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MEMORANDUM

FLIGHT INVESTIGATION OF THE STABILITY
AND CONTROL CHARACTERISTICS OF A 1/4-SCALE MODEL OF A
TILT-WING VERTICAL-TAKE-OFF-AND-LANDING AIRCRAFT

By Louis P. Tosti

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Langley Field, Va.

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MEMORANDUM 11-4-58L

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SUMMARY

An experimental investigation has been conducted to determine the dynamic stability and control characteristics of a tilt-wing vertical-take-off-and-landing aircraft with the use of a remotely controlled 1/4-scale free-flight model. The model had two propellers with hinged (flapping) blades mounted on the wing which could be tilted up to an incidence angle of nearly 90° for vertical take-off and landing. The investigation consisted of hovering flights in still air, vertical take-offs and landings, and slow constant-altitude transitions from hovering to forward flight.

The stability and control characteristics of the model were generally satisfactory except for the following characteristics. In hovering flight, the model had an unstable pitching oscillation of relatively long period which the pilots were able to control without artificial stabilization but which could not be considered entirely satisfactory. At very low speeds and angles of wing incidence on the order of 70°, the model experienced large nose-up pitching moments which severely limited the allowable center-of-gravity range.

INTRODUCTION

An investigation has been conducted to determine the dynamic stability and control characteristics of a 1/4-scale flying model of the Vertol 76 tilt-wing VTOL aircraft.

The first phase of this investigation, which was reported in reference 1, dealt with the results of force tests of the model. The present phase of the investigation consisted of hovering flights near the ground and well above the ground, vertical take-offs and landings, and slow constant-altitude transitions from hovering to forward flight in the Langley full-scale tunnel. The results were obtained mainly from pilots' observations and from studies of motion-picture records of the flights.

APPARATUS AND TESTS

Model

A photograph of the 1/4-scale model of the Vertol 76 tilt-wing VTOL aircraft is shown in figure 1 and a three-view sketch showing some of the more important dimensions is shown in figure 2. Tables I and II list the geometric and mass characteristics of the model. The model had two 3-blade propellers with flapping hinges and was powered by a 6-horsepower electric motor which drove the propellers through shafting and right angle gear boxes. The speed of the motor was changed to vary the thrust of the propellers.

The wing was pivoted at the 37-percent-chord station and could be rotated between incidences of 4° and 86° during flight. The model had an all-movable horizontal tail and conventional aileron and rudder controls for forward flight. Roll control in hovering flight was provided by varying the pitch of the propellers differentially. For pitch and yaw control in hovering flight, the model had jet-reaction controls in the rear of the fuselage instead of recessed tail fans in the horizontal and vertical tails which are used on the airplane. The jet-reaction controls were used on the model to reduce the cost and expedite the model construction since the tail fans would have been so small that their design, construction, drive system, and maintenance would have been very difficult and time consuming.

The controls were deflected by flicker-type (full-on or full-off) pneumatic actuators which were remotely operated by the pilots by means of solenoid-operated valves. The control actuators were equipped with integrating-type trimmers which trimmed the controls a small amount each time a control was applied. With actuators of this type, a model becomes accurately trimmed after flying a short time in a given flight condition.

Test Equipment and Setup

The test setup used in the hovering flight tests and in the transition flight tests in the Langley full-scale tunnel was essentially the same and is illustrated by the sketch shown in figure 3. The power for the main propulsion motor, the wing-tilting motor, and electric-control solenoids was supplied through wires, and the air for the control actuators and tail control jets was supplied through plastic tubes. These wires and tubes were suspended from above and taped to a safety cable (1/16-inch braided aircraft cable) from a point about 15 feet above the model down to the model itself. The safety cable, which was attached to the fuselage near the center of gravity, was used to prevent crashes in the event of a power or control failure or in the event that the pilots lost control of the model. During flight, the cable was kept slack so that it did not appreciably influence the motions of the model. Separate pilots are used to control the model in pitch, roll, and yaw since it has been found that if a single pilot operates all three controls, he is so busy controlling the model that he has difficulty in ascertaining the true stability and control characteristics of the model about its various axes. The take-off, landing, hovering, and oscillation tests were made with an almost identical setup in a large building that provided protection from inclement weather and the random effects of outside air currents.

