust/weight and wing loading) on jump strut ground roll distance.
- Experimentally verify the reduction of takeoff ground roll distances predicted by the Lockheed study (ref. 3).
- Evaluate jump strut system performance, loads, and service operations.
- Determine the repeatability of jump strut ground roll distance.
- Identify areas for further study.

4. Instrumentation

The instrumentation installed in the QSRA before this project was developed specifically to document the aircraft state, operating conditions, and control positions and forces for flight investigations in the terminal area flight regime. Several parameters were added to this existing QSRA instrumentation list to satisfy the requirements of this project.

Data from the transducers are transmitted to a remote multiplexer/digitizer unit (RMDU) which provides signal conditioning for the transducer, converts the analog data to digital form and encodes the data into a pulse code modulation (PCM) serial bit stream. Approximately 130 QSRA parameters are sampled at 100 samples/second and an additional 18 parameters are acquired at 20 samples/second. The PCM bit stream is recorded on an on-board tape recorder and telemetered to the ground data monitoring station. The telemetered signal is also recorded on the ground. The ground recording includes ground-based data such as aircraft tracking position and ambient (atmospheric) conditions. Selected parameters are displayed in engineering units in real time in the ground station to enable safety and programmatic monitoring. The formats used included time histories ("strip charts"), digital displays, and x–y plots. Laser and radar tracking data was acquired from the existing Crows Landing NASA test range equipment.

5. Vehicle/System Description

5.1 Aircraft

The QSRA (fig. 2) was first flown by NASA Ames Research Center in 1978 as a research aircraft to investigate propulsive lift and to demonstrate, simultaneously, the low noise benefit obtained by placing the engines over the wings. These dual purposes complemented each other in that the over-the-wing engine exhaust flow uses the Coanda effect, thereby developing the high lift effectiveness due to exhaust flow deflection and supercirculation (ref. 4). This configuration is referred to as USB.

The QSRA has been performing STOL flight research at Ames Research Center since 1978. These prior flights provided the low speed performance and flying quality data that supported the use of the QSRA for the jump strut evaluation.

The QSRA consists of a deHavilland C-8A Buffalo fuselage and empennage with a modified wing/propulsion system designed and fabricated by Boeing. The high T-tail on the C-8A Buffalo was modified to include fully powered elevator operation. The four YF-102 AVCO Lycoming fan jet engines, which are capable of producing approximately 6,000 pounds of thrust each, are mounted above the wing in acoustically treated nacelles. Neither the main nor the nose landing gear is retractable.

5.2 Jump Strut System

The jump strut system can be divided into three elements, as illustrated in figure 3:

- The jump strut nose gear,
- The pneumatic system, and
- The electronic control system.

5.2.1 Nose gear and strut– The original QSRA nose landing gear assembly is a two-stage device which has both high and low pressure air chambers. The gear features both air and oil to provide shock absorbing and rebound damping during all aircraft ground operations. Figure 4 shows the original nose landing gear prior to modification. The rate of the strut movement is controlled by regulating oil flow through the oil metering device comprising the piston head, flapper, and metering pin.

A nonserviceable QSRA nose gear/strut was reconditioned and modified to provide a movable "jump piston" (see fig. 5). The metering pin is attached to the added jump piston instead of the trunnion. A hole was drilled through the trunnion to enable the injection of high pressure gas into the chamber above the jump piston.

In the jump strut mode, the application of high pressure gas to the upper chamber extends the strut, and the subsequent reaction forces from the runway cause the nose of the aircraft to lift.

AERODYNAMIC DATA

	WING	HORIZ	VERT
AREA (TRAP). ft^2	600.00	233.00	152.00
SPAN, ft	73.50	32.00	14.00
ASPECT RATIO	9.00	4.40	1.22
TAPER RATIO	0.30	0.75	0.60
SWEEP, C4, deg	15.00	3.00	18.00
M.A.C. in.	107.40	88.00	137.00
CHORD ROOT, in.	150.70	100.00	168.00
CHORD TIP, in.	45.20	75.00	100.00
T/C BODY SIDE, %	18.54	14.00	14.00
T/C TIP, %	15.12	12.00	14.00
INCIDENCE, deg	4.50	-	-
DIHEDRAL, deg	0.00	-	-
TAIL ARM, in.	-	525.0 in.	488.0 in.
VOL COEFF V	-	1.898	0.1402

CONTROL SURFACES

	ft^2/APL*	BLOWN
AILERON	32.2	BLC
FLAPS INBD	105.0	USB
FLAPS OUTBD	40.2	NONE
SPOILERS	33.7	NONE
L.E. FLAPS	54.3	NONE
ELEVATOR	81.6	NONE
RUDDER	60.8	NONE

*THEORETICAL RETRACTED AREA

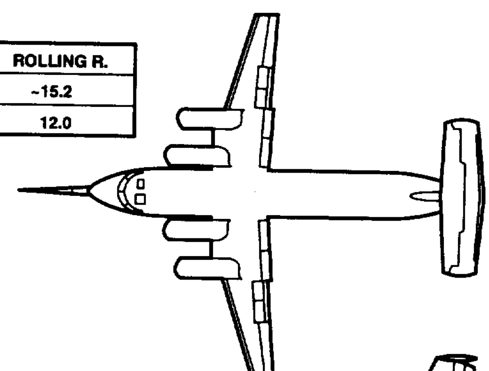
PROPULSION

ENGINE	LYCOMING YF-102
STATIC THRUST	6225**
FAN P.R.	1.45
BY-PASS RATIO	6.00

**MEASURED THRUST

LANDING GEAR

GEAR	STROKE	TIRE	TIRE O.D.	ROLLING R.
MLG, in.	21.0	14 x 15	37.0	~15.2
NLG, in.	17.5	8.90-12.50 TYPE III	27.5	12.0



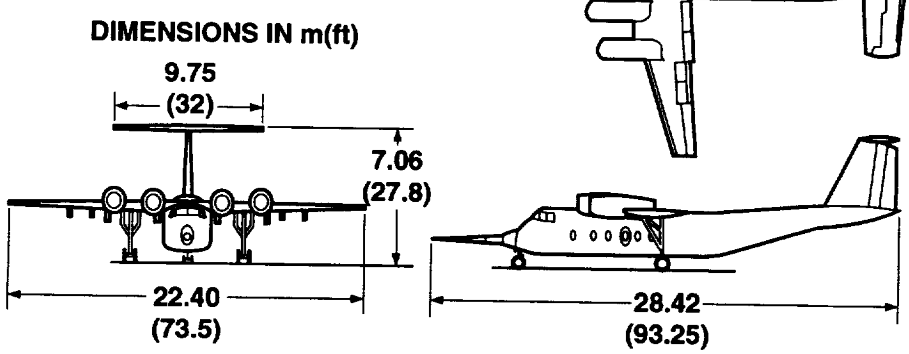


Figure 2. Quiet Short-Haul Research Aircraft configuration and dimension details (from ref. 4).

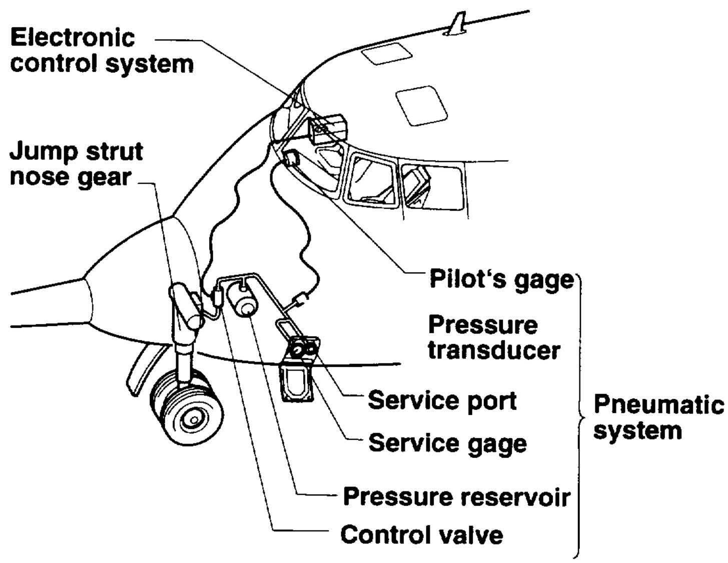


Figure 3. Jump strut installation.

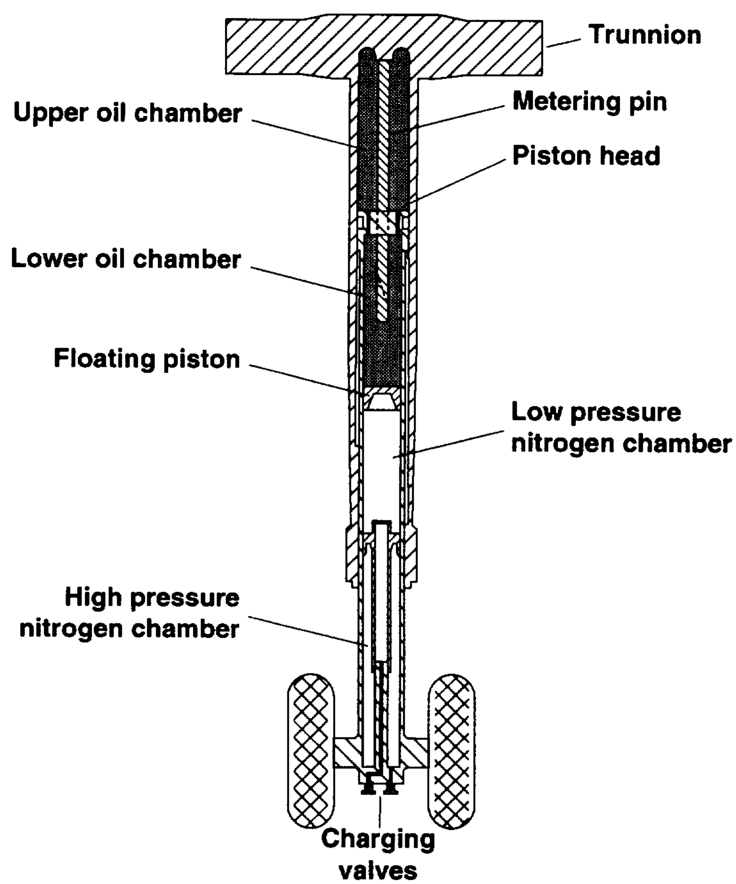


Figure 4. Original QSRA nose gear.

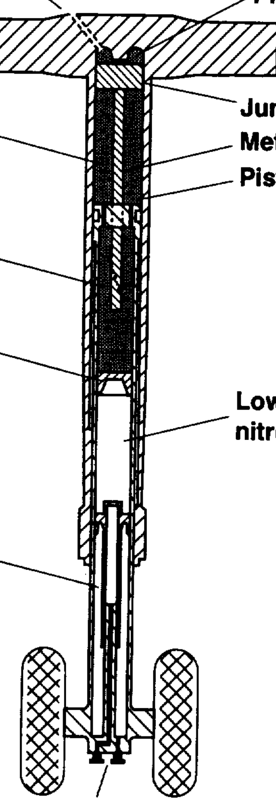


Figure 5. Jump strut nose gear.

5.2.2 Pneumatic system– Figure 6 shows the jump strut pneumatic system. The main components are the storage tank (pneumatic reservoir), control valve, safety valves, and gages. Briefly, the operation is as follows.

The storage tank is charged to the desired pressure through a service port located on the port side of the aircraft. A separate pressure gage is provided for both the flight and ground crews. The required equipment was both small and light which enabled the storage tank and control valve to be located in the nose wheel well. The storage tank weighs 20 pounds and has a volume of 425 cubic inches and a maximum operating pressure of 3,000 psig. The relief valve, set to open at 3,500 psig, protects against overpressurization, while the vent on the electrically activated control valve exhausts the supply lines to atmospheric pressure when the valve is not supplying high-pressure gas to the upper cylinder. The bleed valve in the system provides an escape for the high-pressure gas so that the jump strut upper chamber is returned to atmospheric pressure within seconds after jump strut operation, thereby returning the nose gear to its conventional state.

5.2.3 Jump strut control system– The electronic control system contains the arming and timing circuits (fig. 7). Operation of the jump strut requires the firing system to be armed prior to triggering the control valve. The timing circuit enables the duration of the valve opening to be set during the flight investigation within the range of 3 to 170 milliseconds. The firing system circuit is completed through the nose gear on-ground (squat) switch, thus the circuit can only be energized when the nose gear is compressed (structural limitations prohibit operating the jump strut with the nose wheel off the ground). Dual firing circuits are provided for safety reasons. If the first timing circuit fails in the "valve open" mode, the second circuit will limit the duration of the valve opening. For these tests, the backup timing circuit was set at the maximum firing time (170 milliseconds).

The arm/disarm circuit protects against inadvertent firing as long as the arm switch is not engaged. Also, after the system is triggered, the circuit is automatically disarmed to avoid an accidental second firing. The firing button was placed on the number-one power lever and the arming and timing controls were placed on the starboard side in the copilot's control area.

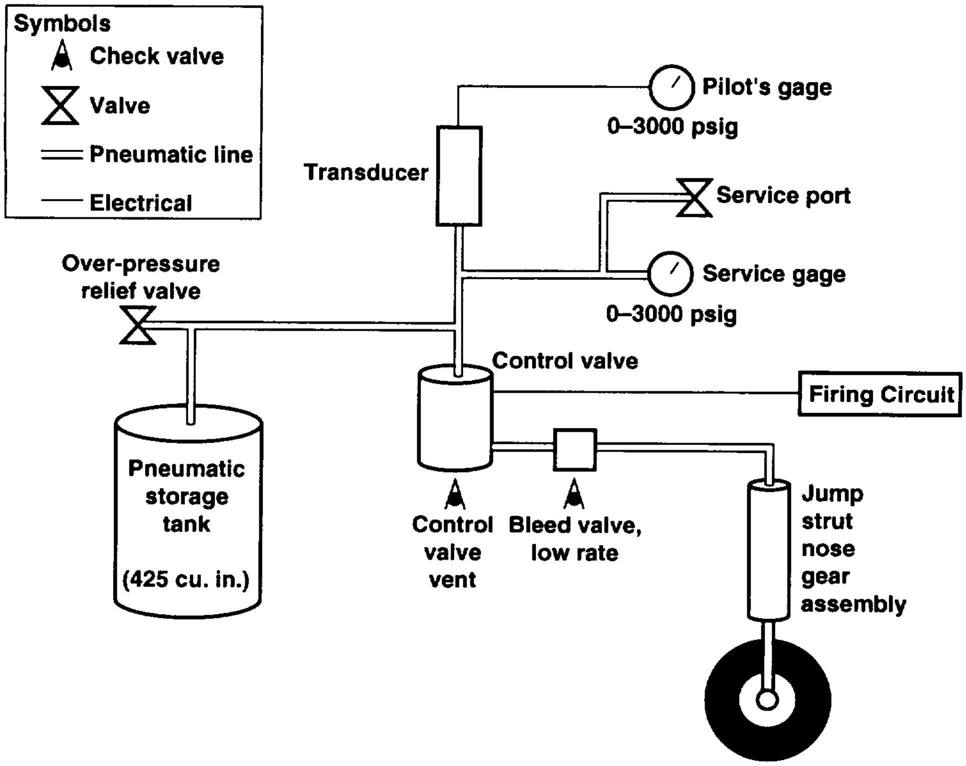


Figure 6. Jump strut pneumatic system.