Tests

The investigation covered in this paper consisted entirely of flight tests. The results were mainly qualitative and consisted of pilots' observations and opinions of the behavior of the model. Motion-picture records were made of all the flights for subsequent and more detailed studies.

The hovering flight tests were made to determine the basic stability and control characteristics of the model in still air at a height of 15 to 20 feet above the ground to eliminate any possible effect of ground proximity. In these tests the uncontrolled pitching motions and the ease with which these motions could be stopped after they had been allowed to develop was also studied. The center-of-gravity location for the uncontrolled-pitching-motion tests was at 1 percent chord forward of the wing pivot. The model was also flown in controlled flight over a range of center-of-gravity positions in an attempt to establish an allowable center-of-gravity range.

Hovering flight tests were also made near the ground to determine the effect of proximity of the ground on the flight behavior of the model. These tests were made with the wheels from about 2 inches to 10 inches above the ground. They consisted entirely of controlled flights since it was not possible for an oscillation to build up before hitting the ground.

Take-off and landing tests were made only for the condition with the center of gravity located at 1 percent chord forward of the wing pivot. The take-off tests were made by rapidly increasing the power to the propellers until the model rose from the ground. The power operator then adjusted the power for hovering and the model was stabilized at various heights above the ground. For the landing tests, the power operator reduced the power in such a manner that the model descended slowly until the landing gear was about 6 inches above the ground. At this point, the power was reduced as quickly as possible and the model settled to the ground on the landing gear.

Flight tests representing slow constant-altitude transitions were made to study the stability and control characteristics of the model and to determine the effects of tail incidence, fuselage attitude, tail-jet force, and center-of-gravity position. The transition flight tests were made for a range of center-of-gravity locations from 13 percent chord forward of the wing pivot to 2 percent chord behind the wing pivot. The center-of-gravity locations are referred to in the discussion of the flight tests in terms of the location when the wing was in the hovering flight position (86° incidence). As the wing rotated to 4° incidence, the center of gravity of the model moved downward approximately 5 percent chord and forward approximately 5 percent chord. The vertical location of the center of gravity of the model for the hovering condition was 2.25 inches below the wing pivot.

The transition tests were made in the Langley full-scale tunnel by starting with the model hovering in the test section at zero airspeed. As the airspeed was increased by the tunnel operator, the wing-tilt operator gradually reduced the wing incidence to maintain the model location in the test section during the transition. These flights covered a speed range from 0 to about 48 knots. Since the model was a 1/4-scale model of the full-scale aircraft, the corresponding scaled-up airspeeds would be twice those of the model. Small adjustments or corrections in the tunnel airspeed could not be made readily; the pitch pilot, wing-tilt operator, and power operator therefore had continually to make adjustments to hold the model in the center of the test section. Flights were also made in which the airspeed was held constant at intermediate speeds of 22, 29, and 36 knots so that the stability and control characteristics at constant speed could be studied.

In all the detailed hovering tests, the maximum up or down force available from the pitch jet was 3.6 percent model weight. A limited number of hovering flight tests were made with pitch-jet forces of ±5.0 and ±7.3 percent model weight. Most of the transition tests were made with a maximum pitch-jet force of ±5.0 percent model weight, although a few preliminary transition tests were made with a force of ±7.3 percent model weight. At the time the tests were made, a value of ±3.6 percent model weight was believed to represent approximately the force available from the pitch-control tail fan on the full-scale aircraft. On the basis of an aircraft gross weight of 3,139 pounds and the difference between the tail length of the pitch-control fan on the aircraft and the scaled-up tail length of the pitch jet on the model, a jet force of ±3.6 percent model weight represented a tail-fan force on the aircraft of about ±135 pounds. A tail-jet force of ±5.0 percent model weight represented a tail-fan force of ±190 pounds and a tail-jet force of ±7.3 percent model weight represented a tail-fan force of ±280 pounds. The horizontal stabilizer when it was used as a pitch control was deflected $\pm 9^{\circ}$ by a flicker-control actuator.