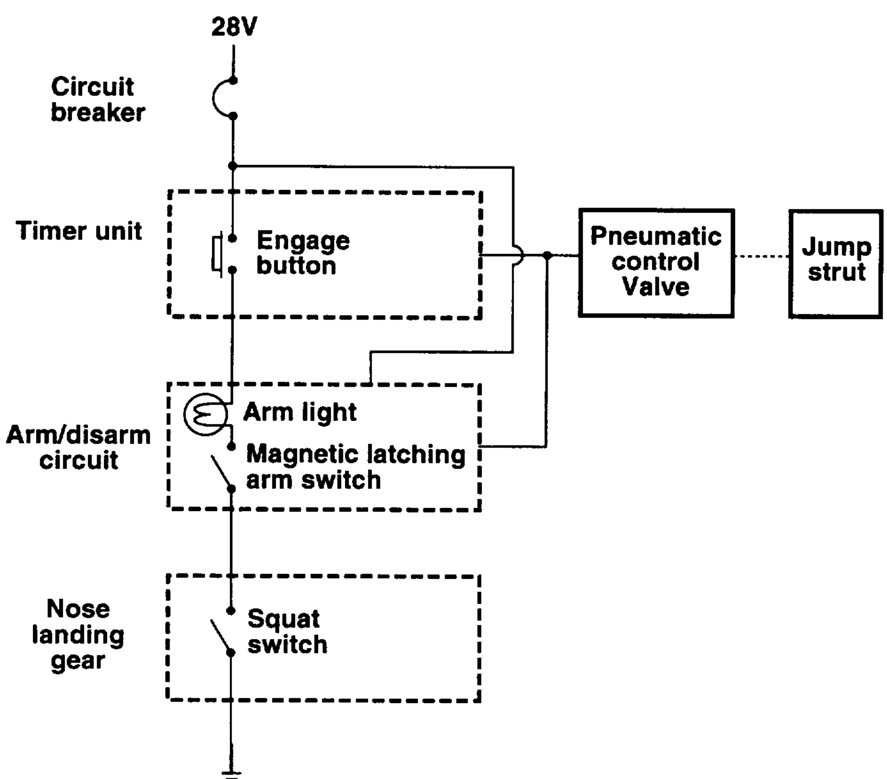


Figure 7. Jump strut electronic system.

6. Wright Laboratory Ground Qualification Tests

The modified QSRA nose strut was functionally tested at the manufacturer's plant. The contractor evaluations consisted of verifying conformance with drawings and specifications, and conducting pressure leakage and jump piston operation tests. Functional acceptance tests were performed at Wright Laboratory using the test setup shown in figure 8.

The tests conducted at Wright Laboratory are described in paragraphs 6.1 through 6.4.

6.1 Documentation of Load-Stroke Curve

The load stroke curve was generated by locking the landing gear trunnion in place and using the stroke of the base (movable table) to compress the strut. The first loading provided an adiabatic compression and release of the strut in 2 seconds. The second test compressed and released the strut in 100 seconds, yielding an isothermal loading.

The results in figure 9(a) duplicated the original specifications of the manufacturer (Menasco) for the two stage nose wheel strut thereby conforming to the requirement that the performance of the modified strut match that of the original configuration.

6.2 Drop Test

This test called for a 12 foot-per-second sink rate (the original nose strut specification) with a nose weight of 4,788 pounds. The weight on the nose is based on a QSRA gross weight of 48,000 pounds and a center of gravity located at 25% of mean aerodynamic chord (MAC). The drop test utilized the minimum available bucket weight of 6,700 pounds and a reduced drop test distance to produce the appropriate impact load. Figure 9(b) shows the vertical forces as a function of the strut compression. The simulated operational loads did not exceed the aircraft and nose gear manufacturer's structural limits.

6.3 Static Jump Tests

The static jumps (fig. 9(c)) simulated a stationary aircraft with a gross weight of 55,000 pounds and a center of gravity located at 26.5% of MAC. The jump strut was fired at various reservoir pressures (1,000 to 3,000 psig) and valve-open time intervals (50 to 130 milliseconds).

For these tests the pneumatic cylinders were used to produce an effective weight on the nose wheel of 5,815 pounds. The figure shows that the vertical forces encountered did not exceed the operational structural limits. The compression of the strut following the full extension shown in this figure would not be experienced in an actual takeoff.

6.4 Dynamic Jump Tests

The dynamic jump strut firings simulated a takeoff operation and were the same as the static jump tests except the effect of wing and tail lift were included, thereby reducing the weight on the nose wheel to about 4,600 pounds. As in the static jumps, the pneumatic cylinders were used to obtain the desired nose wheel load. The wing lift was calculated assuming a QSRA runway speed of 60 knots indicated airspeed (the nominal velocity at start of rotation). Figure 9(d) shows that the extension and compression of the strut remained within operational limits. Again, as in the static jump, the compression due to the wheel recontacting the ground after full extension would not occur during an actual takeoff.

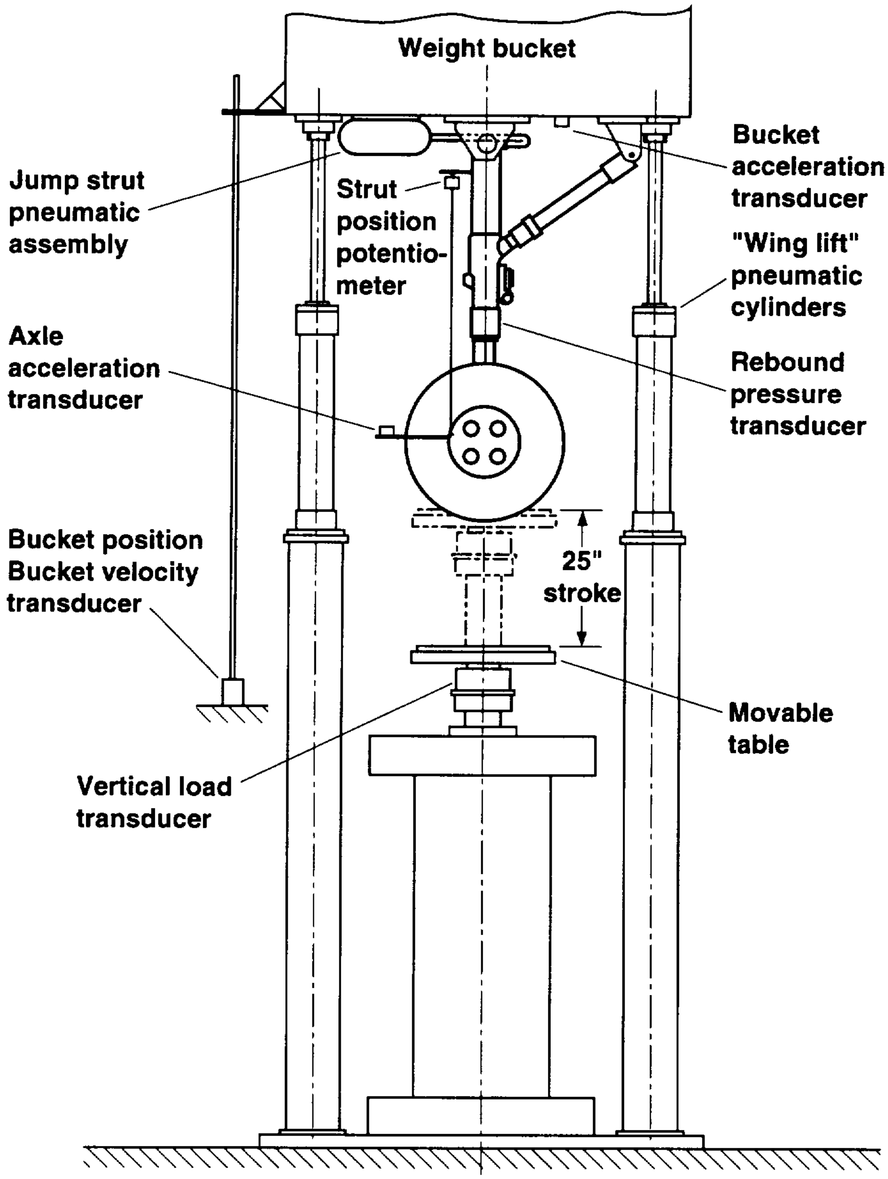


Figure 8. Wright Laboratory landing gear test stand.

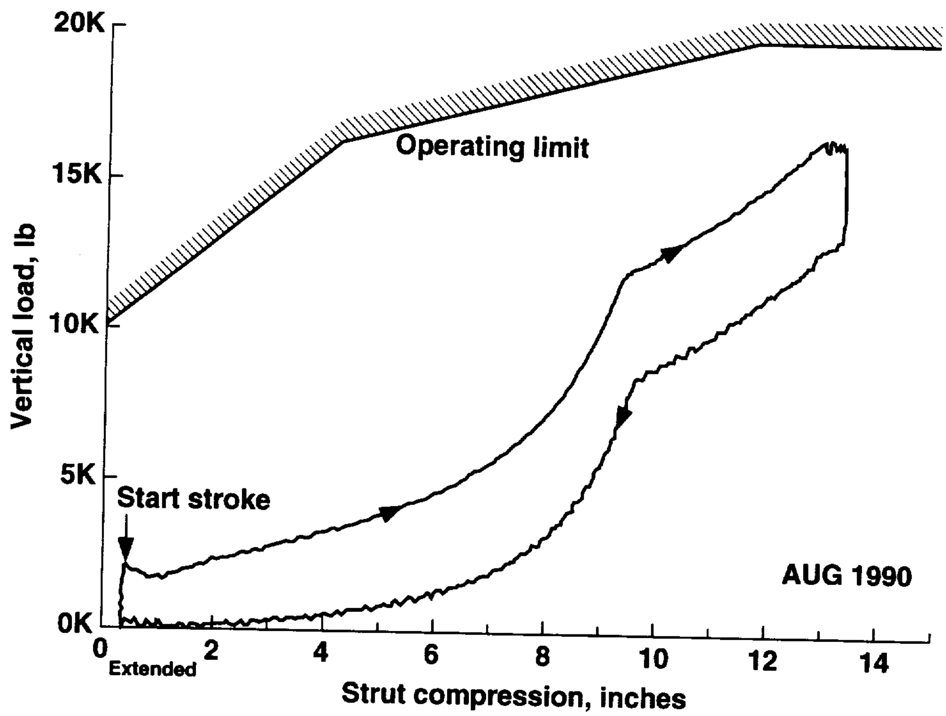


Figure 9(a). Adiabatic load/stroke variation (Wright Laboratory).

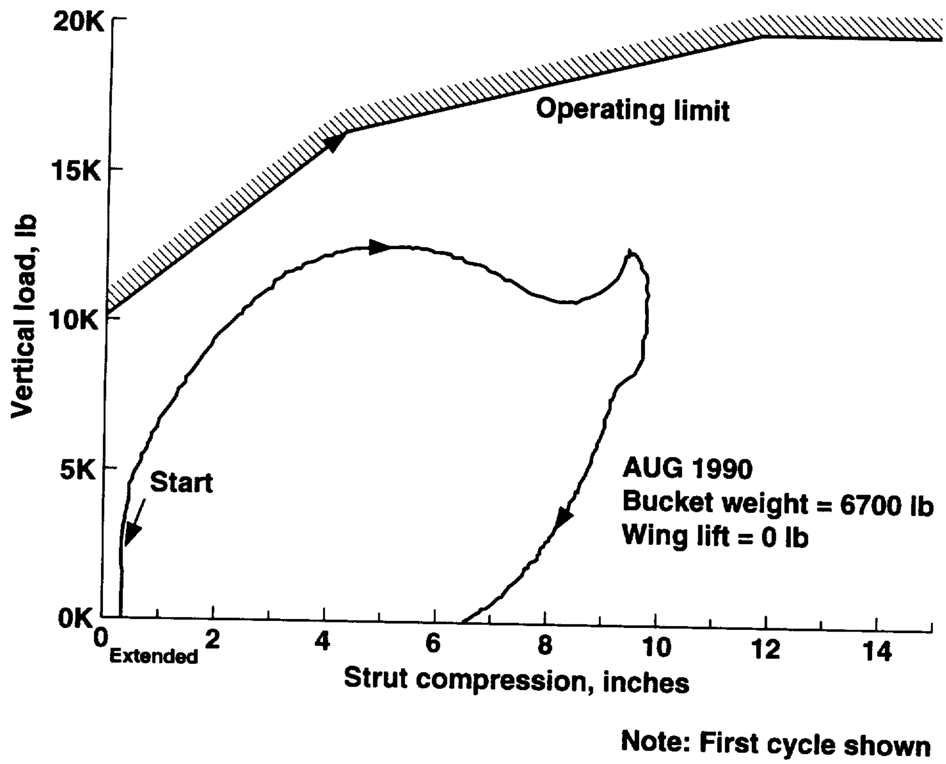


Figure 9(b). Drop test load/stroke variation (Wright Laboratory).

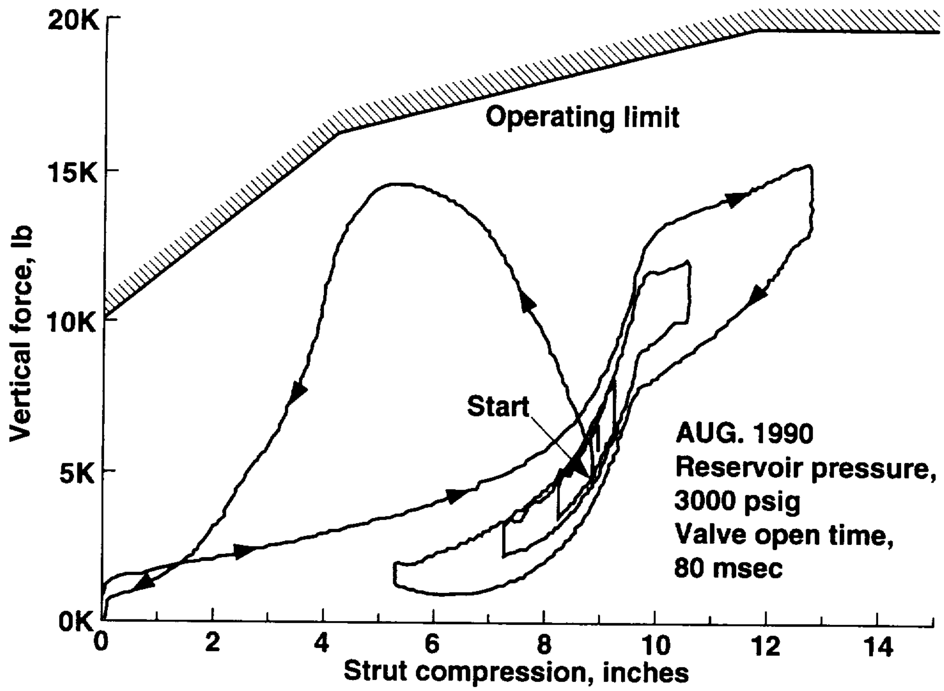


Figure 9(c). Static jump load/stroke variation (Wright Laboratory).

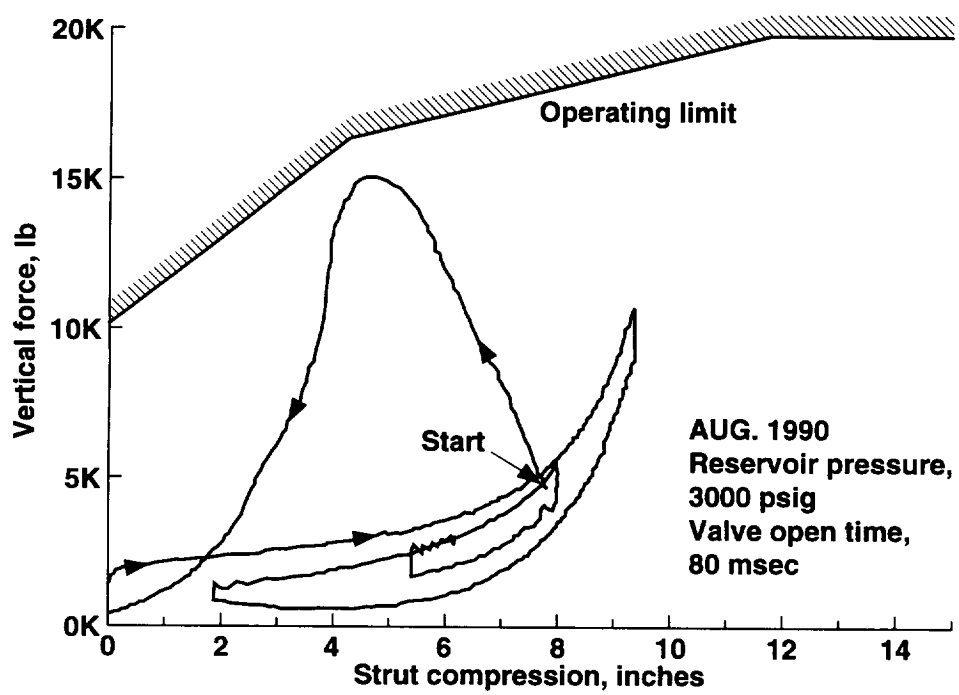


Figure 9(d). Dynamic load/stroke variation (Wright 'Laboratory).

7. Ames QSRA Static Jump Strut Tests

The instrumentation and the electronic control system were calibrated on the QSRA prior to jump strut test operations. The nose gear vertical load was determined by measuring the bending moment on the trunnion which was calibrated by placing the nose wheel on scales. The main wheels were elevated to level the aircraft. The QSRA static calibration arrangement is shown in figure 10. A broad range of nose gear vertical loads was obtained by varying the thrust of the engines. The summation of moments about the main gear provided a means of assessing engine thrust as a function of fan RPM. The results of this data analysis compared very well with prior engine static thrust calibration data.

Figure 11 shows the vertical nose gear maximum load versus the jump strut control valve open time for both the Wright Laboratory tests and the QSRA static jump tests. Both sets of data show that the maximum load is essentially independent of valve open time but increases with reservoir pressure. The maximum load obtained from the Wright Laboratory test was found to be about 10% greater than the QSRA test data. The source of this difference has not been identified. Figure 12 shows the effect of valve open time on the load/stroke cycle. The larger time maintained higher loads for nearly the full extension of the strut, thereby approaching the structural limits of the system. It should be noted that the difference between the Wright Laboratory data (fig. 9(c)) and the QSRA data (fig. 12) in the stroke/load curve shape, during the extension of the strut after the peak load is reached, is primarily due to the differences in the load on the nose gear.

Typical time histories, illustrating the variation of the load on the nose gear and the nose gear extension during the static QSRA jump strut operation, are presented in figure 13.

The performance of the system measured during static tests at Wright Laboratory and Ames Research Center is summarized in figures 14 and 15 which present the effect of valve open time at constant pressure, and the effect of reservoir pressure at constant valve open time. In both of these figures, the time to reach the maximum load level, following the firing of the jump strut, is nearly constant and is independent of valve open time (between 80 and 170 milliseconds) and reservoir pressure. The time increment for the nose wheel to lift off the ground after the jump strut activation is seen to be greater at the lowest duration of the control valve opening (from the Wright Laboratory data), compared to higher valve open times (fig. 14). However, within the range of valve open times used during the QSRA flight tests (80 to 170 milliseconds) the time for the nose wheel to lift off the ground is relatively constant although from figure 13(c) the strut velocities (or aircraft pitch rate) were slightly higher for the longer valve open times. In figure 15, while the maximum load is seen to increase with pressure (as previously noted), the time for the nose wheel to break contact with the ground decreases slightly and the strut velocities increase slightly as reservoir pressure is increased.

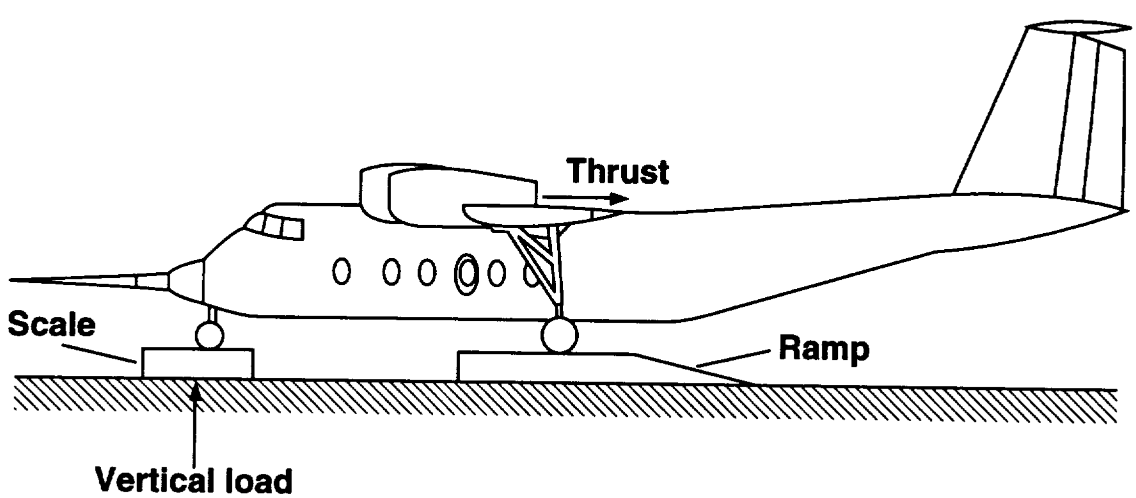


Figure 10. Calibration configuration for thrust and nose gear load.

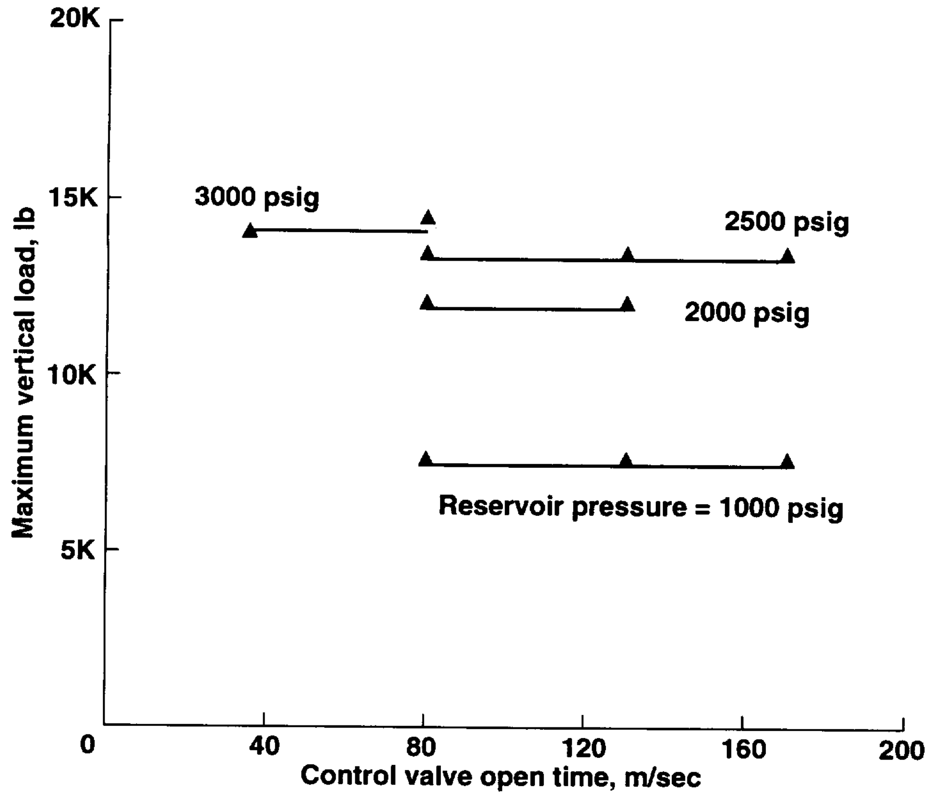


Figure 11(a). Variation of maximum load with valve open time and reservoir pressure (Wright Laboratory).

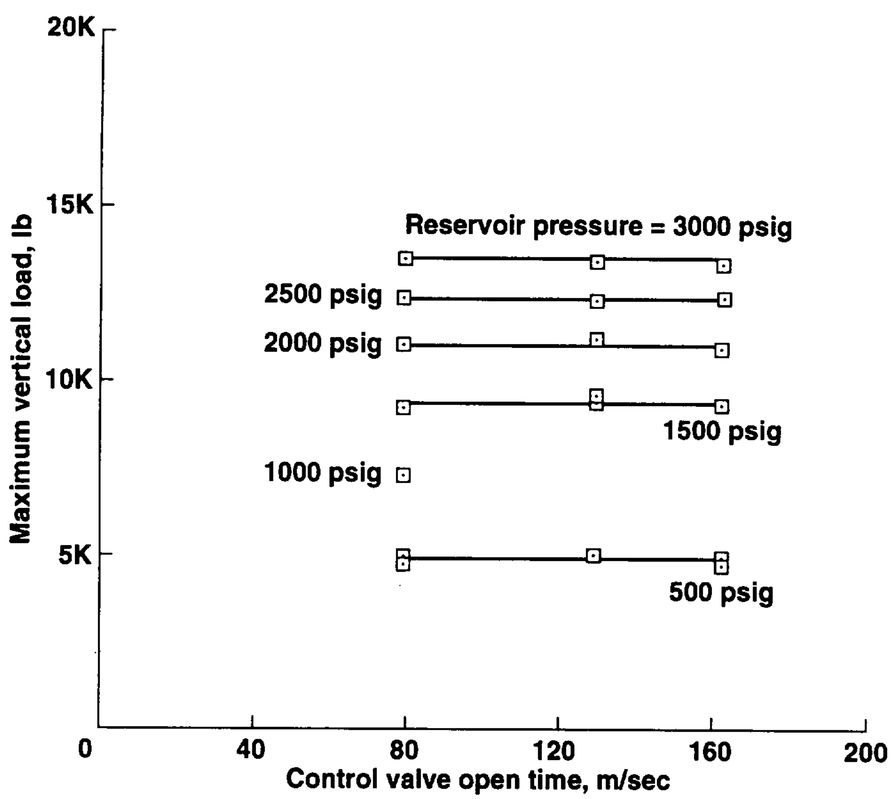


Figure 11(b). Variation of maximum load with valve open time and reservoir pressure (QSRA).

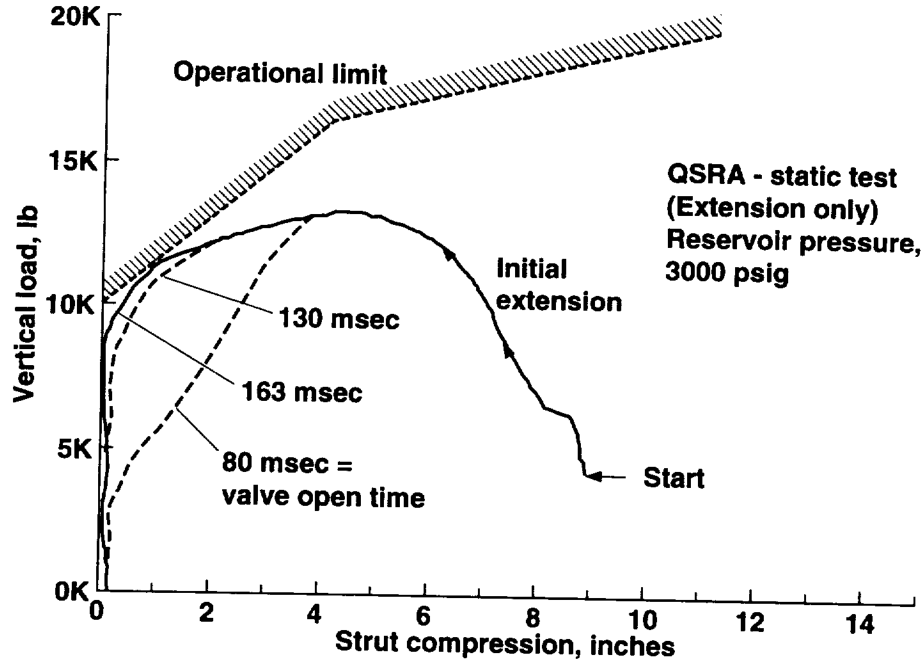


Figure 12. Effect of valve open time on QSRA strut load/stroke.

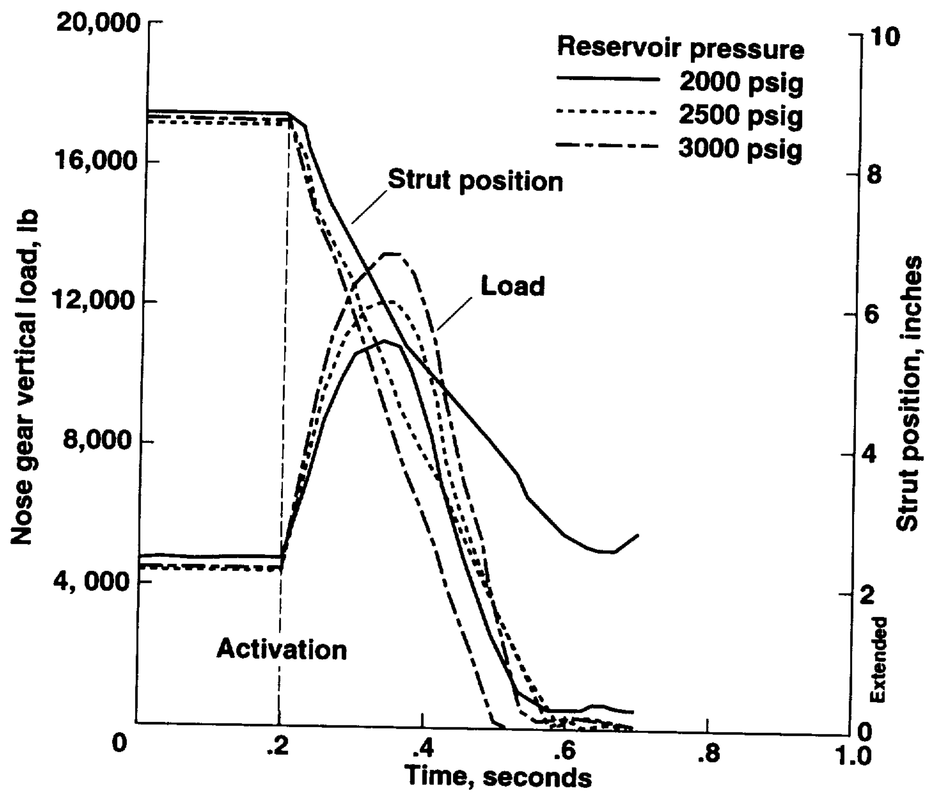


Figure 13(a). Jump strut time history valve open time = 80 msec.

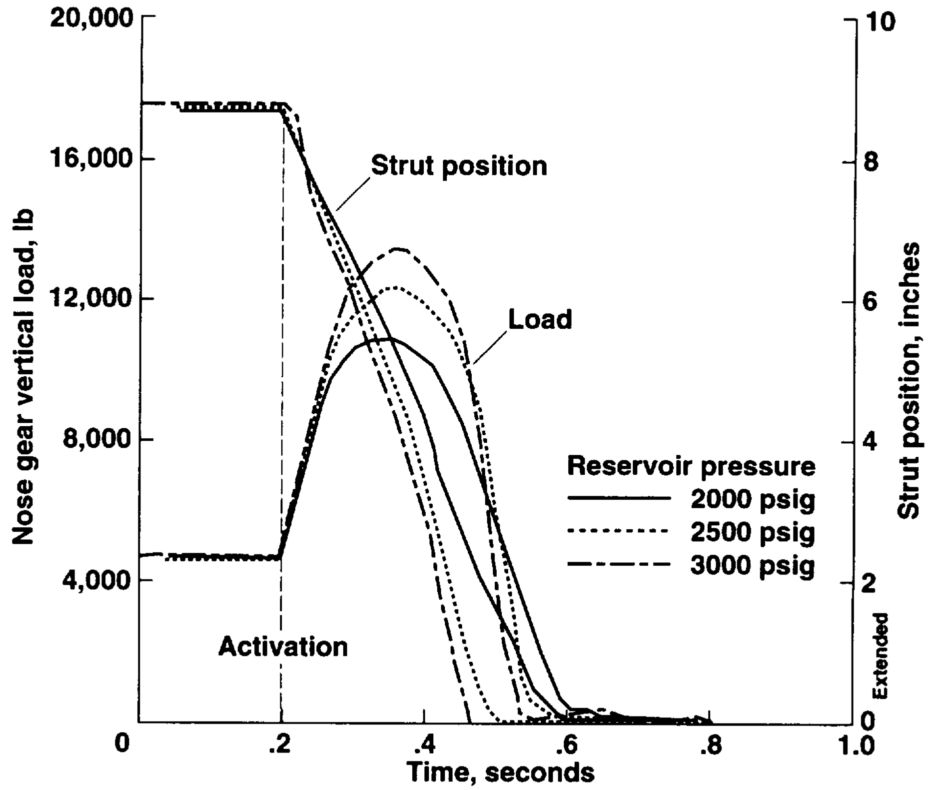


Figure 13(b). Jump strut time history, valve open time = 170 msec.