Yaw control in hovering and low-speed flight was obtained by a compressed-air tail jet to produce a maximum sideward force which was always one-half of that used for pitch control. The rudder could be switched into and out of the yaw-control circuit but it usually operated during the entire transition flight. Shortly after the speed had built up sufficiently to give adequate yaw control with the rudder alone, the yaw pilot generally switched out the yaw jet and flew with the rudder only. The rudder deflection that was used was $\pm 11^{\circ}$.

Roll control in hovering and during the low speed part of transition flight was obtained by varying the pitch of the propellers differentially $\pm 1\frac{1}{2}^{\circ}$. At the higher speeds, or lower angles of incidence, the ailerons were switched in to work in conjunction with the propellers, and for the remainder of the flight both the propellers and the ailerons were used for roll control. The ailerons, when used, were deflected $\pm 18^{\circ}$.

RESULTS AND DISCUSSION

A motion-picture film supplement to this paper has been prepared and is available on loan. A request card form and a description of the film will be found at the back of this paper, on the page immediately preceding the abstract and index pages.

The overall impression of the pilots after flying the model throughout the test program was that the stability and control characteristics were generally satisfactory and the model could be flown reasonably easily and safely without the use of artificial stabilization. They felt, however, that when the amount of longitudinal control currently used in the full-scale aircraft (pitch-fan force of ±200 pounds) was simulated on the model, the control was somewhat weaker than was desired to cope with the unstable pitching oscillation encountered in hovering and the large nose-up pitching moment encountered at low forward speeds at wing incidence of about 70°.

Hovering Flight

Pitching motions.- The flight tests showed that the model had an unstable pitching oscillation with a period of about 3 seconds and a time to double the amplitude of about 0.7 second. With a pitch jet-reaction-control force of ±3.6 percent of the model weight, the pilot was able to control the model as long as it was not subjected to any large disturbances. When the model was allowed to build up a fairly high pitching velocity, however, the pitch control was not sufficiently powerful to enable the pilot to stop the unstable pitching oscillation and restore the model to steady flight. In some flights in which the available tail-jet pitch control was doubled (±7.3 percent of the model weight), the control seemed to be adequate to control the oscillations. The controllability of the full-scale aircraft might be slightly better than is implied by these results because the pitching radius of gyration of the aircraft is about 12 percent less than that of the model.

In hovering with a tail-jet-reaction control of ±3.6 percent of the model weight for pitch control, the model could be trimmed with sufficient margin for control for steady flight in still air for a longitudinal center-of-gravity range from 7 percent chord forward of the wing pivot to 10 percent chord behind the pivot. The actual center of gravity of the full-scale aircraft as first flown with one pilot and the research instrumentation aboard was 0.6 percent chord behind the pivot, which is very nearly in the middle of the center-of-gravity range that could be trimmed in hovering.

Rolling motions.- The model was very easy to control in roll. The roll control travel of $\pm 1\frac{1}{2}^{\circ}$ differential propeller pitch was adequate in all the hovering flight tests. No attempt was made to determine the characteristics of the uncontrolled rolling motions because of the danger of the propellers hitting the flight cable and because the exact character of the motions did not seem important since the model was so easy to control. Experience with other models of this general type, such as that of reference 2, has shown that they have unstable rolling oscillations of very long period which in all cases have been easy to control provided adequate rolling moments and rates of application were available from the control system.

Yawing motions.- There was, of course, no stability of yaw position because there was no static restoring moment in yaw. Continual use of yaw control was therefore required to prevent yawing as a result of random disturbances on the model. It is important to maintain a constant heading when flying the model because the model must be properly oriented with respect to the remote pilots in order for them to control it efficiently. The yaw pilot was always able to keep the model properly oriented regardless of the attitude or speed of translation that developed in the hovering flight tests. The model was controllable with a yaw-jet force of ±1.8 percent of the model weight but was not as lively as the pilot considered desirable. The pilot felt that the yaw-jet force of ±3.6 percent of the model weight was the minimum that would give satisfactory control. Considering the difference in moments of inertia as well as the differences in tail lengths, a yaw-jet force of ±3.6 percent of the model weight gave a yawing acceleration representative of that obtainable on the full-scale aircraft with a yaw-fan force of ±110 pounds, which was the design value.