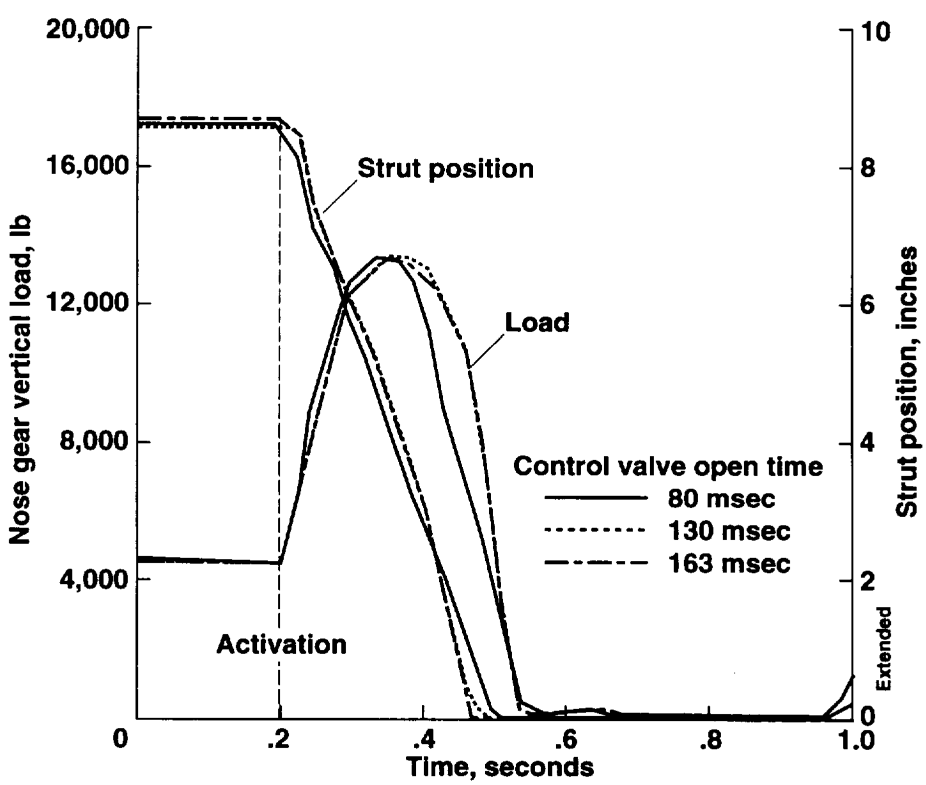


Figure 13(c). Jump strut time history, pressure = 3,000 psig.

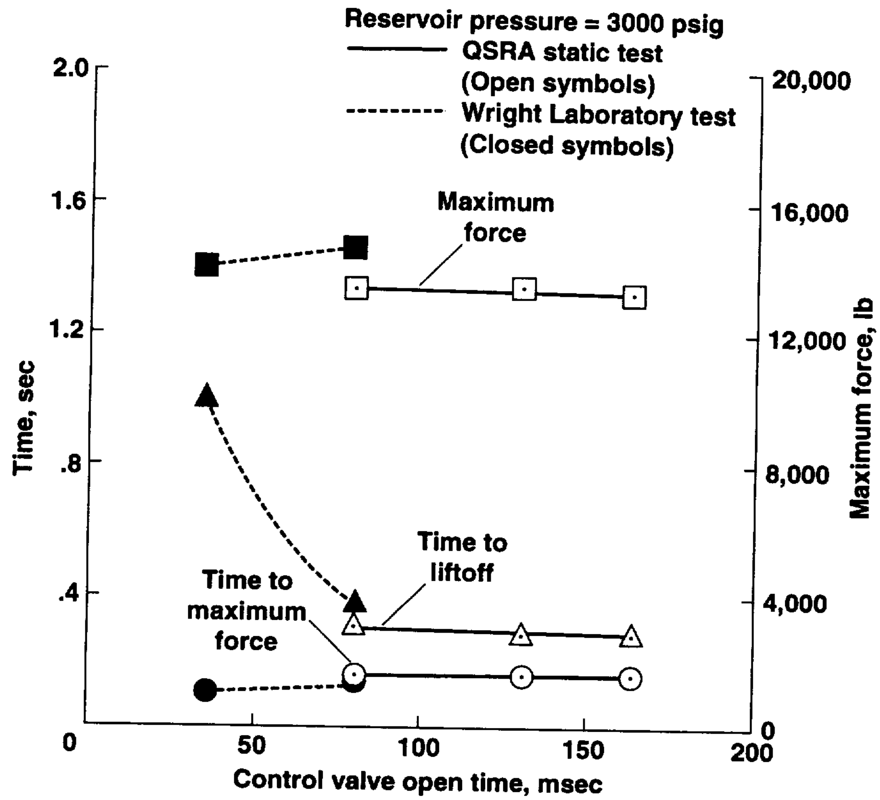


Figure 14. Jump strut performance, effect of control valve open time.

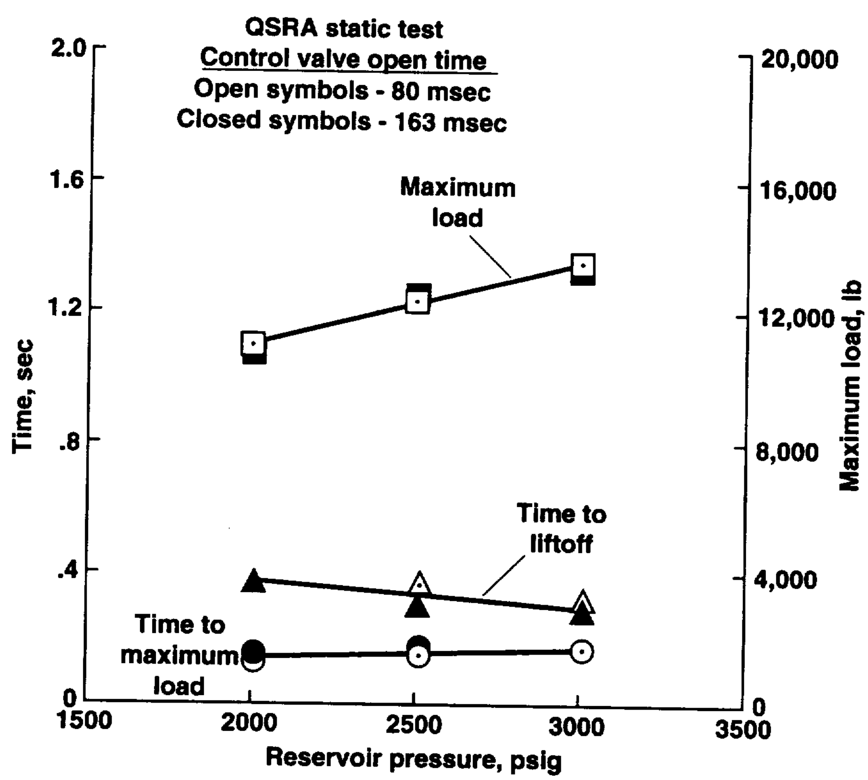


Figure 15. Jump strut performance, effect of reservoir pressure.

8. Jump Strut Flight Test

The objective of the flight test was to evaluate takeoff performance with and without jump strut assistance. Thrust to weight (T/W) ratio values of 0.3, 0.35, 0.4, and 0.45; valve open duration of 80, 130, and 170 milliseconds; and pneumatic reservoir pressures of 2,000, 2,500, and 3,000 psig were investigated. Each point on the matrix required several takeoffs to determine the performance as a function of airspeed. Also, to establish baseline performance levels, takeoffs had to be made at various thrust to weight ratios for a range of airspeeds without the jump strut.

For consistency during the data takeoffs, a series of preliminary flight tests was conducted to define the nominal aircraft configuration and pilot takeoff technique. It was decided to set the control column for an elevator position of 5 degrees nose down prior to brake release, to maintain a fixed column position during the takeoff roll (allowing the elevator to float up to near zero degrees during the acceleration), and to snap the elevator full aft simultaneously with firing the jump strut at the target airspeed. Full up elevator was then held until 15 degrees of pitch attitude was attained. This pitch attitude was then held until the aircraft was well airborne. For all operations the double slotted flaps were set at 59 degrees and the USB flaps were full up (0 degrees). Also, fan RPM was selected prior to each takeoff to obtain the desired thrust to weight ratio for the ambient conditions. Appendix B shows the variation of fan RPM with temperature and pressure for families of constant thrust to weight ratios at a gross weight of 53,000 pounds. The initial nominal wing loading of 88 pounds per square foot and nominal c.g. were achieved by operating with full, or nearly full wing tanks. The maximum thrust to weight ratio attainable for this configuration, due to engine thrust limitations, was approximately 0.4. Since the jump strut pneumatic reservoir had to be recharged for each jump takeoff, refueling was accomplished simultaneously to maintain the appropriate gross weight. Additional testing was performed at a wing loading of 77 pounds per square foot by reducing the fuel load. At this wing loading it was possible to achieve a thrust to weight ratio of about 0.45.

To ensure against accidental firing of the jump strut, the jump strut circuit was not armed until after brake release on the runway, immediately prior to takeoff. This procedure eliminated the possibility of firing the jump strut with a high initial static load on the nose gear due to engine thrust, which could result in exceeding the allowable jump strut/airframe structural load limitations.

8.1 Flight Test Data

The takeoff ground roll distance was measured using a calibrated ground-based laser tracking system and a laser reflector mounted on the side of the fuselage. For this evaluation, the takeoff ground roll distance is measured from the point of brake release to the point of full extension of the main landing gear strut. Figure 16 illustrates the method used for determining ground roll takeoff distance. In addition to position on the runway, the true ground speed could be derived from the laser tracker data. The ground roll distance was then corrected for ambient wind using the method provided in reference 5, where the magnitude of the runway wind component was obtained by taking the difference between the aircraft airspeed and the derived ground speed. The uncorrected and corrected flight test data and the ground-based ambient and laser-tracker data are presented in appendix C. Typical time histories of key parameters for unassisted and jump strut assisted takeoffs, at thrust to weight ratios of 0.3 and 0.4, are shown in figures 17(a) and 17(b).

Because of the sensitivity of engine thrust to RPM setting and the ambient temperature and pressure, the actual T/W always differed slightly from the targeted value. The takeoff distances, therefore, were also corrected to the targeted T/W levels. To avoid possible errors induced by large corrections to the measured data, takeoffs that resulted in excursions from the targeted thrust to weight ratio greater than 0.01 are not included in the plotted data.

A total of 69 takeoffs were completed. Of these takeoffs, 44 were jump strut assisted. Throughout the tests, all forces, pressures, and accelerations remained within monitoring limits.

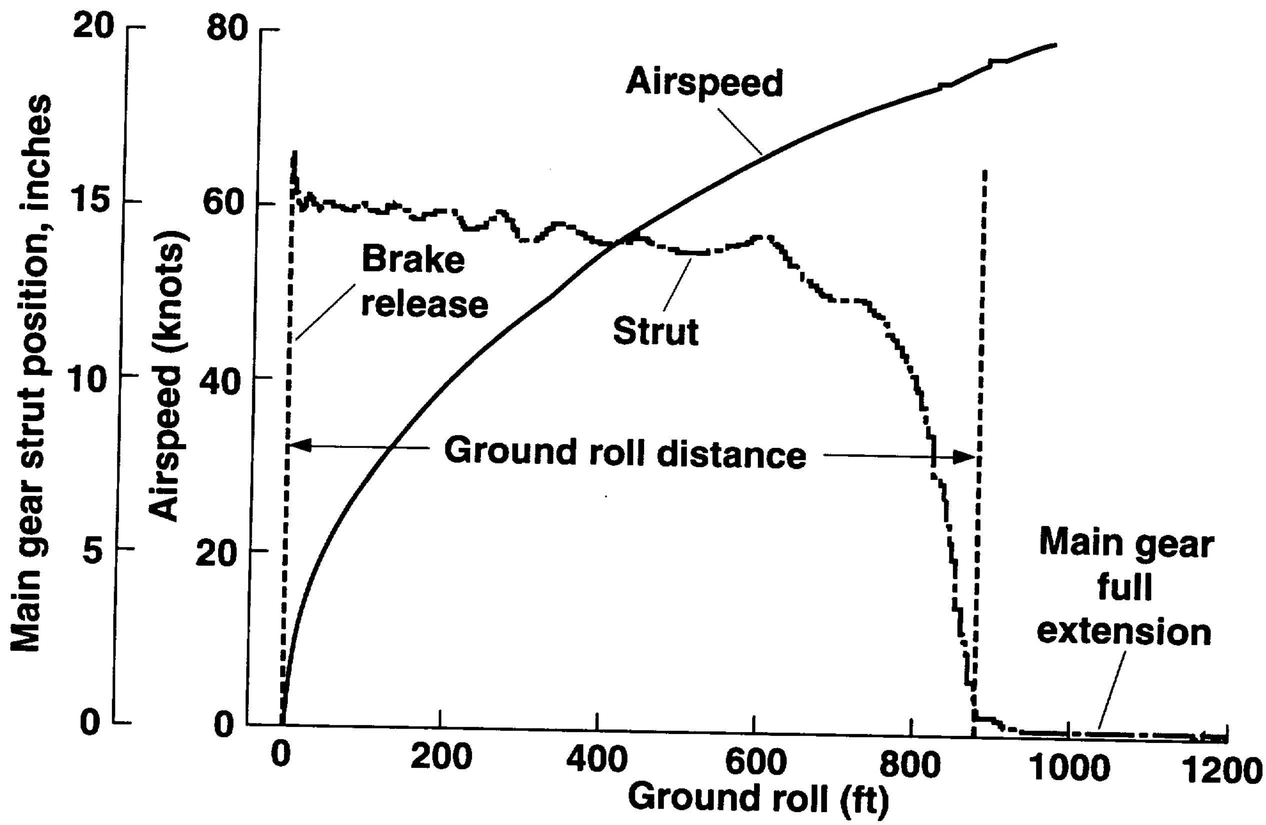


Figure 16. Determination of takeoff ground roll distance.

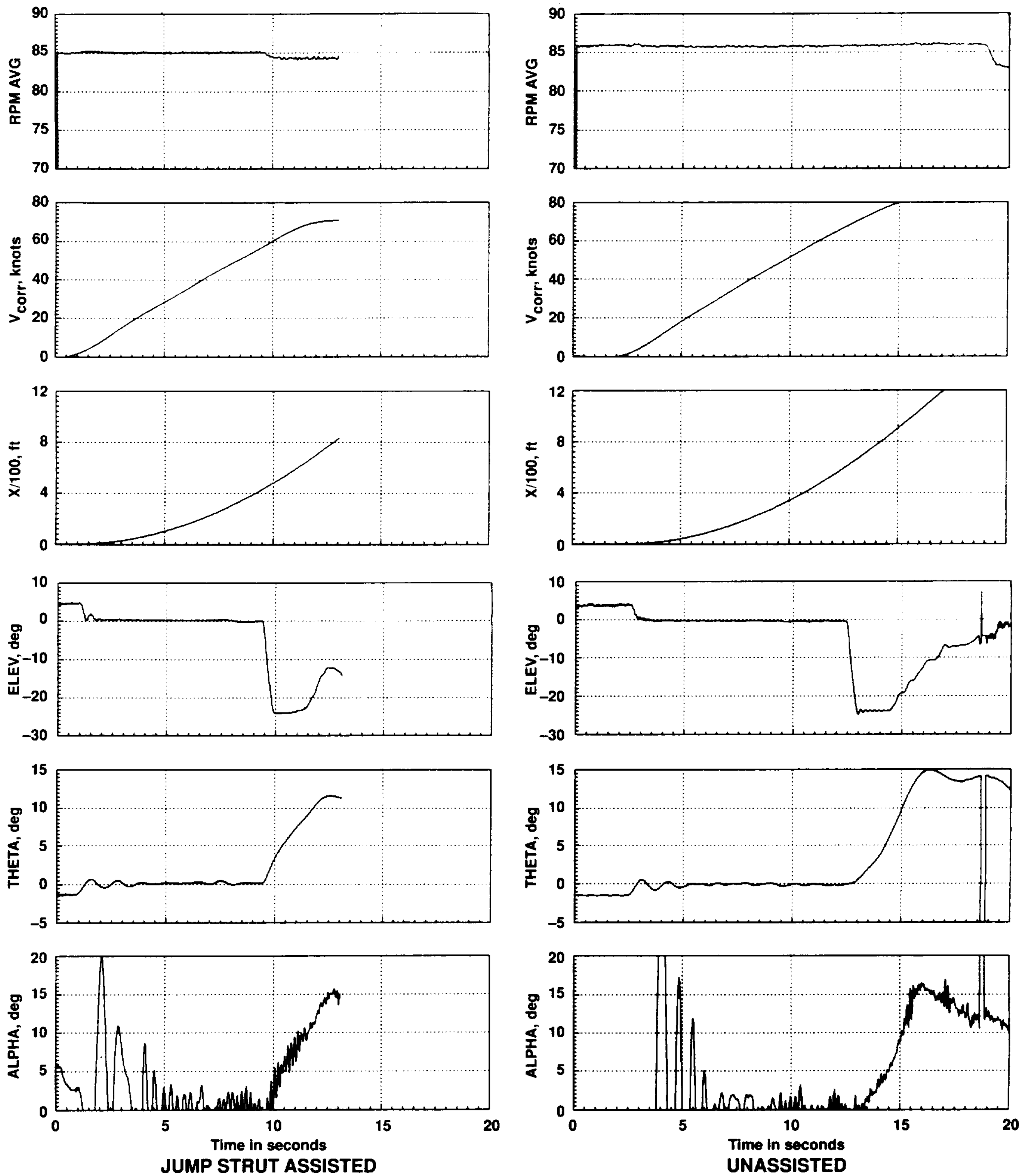


Figure 17(a) Typical time histories for unassisted and jump strut assisted takeoffs, at thrust to weight ratio of 0.4.

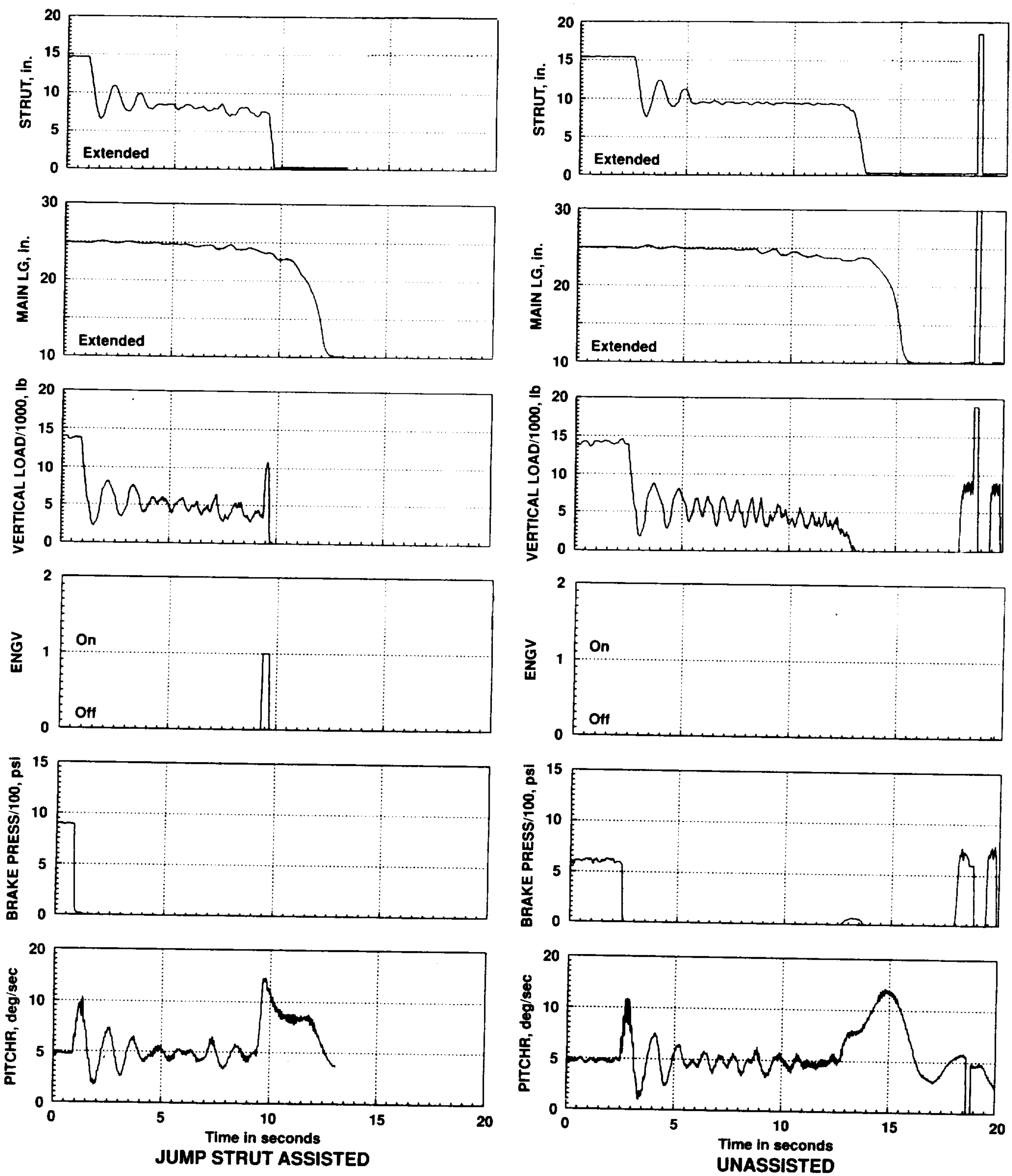


Figure 17(a). Concluded.

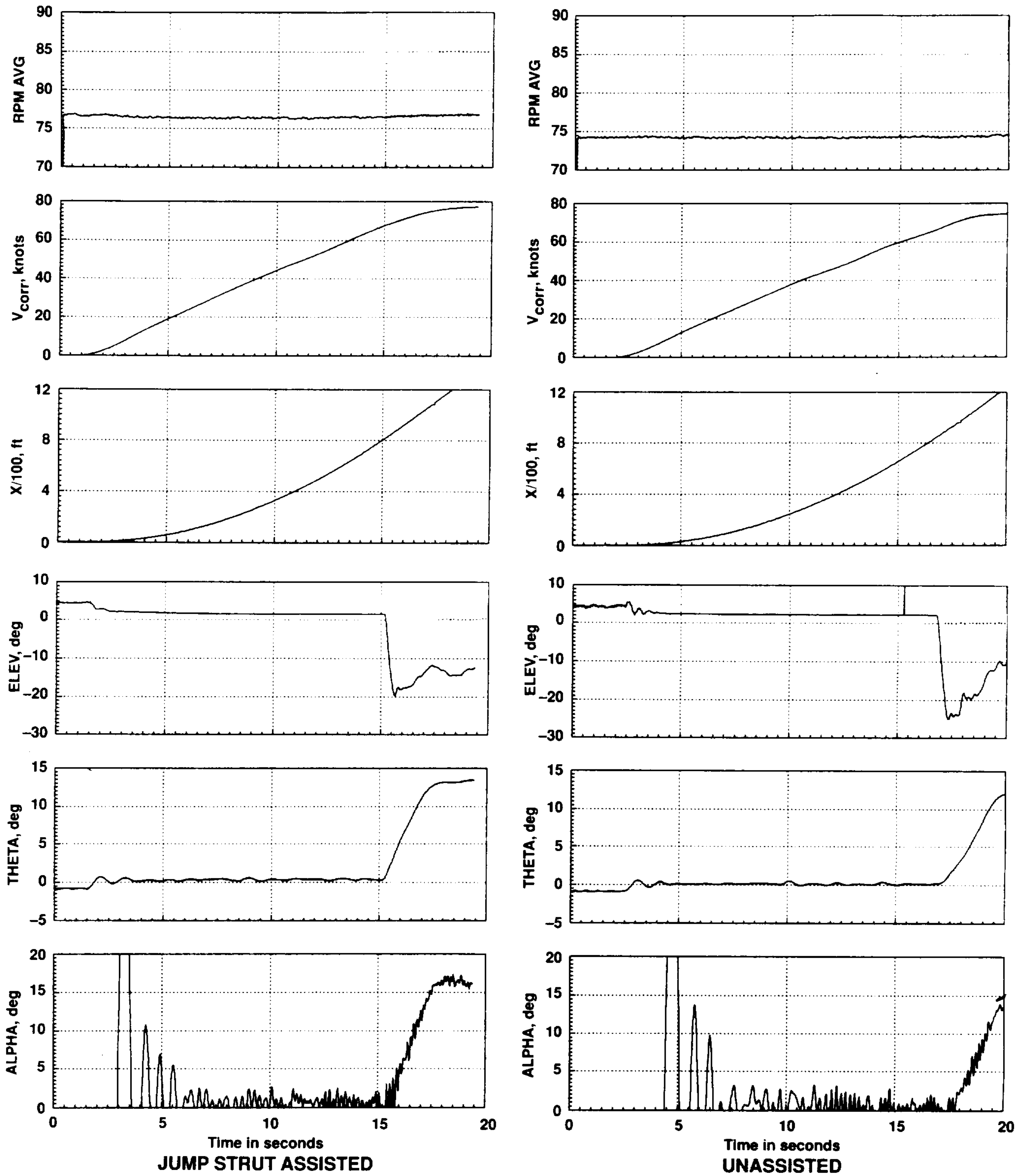


Figure 17(b). Typical time histories for unassisted and jump strut assisted takeoffs, at thrust to weight ratio of 0.3.

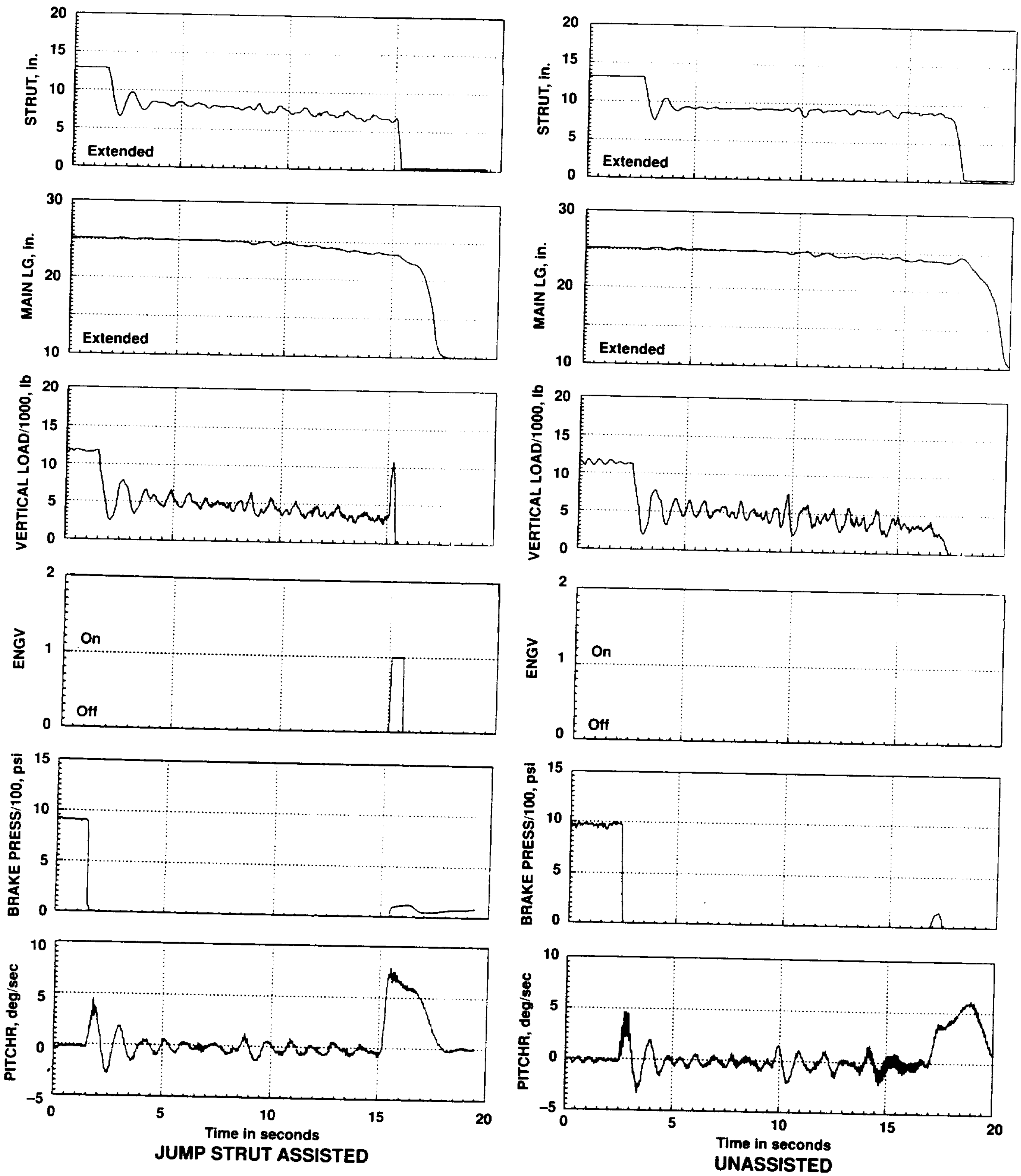


Figure 17(b). Concluded.

9. Discussion of Results

The vertical nose gear loads, the nose gear cylinder rebound pressure, and the nose gear axle acceleration were found to remain within the allowable limits throughout the flight test evaluation of the jump strut system. A typical load/stroke history recorded during a jump strut takeoff is given in figure 18. The start point (1) shows the initial high load and resulting compression of the nose gear due to the application of thrust prior to brake release. As the aircraft accelerates from the static, the load on the nose gear reduces and the nose of the aircraft pitches up. This pitch-up produces a few noticeable pitch oscillations which damp out rapidly as the aircraft continues along the runway. During the ground roll, load variations without large strut movement are seen, probably due to runway surface roughness. At the desired speed, the jump strut is activated producing a rapid extension and an accompanying increase in load. The load diminishes as the extension continues until lift-off occurs.

9.1 Effect of Pneumatic Reservoir Pressure

Figure 19 shows the effect of pneumatic reservoir pressure on takeoff performance for a 0.4 thrust to weight ratio and a 170 millisecond valve-open duration. It should be noted that the fairing of the test data shown on this and subsequent figures represents the minimum measured distance, since any deviation from optimum conditions could contribute to a longer takeoff roll. The use of the jump strut reduces the minimum ground roll distance by about 110 feet compared to the unassisted takeoffs. However, no clear trend with respect to the effect of the initial reservoir pressure is detected. Although the maximum static nose gear load was earlier seen to increase with pressure, it appears that the dominant performance factors during the flight operations are the initial rate of load increase and the time to achieve maximum load, illustrated in figure 13, which shows that the initial rate of extension, the initial rate of load increase, and the time to achieve maximum load do not vary significantly for reservoir pressures between 2,000 to 3,000 psig.

9.2 Effect of Valve-Open Time

The effect of valve-open duration is illustrated in figure 20. For this comparison the thrust to weight ratio is held at 0.4 and the initial reservoir pressure is 3,000 psig. As noted in the discussion of the effect of reservoir pressure, while the assisted takeoffs are approximately 110 feet shorter than the unassisted operations, no significant difference in performance due to valve-open time is detected.