Take-Offs and Landings

Take-offs and landings were easy to perform and involved no special problems other than those associated with hovering flight which were discussed in the previous sections. There was no noticeable effect of ground proximity on dynamic stability and control either in take-offs and landings or when the model was hovered for considerable lengths of time at heights from 2 to 10 inches above the ground. In these flights the pilots noted that it was easy to maneuver the model or keep it over a spot and they were unable to detect any variation of lift or pitching moments with height above the ground.

Previous experience with ground effect on models of this general type (see refs. 2, 3, and 4) indicates that if the open fuselage of the aircraft is covered, some appreciable ground effect may be introduced. The presence of the ground for a configuration of this type causes a strong upwash under the fuselage which, on a covered fuselage, can produce large changes in pitching moment and lift. The sign and magnitude of the pitching moments are greatly influenced by the fuselage shape and position (ref. 3).

Transition Flight

Pitching motions.- The most noticeable longitudinal characteristic of the model was that it developed a large nose-up pitching moment as it started through transition at wing incidences somewhere between 80° and 60°. This change in trim with speed and wing incidence severely limited the range of center-of-gravity positions for which it was possible to perform the transition successfully. With the pitch-jet force of ±5.0 percent of the model weight, the model could be flown through the transition easily with a fuselage angle of attack and tail incidence of 0° for a range of center-of-gravity positions from 7 to 13 percent chord forward of the wing pivot. The forward end of the center-of-gravity range was determined by the fact that the 13-percent-chord center-of-gravity location was the most forward that could be trimmed and controlled with the pitch-jet force available in hovering flight (±5.0 percent of the model weight). The rearward end of the center-of-gravity range was determined by the fact that with the center of gravity at a position 4 percent chord forward of the wing pivot there was not sufficient nose-down pitching moment available to trim the model at a wing incidence of about 75°.

In order to increase the nose-down pitching moment available for trimming the model in this high-wing-incidence range, the incidence of the tail was set at 10°, and, although some improvement was afforded, a complete transition still was not possible with the center of gravity at a position 4 percent chord ahead of the wing pivot. With a further increase in tail incidence to 20°, it was then barely possible to complete the transition. Since with the tail incidence at 0° and center of gravity located at 7 percent chord forward of the wing pivot it was possible to trim out the nose-up pitching moments with some appreciable margin for control, it seems that the use of 20° positive tail incidence moved the rearward end of the allowable center-of-gravity range back only about 1 or 2 percent chord.

A study of the effect of fuselage angle of attack on the longitudinal trim problem was made with the tail incidence at 0° and with a pitch-jet force of ± 5.0 percent of the model weight. With the center of gravity located 4 percent forward of the wing pivot, it was found that the nose-up pitching moments were even greater with the fuselage in a 10° nose-down attitude than with it level. With the fuselage in the 10° nose-up attitude, the longitudinal trim problem was greatly relieved. In order to determine the rearward center-of-gravity limit of the model when flown with the fuselage in the 10° nose-up attitude, the center of gravity was moved back progressively from a position 4 percent chord forward of the wing pivot. The most rearward center-of-gravity position at which transition was made was 1 percent chord forward of the pivot. Flights of the model with the center of gravity at 2 percent chord behind the wing pivot were not possible because the available nose-down pitch control was inadequate. Since the model center of gravity was moved in 3-percent-chord increments and the model was fairly easy to control with the center of gravity at 1 percent chord forward of the pivot, it is probable that the most rearward center-of-gravity position which was flyable was somewhat more rearward than this position. On the basis of the foregoing results it seems that the full-scale aircraft with the center of gravity at 1 percent chord behind the wing pivot and with the available pitch-fan force of ± 200 pounds should be able to perform satisfactorily slow constant-altitude transitions with a fuselage attitude of about 10° and a tail incidence of about 20°.

In order to determine the possible improvement in the rearward center-of-gravity limit by increased tail-jet force, transitions were made with the tail-jet force increased to ± 7.3 percent of the model weight. It was found that the most rearward center-of-gravity location with which transition could be made successfully with the fuselage level and a tail incidence of 0° was moved back from 7 percent chord forward to 2 percent chord behind the wing pivot. It is presumed that a similar 9-percent-chord improvement in the allowable center-of-gravity range could be obtained for other conditions such as a positive fuselage angle of attack.