9.3 Effect of Thrust to Weight Ratio

Figure 21(a) depicts the influence of thrust to weight ratio on ground roll distance for jump strut assisted and unassisted takeoffs at a wing loading of 88 pounds per square foot. As expected, the lower T/W levels result in greater takeoff distances at all tested speeds as well as higher rotation airspeeds for the minimum distances. Figure 21(b) shows the minimum ground roll distances as a function of T/W for both the jump strut and unassisted takeoffs. The reduction of ground roll distance obtained with the use of the jump strut is seen to diminish at the lower values of thrust to weight tested. At 0.4 T/W a 13% reduction of ground roll distance (fig. 19) was established by the flight test data. These results validate the estimated improvements of 10–12% predicted in the reference 3 study.

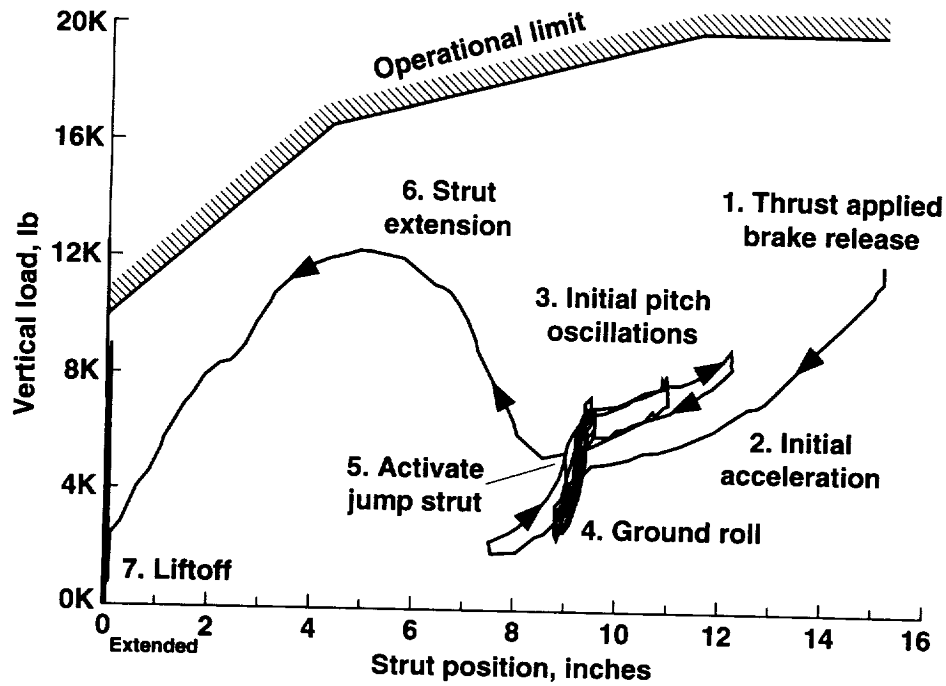


Figure 18. Typical operational load stroke curve.

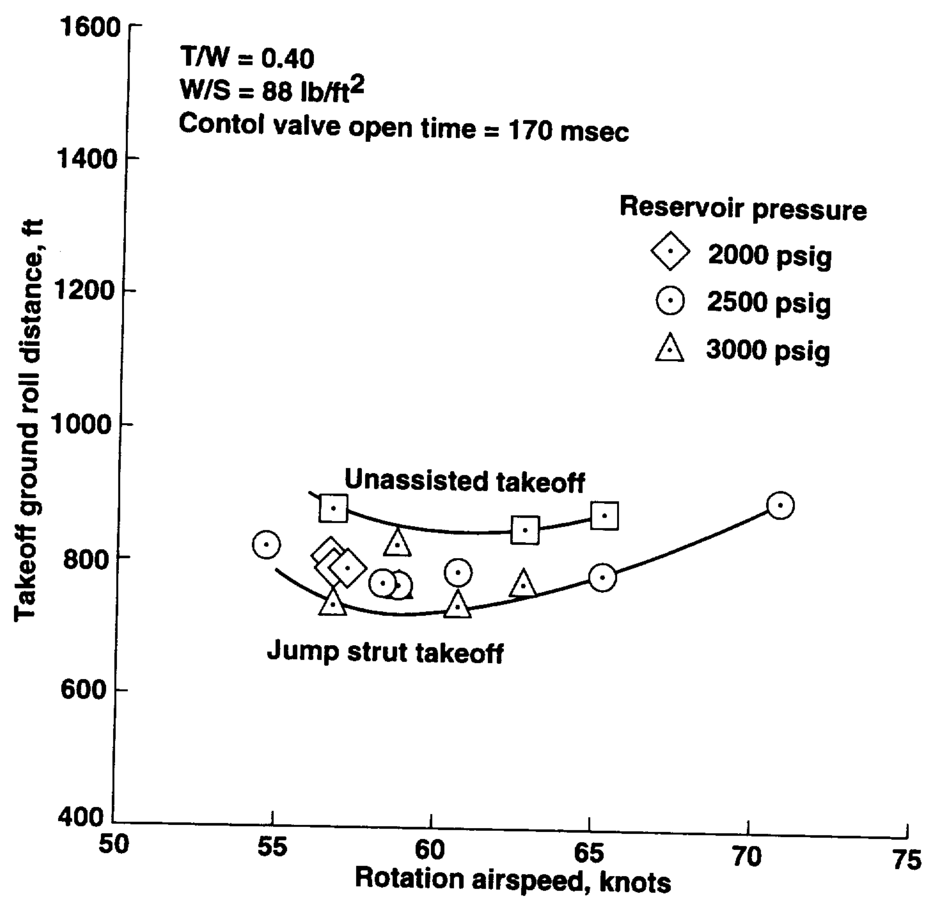


Figure 19. Unassisted and jump strut assisted takeoff performance with variation of reservoir pressure.

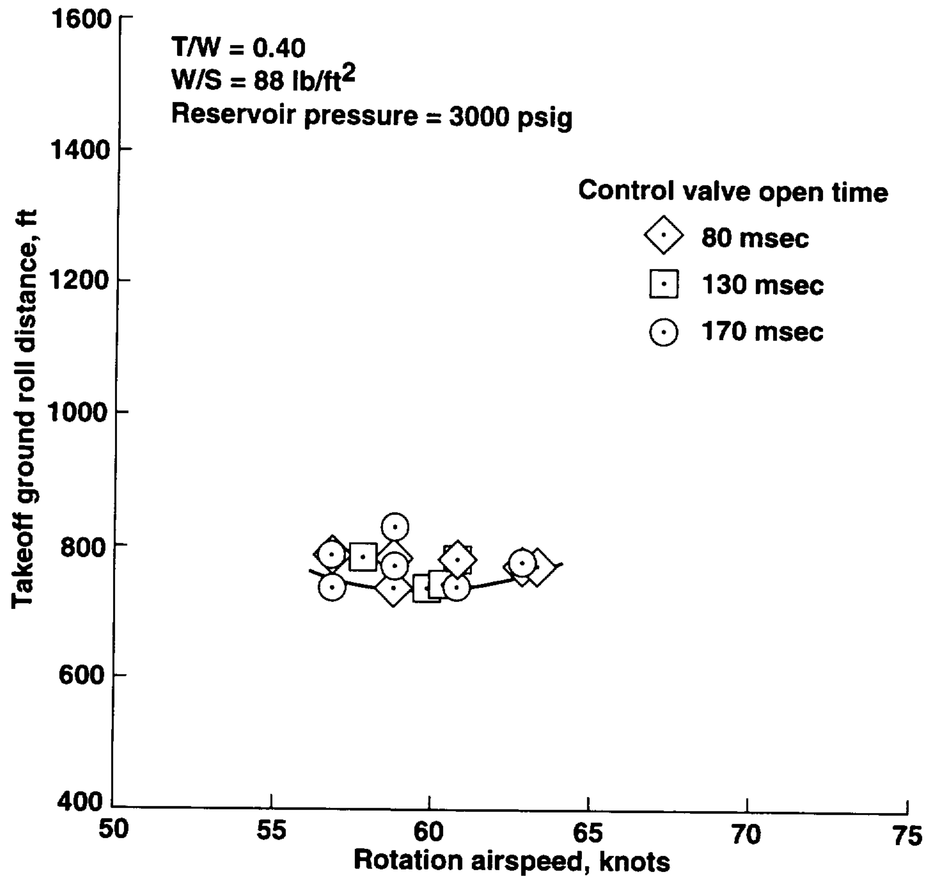


Figure 20. Jump strut assisted takeoff performance with variation of valve open time.

9.4 Effect of Wing Loading

The method of altering wing loading involved only the variation of fuel quantity in the wing tanks, resulting in a change of center of gravity position as a function of fuel level. The two wing loadings tested were 88 and 77 pounds per square foot, with associated c.g. positions of 29.5% and 31.9% MAC, respectively. Because the flight tests were prematurely discontinued due to aircraft mechanical problems, only the data from the unassisted takeoffs are available, as shown in figure 22(a). A plot of the minimum distance variation with wing loading is presented in figure 22(b).

9.5 Jump Strut System Servicing and Operational Considerations

The jump strut system tested was lightweight and was not complex, thereby making it representative of possible operational configurations. All elements operated reliably during the flight test program, although a failure of the magnetic-latching arm switch occurred during taxi tests after the completion of the flight activities. Servicing the pneumatic system required the development and application of safety procedures due to the handling of the high pressure gas. Servicing was conducted between test takeoffs, often with the engines running, and proved to be straightforward and safe and presented no special problems. The pneumatic system was charged with nitrogen during the initial tests and with dry air during the later flight tests. This change was made because of logistics problems associated with delivering the large quantity of pressurized nitrogen to the remote test site. No change in the operation of the jump strut system was observed. Postflight inspections of the nose gear assembly and associated airframe structure revealed no adverse effects as a result of the jump strut operations.

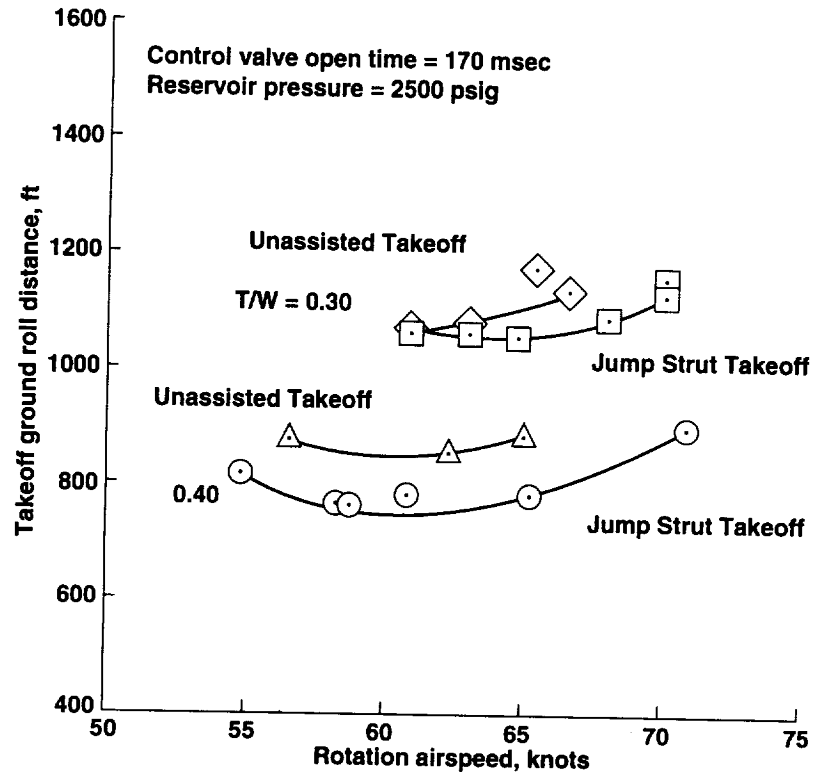


Figure 21(a). Jump strut assisted and unassisted takeoff performance with variation of thrust to weight ratio.

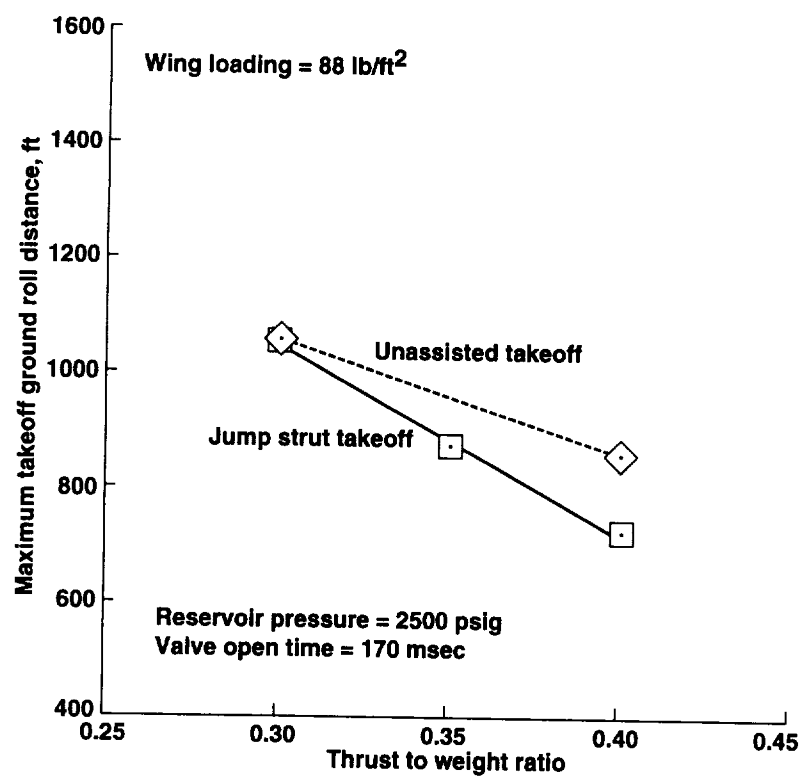


Figure 21(b). Effect of thrust to weight ratio on minimum ground roll distance for jump strut assisted and unassisted takeoffs.

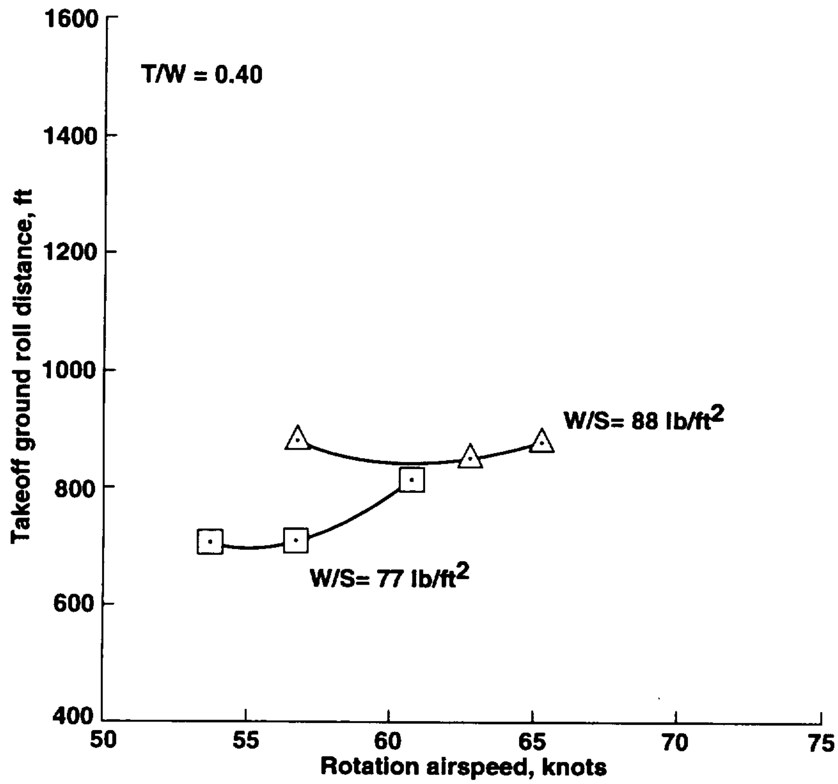


Figure 22(a). Effect of wing loading on unassisted takeoff ground roll distance.

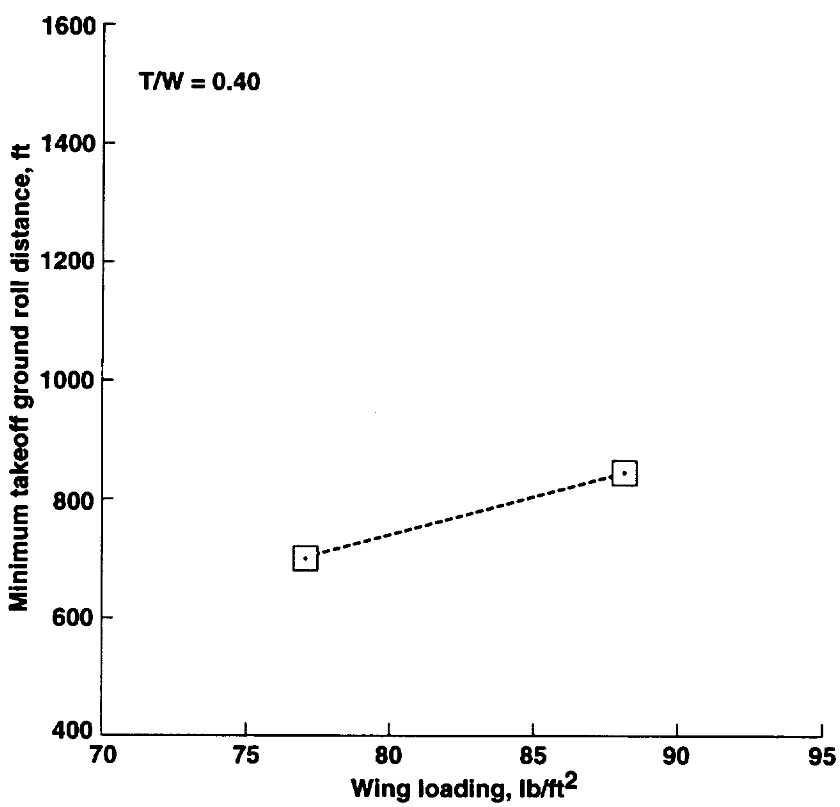


Figure 22(b). Unassisted takeoff performance with variation of wing loading.

9.6 Repeatability of Jump Strut Ground Roll Distance

Considerable variations in the measured takeoff ground roll distance (up to 80 feet greater than the minimum distances) were observed when test conditions were repeated. Variables such as wind effects and pilot technique (e.g., the rate of the aft movement of the control column upon activating the jump strut and the attitude held for liftoff and climb-out) are suspected to contribute to these variations. Adequate data, however, were produced to determine the maximum performance (minimum) takeoff ground roll distances for both the jump strut assisted and unassisted takeoffs.

10. Recommendations

Preliminary testing indicated that piloting technique prior to and during the rotation is critical in consistently obtaining minimum ground roll distance. Because limited test opportunities prevented a comprehensive investigation of ground roll and rotation piloting techniques, it is recommended that this area be explored.

Design innovations that improve the effectiveness and utilization of the jump strut (such as the use of a longer, single stage strut and the automatic inflight recharging of the pressure reservoir) are additional areas for further development.

11. Conclusions

A pneumatic jump strut development program and flight test evaluation to determine the influence of a nose gear jump strut on takeoff ground roll distance was conducted using the NASA Quiet Short-Haul Research Aircraft. The operational experience with the jump strut and the test data support the following conclusions.

The use of the jump strut reduces the takeoff ground roll distance for all conditions examined in the flight test investigation. The reduction of takeoff distance was found to improve with increasing thrust to weight ratio.

At a thrust to weight ratio of 0.4 and a wing loading of 88 lb/ft^2, the use of the jump strut reduced the takeoff ground roll distance by 110 feet, or 13% of the unassisted takeoff distance. This reduction of takeoff distance was found to diminish to a negligible amount when the thrust to weight ratio is decreased to 0.3.

Thrust to weight ratio more strongly influenced the takeoff ground roll distance for the jump strut assisted takeoff compared to the unassisted takeoff distance. For the nominal wing loading of 88 lb/ft^2, the assisted takeoff ground roll distance was reduced by approximately 320 feet by increasing T/W from 0.3 to 0.4. The unassisted takeoff distance was reduced by only 210 feet for the same change in T/W.

Variations of reservoir pressure between 2,000 and 3,000 psig and variations of control valve opening durations from 80 to 170 milliseconds, did not have a significant effect on the ground roll distance for jump strut assisted takeoffs.

For fixed valve opening times of 80 and 170 milliseconds, at initial pressure values from 2,000 to 3,000 psig, the maximum load produced by the jump strut increases slightly with increasing pressure.

The variation of wing loading between 77 and 88 pounds per square foot and associated c.g.s at 0.4 T/W for unassisted (no jump strut) takeoffs showed, as expected, that at the higher wing loading and more forword c.g. condition the aircraft lifts off at a higher airspeed and therefore requires a longer ground roll. Data were not obtained to evaluate the effect of the jump strut on takeoff distance for 0.4 T/W at a wing loading of 77 pounds per square foot.

For initial pneumatic source pressure ranging from 2,000 to 3,000 psig, the maximum load and the time required to reach that load after activating the jump strut are essentially unaffected by the duration of the control valve opening for values from 80 to 170 milliseconds. The longer durations, however, maintained higher loads for a greater portion of the strut extension.

References

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2. Wright Laboratory Advanced Transport Technology Mission Analysis. NASA Ames/U.S. Air Force Wright Laboratory MOU Annex Task 10, Jan. 23, 1989.

3. Study of Powered-Lift Aircraft Using Jump Struts. Lockheed, Burbank, NASA Ames Purchase Order A54556C, Final Report, Oct. 1987.

4. Riddle, D. W.; Innis, R. C.; Martin , J. L.; and Cochrane, J. A.: Powered-Lift Takeoff Performance Characteristics Determined from Flight Test of the Quiet Short-Haul Research Aircraft (QSRA). AIAA Paper 81-2409, AIAA/SEPT/SFTE/SAE First Flight Testing Conference, Las Vegas, Nevada, Nov. 1981.

5. Hurt, H. H., Jr.: Aerodynamics for Naval Aviators. University of Southern California, NAVAIR Rept. 00-80T-80.

Appendix A – QSRA/Jump Strut Hazard Analysis Summary

NASA - AMES RESEARCH CENTER

HAZARD CLASSIFICATION, RISK ASSESSMENT, AND RESOLUTION PRIORITY

Identified hazards will be classified according to HAZARD SEVERITY and HAZARD PROBABILITY. The urgency for resolution of a hazard is dependent upon the combination of the severity and probability of each hazard, or the HAZARD RISK ASSESSMENT (HRA).

1. HAZARD SEVERITY

A hazardous condition whose worst case feasible effects (immediate or long term cumulative) on personnel and/or the system (equipment/facility/aircraft) may be:

CATEGORY I	(CATASTROPHIC)	Death or permanent disabling injury and/or extensive damage resulting in loss of mission.
CATEGORY II	(CRITICAL)	Severe injury/illness or lost time injury (> 6 months) and/or serious damage resulting in significant delay of mission.
CATEGORY III	(MARGINAL)	Minor injury/illness or lost time injury (> 1 day < 6 months) and/or minor damage resulting in limited delay of mission.
CATEGORY IV	(NEGLIGIBLE)	No lost time injury/illness and/or neglible system damage.

2. HAZARD PROBABILITY

LEVEL A (PROBABLE)	Likely to occur several times in the life of the system.
LEVEL B (REMOTE)	Likely to occur once in the life of the system.
LEVEL C (IMPROBABLE)	Not likely to occur in the life of the system.
LEVEL D (HIGHLY IMPROBABLE)	Occurrence is considered to be extremely unlikely in the life of the system.

3. HAZARD RISK ASSESSMENT (HRA) MATRIX

Hazard Probability	Hazard Severity I	II	III	IV
A	1	1	2	3
B	1	1	2	3
C	2	2	3	4
D	3	3	4	4

4. HAZARD RESOLUTION PRIORITY

Initial HRA		Priority
1	(UNACCEPTABLE)	Resolve or accept residual risk prior to any testing or flight.
2	(UNDESIRABLE)	Resolved or accept residual risk prior to start of research.
3	(ACCEPTABLE WITH REVIEW)	Resolution is desirable.
4	(ACCEPTABLE WITHOUT REVIEW)	Resolution is not required.

5. RESIDUAL RISK ACCEPTANCE

Final HRA		Required Sign-Offs
1	(UNACCEPTABLE)	Project Mgr., User Division Line Mgmt., User Org. Director, Center Director.
2	(UNDESIRABLE)	Project Mgr., User Division Line Mgmt.
3	(ACCEPTABLE WITH REVIEW)	Project Mgr., User Branch Line Mgmt.
4	(ACCEPTABLE WITHOUT REVIEW)	Project Mgr.

12/4/90

QSRA JUMP STRUT HAZARD SUMMARY				
Document: FMEA		Safety Engineer: J. Barnes		* Projected final HRAs assuming completion of Planned Actions.
HR # ARCX-03	INITIAL HRA	FINAL HRA *	Status	Hazard Consequence
JS001	2	3	O	Personnel injury from exposure to invisible pin-hole sized N2 leak during maintenance/servicing.
JS002	3	3	O	Personnel injury from exposure to blast or flying fragments due to overpressure and rupture during servicing.
JS003	4	4	O	Minor damage to system from explosive release of N2 due to actuation with 3,500 psi in system.
JS004	4	4	O	Loss of test run from inability to pressurize system due to blockage from contamination/corrosion.
JS005	3	3	O	Serious system damage and delay of project from structural failure of components due to aerodynamic forces or hard landing.
JS006	3	3	O	Loss of control, loss of aircraft and loss of crew from excess energy in pneumatic system due to improperly servicing to 3,500 psi.
JS007	4	4	O	Loss of test run, inaccurate data, degraded system performance from inadequate energy in the system due to imporper system servicing.
JS008	4	4	O	Loss of test run; system down from failure of pilot's system pressure gage.
JS009	4	4	O	Loss of test run; system down from inability to service with N2 due to defective servicing valve.
JS010	4	4	O	Loss of test run; degraded performance from blockage in system from contamination/corrosion.
JS011	4	4	O	Loss of test run; no flow of N2 to jump strut from blockage in system or other electrical or mechanical failure.
JS012	2	3	O	Loss of control (over-rotation), loss of aircraft, and loss of crew from excess energy in the jump strut due to main valve opening but failing to close.
JS013	2	3	O	Loss of control (landing on damaged or separated strut), loss of aircraft, and loss of crew from excess energy in the jump strut due to main valve opening but failing to close.
JS014	4	4	O	Loss of primary path for exhausting gas from strut after actuation; system functions normally on back-up exhaust path but is down until blockage is removed.
JS015	4	4	O	Loss of secondary path for exhausting gas from strut after actuation; system functions normally on primary exhaust path but is down until blockage is removed.
JS016	4	4	O	Loss of system integrity and possible interior corrosion from moisture and contamination due to failure of either exhaust check valve or vent check valve failing to close (broken spring).

QSRA JUMP STRUT HAZARD SUMMARY				
Document: FMEA		Safety Engineer: J. Barnes		* Projected final HRAs assuming completion of Planned Actions.
HR # ARCX-03	INITIAL HRA	FINAL HRA *	Status	Hazard Consequence
JS017	3	3	O	Serious damage to strut and delay of project from landing on strut stuck in fully extended position due to blockage from contamination/corrosion.
JS018	4	4	O	Loss of test run; unable to Arm system due to Squat switch failed in AIR position, Arm/Disarm switch failed in DISARM position, open circuit, short circuit, or loss of 28 vdc power.
JS019	4	4	O	Loss of test run; system down due to loss of safety feature of Squat switch (failed in GND (closed) position).
JS020	4	4	O	Loss of test run; system down when armed continuously on the ground or system goes to ARM after landing due to Arm/Disarm switch failed in the ARM position or sneak circuit.
JS021	4	4	O	Loss of test run; system down when unable to monitor system condition (Arm light will not come on when ARMED) due to burned out bulb, other open circuit, or loss of 28 vdc power.
JS022	4	4	O	Loss of test run; system down when backup timers fail to operate due to loss of initiating signal or IC malfunction.
JS023	4	4	O	Loss of test run; system down when backup timers run uncommanded or provide continuous output due to sneak circuit or IC malfunction.
JS024	4	4	O	Loss of test run; degraded performance or no actuation at all from Lewis timer failure due to IC, diode, Engage button or relay malfunction.
JS025	2	3	O	Personnel injury or death from impact by nose or tail ramp from uncommanded actuation on preflight or ground checkout due to Engage button or relay failing in the on (short circuit) position.
JS026	3	3	O	Loss of aircraft and crew from electrical fire due to short circuit in 28 vdc power circuit.
JS027	4	4	O	Loss of test run and overcurrent protection; system down due to 28 vdc circuit malfunction (circuit breaker will not open).
JS028	2	3	O	Serious damage to strut and project delay from landing on a "flat" strut due to loss of hydraulic fluid or N2 from low or high pressure chambers of strut.
JS029	3	3	O	Serious damage (excess shimmy or collapse) to strut and project delay from landing with nose wheel cocked due to upper or lower cams failing to center strut before landing.
JS030	3	3	O	Serious damage to aircraft (structural) from excess upward force to nose support structure due to normal jump strut activation.
JS031	3	3	O	Serious damage to aircraft from running off end of runway due to uncommanded premature rotation due to sneak circuit.

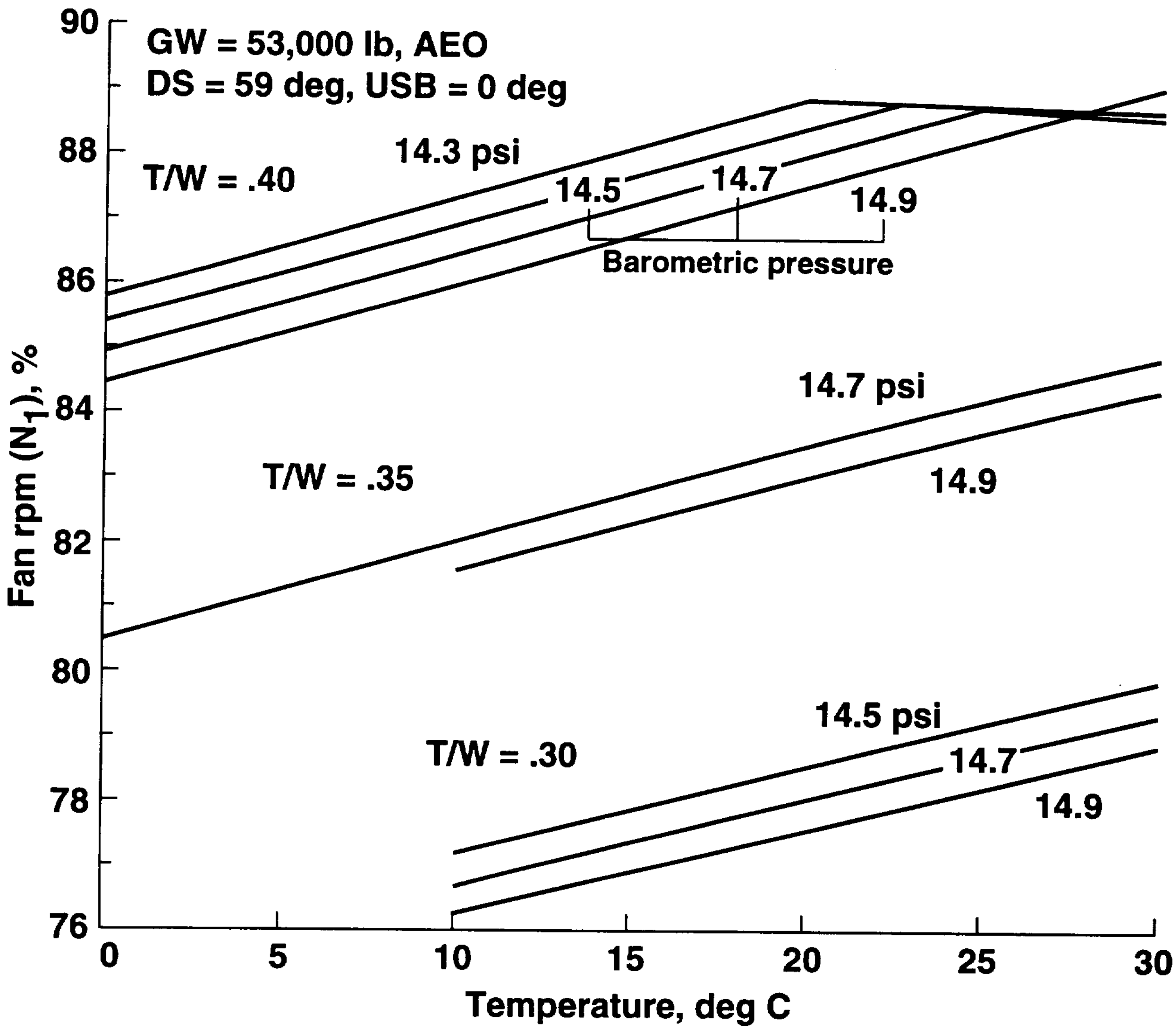

Figure B.1 QSRA-installed engine (YF-102) performance.