Rolling motions.- Roll control is the most complex of the controls since the differential propeller pitch and ailerons interchange their functions between rolling and yawing moments as the wing tilts. With the full-scale aircraft, a system for phasing the differential propeller pitch out of and the ailerons into the roll-control circuit, as a function of wing incidence, is used to accomplish a smooth changeover from one control in hovering to the other in forward flight with the object of providing pure rolling moments through the transition. The model was not provided with a similar system for phasing one control out and the other in since, at the time the model was designed, no aerodynamic information was available on which to base the design of such a system. The technique used for roll control in transition with the model was to use only the differential propeller pitch for roll control until the pilot felt he was getting too much favorable yaw from the propellers. At that time, which occurred near the end of the transition (wing incidence of approximately 35° and speed of approximately 35 knots), the pilot switched the ailerons into the roll-control circuit. When the ailerons were used in conjunction with the differential propeller pitch for roll control, the adverse yawing moments of the ailerons tended to offset the excessive favorable yawing moments produced by the change in propeller pitch whereas the rolling moments of the ailerons tended to augment those produced by the propeller-pitch change.

The fact that the propeller-pitch change gave reasonably good roll control at low angles of wing incidence results from the change in velocity over the part of the wing in the propeller slipstream. For example, an increase in the pitch of the propeller on one wing increases the velocity over the wing behind the propeller and thereby causes an increase in the lift and drag of that part of the wing. The increase in lift gives a sizeable rolling moment whereas the increase in drag tends to offset the increase in thrust of the propeller.

Flights were made in which the airspeed was held constant at 22, 29, and 36 knots, and various combinations of aileron and differential propeller pitch were tried for roll control. At these three airspeeds good roll control was obtained by using only the differential propeller pitch control. Adding the aileron control to the differential propeller pitch control at 22 and 29 knots (wing incidence equals 53° and 43°, respectively) was undesirable since this combined roll control produced adverse yawing motions. With the airspeed held constant at 36 knots (wing incidence equals 36°), the roll control was satisfactory whether or not the ailerons were used in the roll-control circuit with the differential propeller pitch control. After transition was completed and the model was flying in the normal-flight range at angles of attack of about 10°, the combination of aileron and differential propeller pitch as roll control was adequate although the combined control did give some slight favorable yawing motions. No attempt was made to control the model with the ailerons alone or with coordinated aileron and rudder control because the number of electric circuits were limited.

Yawing motions.- The model was easy to control in yaw throughout the transition. The model required a certain amount of yaw control throughout the transition since it did not appear to have sufficient directional stability to avoid excessive yawing due to gusts in the tunnel and due to the use of roll control. At angles of wing incidence below 20°, the directional stability was adequate to permit the model to fly satisfactorily without the use of any yaw control. Most of the transitions were made with both the rudder and yaw jet operating. Successful transitions could be made, however, with only the tail jet used for yaw control.

In some of the transitions, the ailerons were switched into the roll-control circuit at too low a speed; thus, the roll control caused large adverse yawing moments. In these cases, yaw control at this time was very difficult. This result indicates the need for phasing the ailerons into the roll-control circuit properly on the full-scale aircraft.

CONCLUSIONS

The following conclusions are drawn from an investigation of the stability and control characteristics of a 1/4-scale flying model of a tilt-wing vertical-take-off-and-landing aircraft:

1. In hovering flight, the model had an unstable pitching oscillation with a period of about 3 seconds and a time to double the amplitude of about 0.7 second. With a pitch jet-reaction-control force of ±3.6 percent of the model weight, the pilot could control the model and fly it smoothly as long as it was not subjected to any large disturbances. With a pitch jet-reaction-control force of ±7.3 percent of the model weight, which is 40 percent more than is currently used on the aircraft, the pitch oscillation could be controlled very easily without the use of artificial stabilization.