Appendix C – Flight Data Summary

QSRA (3.1) CURRENT 10/21/93

Mon, Oct 25, 1993 11:12 AM

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	CNTR	VCAIRK	Vcorr	RPM.AVG	Pa	TEMPC	W	W/S	Initial Pv	T valve	Target T/W	U,NJS,.45	U,NJS,.4	U,NJS,.3	U,JS.4,2.5K,10	U,JS.4,3K,10
1	149	62.0	64.7	85.0	14.77	14.5	52655	87.76			0.400		960			
2	150	60.0	62.7	85.0	14.75	16.1	52399	87.33			0.400		850			
3	152	58.0	60.7	85.0	14.74	16.2	52392	87.32			0.400		890			
4	153	56.0	58.7	85.0	14.74	16.2	52298	87.16			0.400		910			
5	154	56.0	58.7	84.0	14.75	16.6	50780	84.63			0.400		950			
6	155	62.0	64.7	85.0	14.74	16.6	52297	87.16	2520	80	0.400				820	
7	156	60.0	62.7	85.0	14.74	16.5	52765	87.94	2600	80	0.400				760	
8	157	58.0	60.7	85.0	14.74	16.4	52734	87.89	2610	80	0.400				760	
9	159	60.0	62.7	85.0	14.76	4.7	49865	83.11			0.400		870			
10	160	59.0	61.7	85.0	14.76	4.8	49464	82.44			0.400		850			
11	161	56.0	58.7	86.0	14.76	5.1	49055	81.76			0.400		820			
12	162	61.0	63.7	84.0	14.76	5.4	48602	81.00			0.400		845			
13	163	60.5	63.2	84.5	14.75	7.4	52869	88.11	2580	170	0.400				780	
14	164	58.0	60.7	85.0	14.74	7.1	52827	88.05	2610	170	0.400				750	
15	165	56.0	58.7	85.0	14.74	7.4	52319	87.20	2600	170	0.400				720	
16	166	55.5	58.2	85.0	14.74	8.1	52850	88.08	2630	170	0.400				775	
17	167	52.0	54.7	85.0	14.74	8.0	52377	87.29	2520	170	0.400				820	
18	168	58.0	60.7	85.0	14.74	7.4	52876	88.13	3120	80	0.400					
19	169	56.0	58.7	85.0	14.73	7.1	52291	87.15	3080	80	0.400					
20	170	54.0	56.7	85.0	14.73	7.5	52844	88.07	3060	80	0.400					
21	171	60.0	62.7	84.5	14.73	7.6	52341	87.24	3020	80	0.400					
22	172	58.0	60.7	85.0	14.72	8.0	52876	88.13	3020	130	0.400					
23	173	57.5	60.2	85.0	14.72	8.3	52380	87.30	3040	130	0.400					
24	174	55.0	57.7	85.0	14.71	8.4	52833	88.05	2960	130	0.400					
25	175	58.0	60.7	85.0	14.72	8.7	52292	87.15	3110	170	0.400					720
26	176	56.0	58.7	85.0	14.72	8.9	52873	88.12	3000	170	0.400					785
27	177	54.0	56.7	85.5	14.72	9.3	52371	87.29	3100	170	0.400					740
28	178	58.0	60.7	85.8	14.71	9.3	52833	88.06	1830	170	0.400					
29	179	54.5	57.2	85.5	14.72	9.3	52332	87.22	2000	170	0.400					
30	180	54.0	56.7	85.2	14.71	9.4	52882	88.14	1980	170	0.400					
31	181	67.0	69.7	76.2	14.71	9.4	52339	87.23	2500	170	0.300					
32	182	67.0	69.7	76.0	14.71	9.5	52871	88.12	2440	170	0.300					
33	183	65.0	67.7	76.5	14.71	9.5	52293	87.16	2550	170	0.300					
34	184	62.0	64.7	76.2	14.71	9.9	52897	88.16	2500	170	0.300					
35	185	60.0	62.7	76.0	14.71	9.6	52396	87.33	2530	170	0.300					
36	186	58.0	60.7	76.0	14.71	9.4	52836	88.06	2470	170	0.300					
37	187	64.0	66.7	76.0	14.77	11.2	50320	83.87			0.300			1170		
38	188	62.5	65.2	74.5	14.77	11.3	49962	83.27			0.300			1205		
39	189	60.0	62.7	76.0	14.77	12.2	52783	87.97			0.300			1200		
40	190	58.0	60.7	76.0	14.77	12.5	52361	87.27			0.300			1145		
41	191	54.0	56.7	86.0	14.76	12.7	52719	87.87			0.400		975			
42	192	60.0	62.7	86.0	14.75	13.1	51820	86.37			0.400		890			
43	193	62.5	65.2	86.0	14.76	13.2	52712	87.85			0.400		940			
44	194	60.5	63.2	86.0	14.75	13.5	52363	87.27	2980	80	0.400					
45	195	58.0	60.7	85.5	14.74	14.0	52585	87.64	2920	80	0.400					
46	196	56.0	58.7	86.0	14.74	13.5	52640	87.73	3020	80	0.400					
47	197	57.0	59.7	85.5	14.75	13.9	51990	86.65	3090	130	0.400					
48	198	56.0	58.7	86.0	14.74	14.3	52727	87.88	3020	170	0.400					800
49	199	58.0	60.7	86.0	14.74	14.5	52098	86.83	3090	170	0.400					800
50	200	60.0	62.7	85.5	14.74	14.6	52673	87.79	3080	170	0.400					910
51	201	54.0	56.7	86.0	14.74	14.8	51991	86.65	3100	170	0.400					820
52	170	62.5	65.2	86.0	14.74	14.9	52745	87.91	2400	170	0.400				865	
53	203	68.0	70.7	86.0	14.74	14.7	52206	87.01	2510	170	0.400				970	
54	204	62.5	65.2	82.0	14.74	14.5	52761	87.93	2400	170	0.350					
55	205	63.0	65.7	82.0	14.74	14.8	52140	86.90	2540	170	0.350					
56	206	59.0	61.7	82.0	14.74	14.7	52751	87.92	2390	170	0.350					
57	207	64.0	66.7	80.5	14.71	17.0	46253	77.09			0.400		1000			
58	208	61.0	63.7	81.0	14.71	17.0	45848	76.41			0.400		930			
59	209	60.0	62.7	81.0	14.71	18.0	46430	77.38			0.400		910			
60	210	58.0	60.7	81.5	14.71	18.1	46160	76.93			0.400		930			
61	211	56.0	58.7	81.0	14.71	18.7	46450	77.42			0.400		890			
62	212	54.0	56.7	81.5	14.71	18.9	46000	76.67			0.400		910			
63	213	51.0	53.7	81.5	14.71	18.6	45880	76.47			0.400		900			
64	214	67.0	69.7	85.5	14.71	19.2	46350	77.25	2440	170	0.450					
65	215	64.0	66.7	85.0	14.70	19.2	46000	76.67			0.450	895				
66	216	62.0	64.7	86.0	14.70	18.9	46500	77.50	2490	170	0.450					
67	217	60.0	62.7	86.0	14.70	19.3	46000	76.67			0.450	745				
68	218	55.0	57.7	86.0	14.70	19.4	46500	77.50	2540	170	0.450					
69	219	54.0	56.7	86.0	14.70	19.8	46177	76.96			0.450	750				

QSRA (3.1) CURRENT 10/21/93 Mon, Oct 25, 1993 11:12 AM

	17	18	19	20	21	22	23	24	25	26	27
	U,JS.4,3K,8	U,JS.4,3K,5	U,JS.4,2K,10	U,JS.3,2.5K,10	U,JS.35,2.5K,10	U,JS.45,2.5K,10	TO.DIST,No Corr	T/W	Target T/W-T/W	X Delta for T/W	Wind
1							960	0.383	0.017	56	-0.5
2							850	0.382	0.018	59	2.7
3							890	0.381	0.019	60	-0.3
4							910	0.382	0.018	58	-1.5
5							950	0.382	0.018	56	0.7
6							820	0.382	0.018	59	0.7
7							760	0.378	0.022	70	1.2
8							760	0.378	0.022	69	2.9
9							870	0.423	-0.023	-72	0.2
10							850	0.426	-0.026	-82	-0.3
11							820	0.440	-0.040	-128	0.0
12							845	0.421	-0.021	-67	-0.1
13							780	0.439	-0.039	-125	1.3
14							750	0.394	0.006	18	2.7
15							720	0.398	0.002	7	2.7
16							775	0.393	0.007	23	0.9
17							820	0.396	0.004	12	0.7
18		830					830	0.393	0.007	21	-1.3
19		785					785	0.398	0.002	6	0.2
20		840					840	0.393	0.007	21	-1.3
21		800					800	0.392	0.008	26	-0.3
22	815						815	0.392	0.008	25	-0.3
23	705						705	0.395	0.005	14	2.7
24	740						740	0.392	0.008	27	3.7
25							720	0.395	0.005	15	1.7
26							785	0.391	0.009	30	0.7
27							740	0.399	0.001	3	2.7
28			745				745	0.399	0.001	5	1.7
29			760				760	0.399	0.001	2	1.7
30			800				800	0.392	0.008	26	1.7
31				1090			1090	0.302	-0.002	-5	1.2
32				1145			1145	0.296	0.004	12	0.9
33				1070			1070	0.305	-0.005	-15	0.4
34				1110			1110	0.298	0.002	7	-1.5
35				1120			1120	0.299	0.001	4	-1.8
36				1130			1130	0.297	0.003	11	-1.3
37							1170	0.309	-0.009	-27	-2.3
38							1205	0.294	0.006	19	-0.8
39							1200	0.293	0.007	24	-3.1
40							1145	0.295	0.005	17	-2.1
41							975	0.395	0.005	16	-3.1
42							890	0.401	-0.001	-3	-1.8
43							940	0.394	0.006	19	-1.8
44		855					855	0.396	0.004	12	-3.3
45		855					855	0.388	0.012	37	-3.3
46		830					830	0.394	0.006	20	-3.3
47	815						815	0.393	0.007	22	-2.6
48							800	0.392	0.008	25	2.7
49							800	0.396	0.004	11	-2.3
50							910	0.387	0.013	42	-3.8
51							820	0.397	0.003	10	-3.3
52							865	0.391	0.009	29	-2.3
53							970	0.395	0.005	15	-2.3
54					920		920	0.350	-0.000	-1	-0.8
55					955		955	0.354	-0.004	-14	-1.8
56					910		910	0.350	-0.000	-1	-1.3
57							1000	0.377	0.023	72	-4.3
58							940	0.387	0.013	43	-5.3
59							920	0.380	0.020	64	-4.3
60							940	0.408	-0.008	-26	-6.3
61							900	0.379	0.021	66	-5.3
62							910	0.390	0.010	31	-7.3
63							900	0.391	0.009	28	-7.3
64						800	800	0.454	-0.004	-13	-2.3
65							895	0.430	0.020	65	-6.3
66						690	690	0.437	0.013	41	-0.3
67							745	0.441	0.009	29	-2.3
68						695	695	0.455	-0.005	-15	-4.3
69							750	0.437	0.013	41	-2:3

QSRA (3.1) CURRENT 10/21/93 Mon, Oct 25, 1993 11:12 AM

	28	29	30	31	32	33	34	35	36	37	38
	K	T.O.DIST w.Wind Corr	T.O.DIST w.Wind & T/W	C,NJS,.45,77	C,NJS,.4,88	C,NJS,.4,77	C,NJS,.3,88	C,JS.4,2.5K,10	C,JS.4,3K,10	C,JS.4,3K,8	C,JS.4,3K,5
1	0.987	948	892		892						
2	1.070	910	851		851						
3	0.992	883	824		824						
4	0.961	875	817		817						
5	1.018	967	911		911						
6	1.018	835	776					776			
7	1.031	784	713					713			
8	1.075	817	748					748			
9	1.005	875	947		947						
10	0.992	843	926		926						
11	1.000	820	948		948						
12	0.997	843	910		910						
13	1.034	806	931					931			
14	1.070	803	785					785			
15	1.070	771	764					764			
16	1.023	793	770					770			
17	1.018	835	823					823			
18	0.966	802	781								781
19	1.005	789	783								783
20	0.966	812	791								791
21	0.992	794	768								768
22	0.992	809	783							783	
23	1.070	754	740							740	
24	1.096	811	785							785	
25	1.044	752	737						737		
26	1.018	799	769						769		
27	1.070	792	789						789		
28	1.044	778	773								
29	1.044	794	792								
30	1.044	835	809								
31	1.031	1124	1129								
32	1.023	1172	1160								
33	1.010	1081	1096								
34	0.961	1067	1059								
35	0.953	1068	1064								
36	0.966	1092	1081								
37	0.940	1100	1128				1128				
38	0.979	1180	1161				1161				
39	0.919	1103	1080				1080				
40	0.945	1082	1065				1065				
41	0.919	896	880		880						
42	0.953	848	852		852						
43	0.953	896	877		877						
44	0.914	782	770								770
45	0.914	782	745								745
46	0.914	759	739								739
47	0.932	760	738							738	
48	1.070	856	831						831		
49	0.940	752	741						741		
50	0.901	820	778						778		
51	0.914	750	739						739		
52	0.940	813	784					784			
53	0.940	912	897					897			
54	0.979	901	902								
55	0.953	910	924								
56	0.966	879	878								
57	0.888	888	816			816					
58	0.862	810	768			768					
59	0.888	817	753			753					
60	0.836	786	812			812					
61	0.862	776	710			710					
62	0.810	737	706			706					
63	0.810	729	701			701					
64	0.940	752	765								
65	0.836	748	683	683							
66	0.992	685	644								
67	0.940	700	671	671							
68	0.888	617	632								
69	0.940	705	664	664							

QSRA (3.1) CURRENT 10/21/93 Mon, Oct 25, 1993 11:12 AM

	39	40	41	42
	C,JS.4,2K,10	C,JS.3,2.5K,10	C,JS.35,2.5K,10	C,JS.45,2.5K,10
1				
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Flight Investigation of the Use of a Nose Gear Jump Strut to Reduce Takeoff Ground Roll Distance of STOL Aircraft

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13. ABSTRACT *(Maximum 200 words)*

A series of flight tests was conducted to evaluate the reduction of takeoff ground roll distance obtainable from a rapid extension of the nose gear strut. The NASA Quiet Short-haul Research Aircraft (QSRA) used for this investigation is a transport-size short takeoff and landing (STOL) research vehicle with a slightly swept wing that employs the upper surface blowing (USB) concept to attain the high lift levels required for its low speed, short-field performance. Minor modifications to the conventional nose gear assembly and the addition of a high pressure pneumatic system and a control system provided the extendible nose gear, or "jump strut," capability. The limited flight test program explored the effects of thrust-to-weight ratio, storage tank initial pressure, and control valve open time duration on the ground roll distance. The data show that the predicted reduction of takeoff ground roll on the order of 10% was achieved with the use of the jump strut as predicted. Takeoff performance with the jump strut was also found to be essentially independent of the pneumatic supply pressure and was only slightly affected by control valve open time within the range of the parameters examined.

14. SUBJECT TERMS

Jump strut, Short takeoff, STOL

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