2. The rolling motions of the model could be controlled easily in hovering flight by varying the total pitch of the propellers differentially $\pm 1\frac{1}{2}^{\circ}$, which is considerably less than the deflection available in the full-scale aircraft.

3. In hovering flight the yawing motions could be controlled satisfactorily with a yaw-jet force of ±3.6 percent of the model weight, which gave a yawing acceleration representative of that obtainable on the full-scale aircraft with a yaw-fan force of ±110 pounds, which was the designed value.

4. There was no noticeable effect of ground proximity on the stability, control, or trim of the model and consequently the take-offs and landings were easy to perform.

5. In the transition from hovering to normal forward flight, the model experienced a large nose-up pitching moment at angles of wing incidence on the order of 60° to 80° which severely limited the allowable center-of-gravity range. The full-scale aircraft with the center of gravity at 1 percent chord behind the wing pivot and with the available pitch-fan force of ±200 pounds should be able to perform satisfactorily slow constant-altitude transitions with a fuselage attitude of about 10° and a tail incidence of about 20°.

6. Rolling motions of the model could be controlled easily throughout the transition range by using only the differential propeller pitch control at angles of wing incidence down to approximately 35° and using both propeller pitch control and ailerons at lower angles of incidence.

7. The model was easy to control in yaw throughout the transition range, although it did not appear to have any appreciable directional stability at speeds corresponding to wing incidence above 20°. At higher speeds the model had sufficient directional stability to permit it to be flown without the use of yaw control.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Field, Va., October 1, 1958.

REFERENCES

1. Newsom, William A., Jr., and Tosti, Louis P.: Force-Test Investigation of the Stability and Control Characteristics of a 1/4-Scale Model of a Tilt-Wing Vertical-Take-Off-and-Landing Aircraft. NASA MEMO 11-3-58L, 1959.

2. Lovell, Powell M., Jr., and Parlett, Lysle P.: Hovering-Flight Tests of a Model of a Transport Vertical-Take-Off Airplane With Tilting Wing and Propellers. NACA TN 3630, 1956.

3. Newsom, William A., Jr.: Effect of Ground Proximity on the Aerodynamic Characteristics of a Four-Engine Vertical-Take-Off-and-Landing Transport-Airplane Model With Tilting Wing and Propellers. NACA TN 4124, 1957.

4. Tosti, Louis P., and Davenport, Edwin E.: Hovering Flight Tests of a Four-Engine-Transport Vertical Take-Off Airplane Model Utilizing a Large Flap and Extensible Vanes for Redirecting the Propeller Slipstream. NACA TN 3440, 1955.

TABLE I.- SCALED-UP GEOMETRIC CHARACTERISTICS OF THE MODEL

Propellers (3 blades each rotor):	
Diameter, ft	9.33
Solidity	0.239
Chord, ft	1.0
Wing:	
Pivot station, percent chord	37
Sweepback (leading edge), deg	0
Airfoil section	NACA 4415
Aspect ratio	5.42
Chord, ft	4.75
Taper ratio	1.0
Area, sq ft	118.2
Span, ft	24.88
Dihedral angle, deg	0
Ailerons (each) -	
Chord, ft	1.22
Span, ft	4.83
Hinge line, percent chord	74.1
Vertical tail:	
Sweepback (leading edge), deg	0
Airfoil section	NACA 0012
Aspect ratio	1.25
Chord, ft	4.0
Taper ratio	1.0
Area, sq ft	20
Span, ft	5.0
Rudder (hinge line perpendicular to fuselage center line) -	
Chord, ft	1.25
Span, ft	5.0
Horizontal tail:	
Sweepback (leading edge), deg	0
Airfoil section	NACA 0012
Aspect ratio	3.10
Chord, ft	3.0
Center-section chord, ft	4.21
Area (including center body), sq ft	29.70
Span, ft	9.90
Dihedral	0

TABLE II.- COMPARISON OF MASS CHARACTERISTICS OF MODEL

(SCALED-UP) AND FULL-SCALE AIRPLANE

	Model (scaled-up)	Full-scale airplane
Gross take-off weight (including one pilot and research instrumentation), lb	3,533	3,290
Rolling moment of inertia, I_X, slug-ft^2 (hovering configuration)	3,280	1,811
Pitching moment of inertia, I_Y, slug-ft^2 (hovering configuration)	3,890	2,851
Yawing moment of inertia, I_Z, slug-ft^2 (hovering configuration)	5,330	3,779

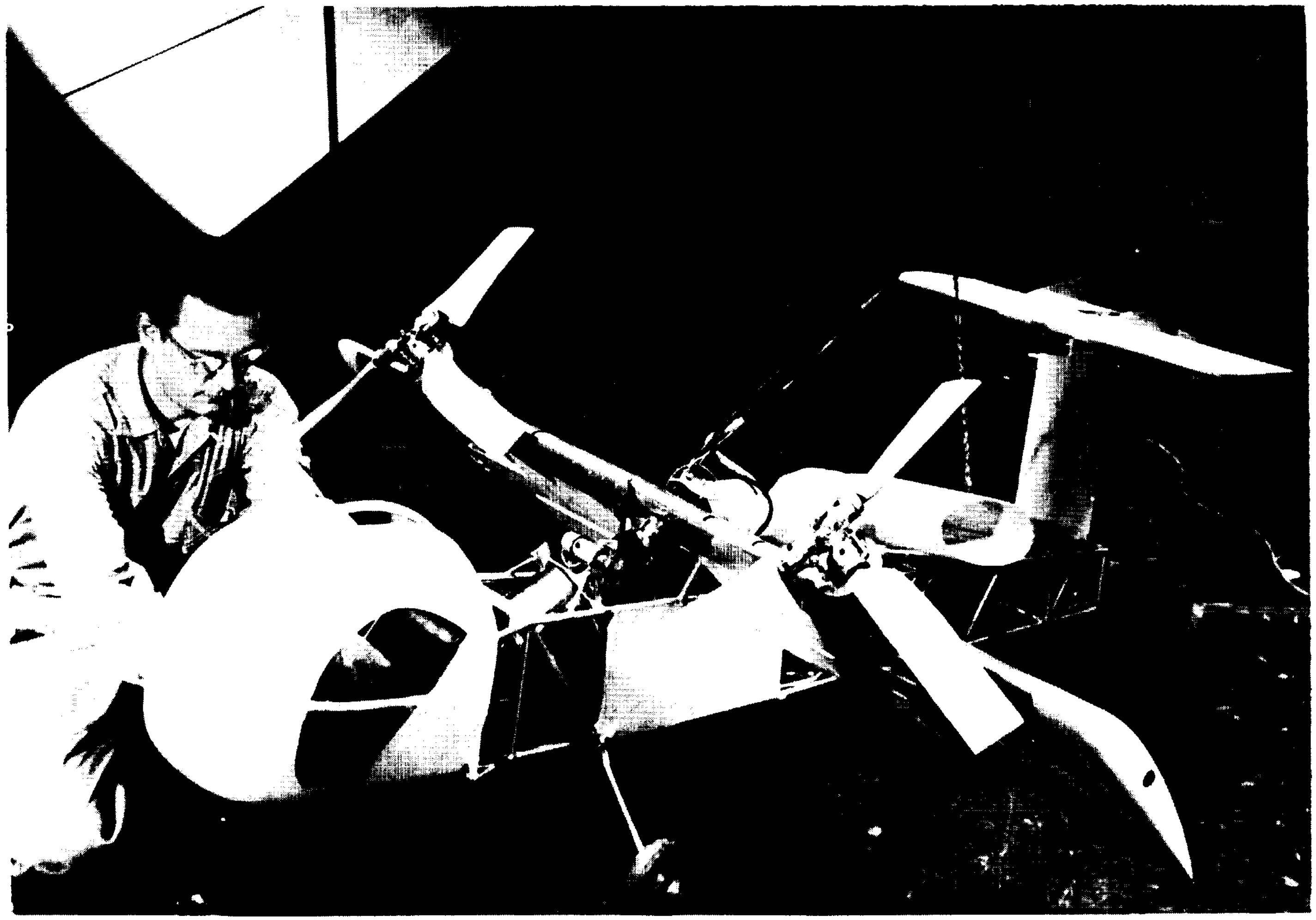

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Figure 1.- Photograph of the 1/4-scale model of the Vertol 76 tilt-wing VTOL aircraft in the Langley full-scale tunnel.

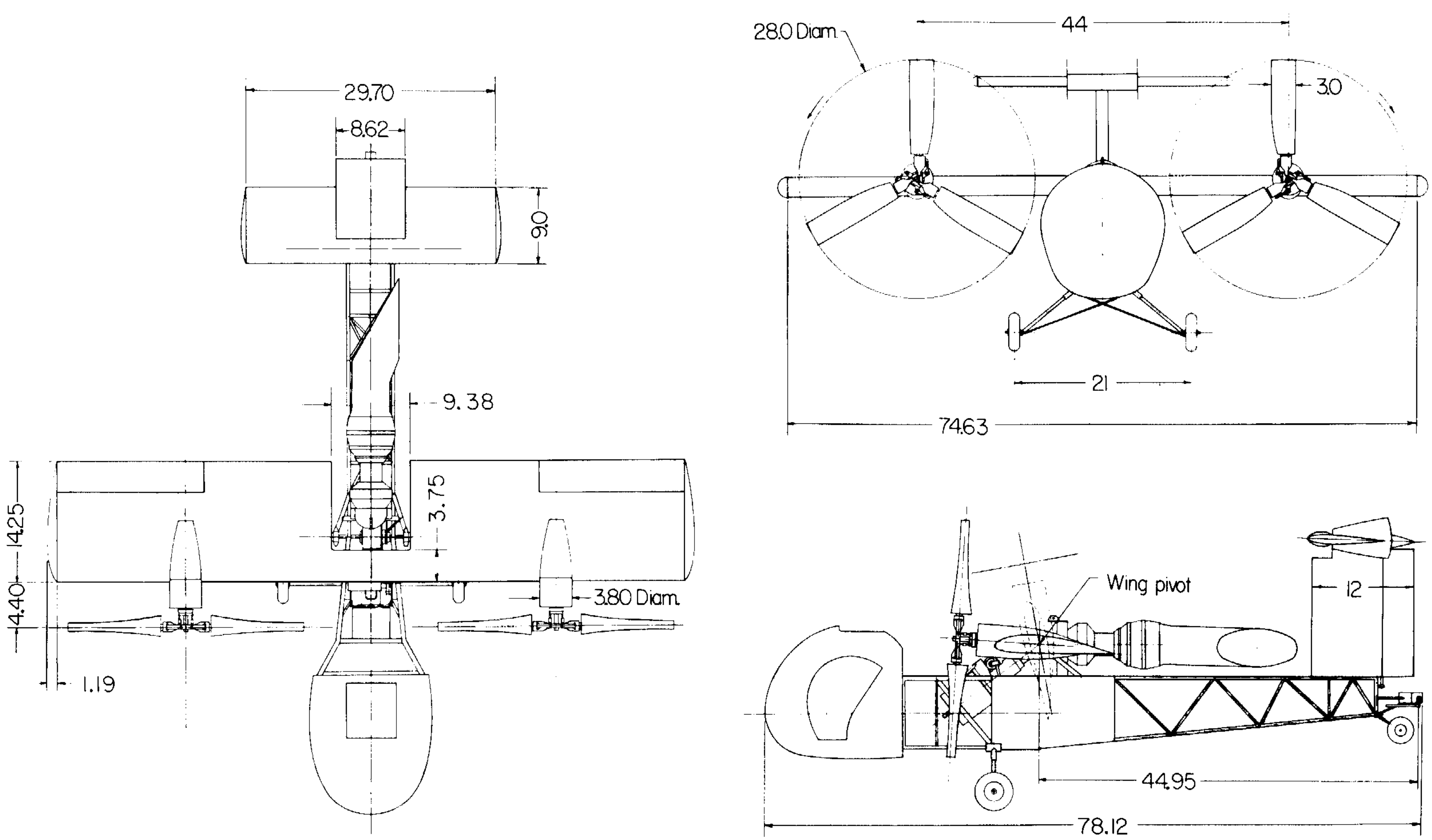

Figure 2.- Three-view sketch of model. All dimensions are in inches.

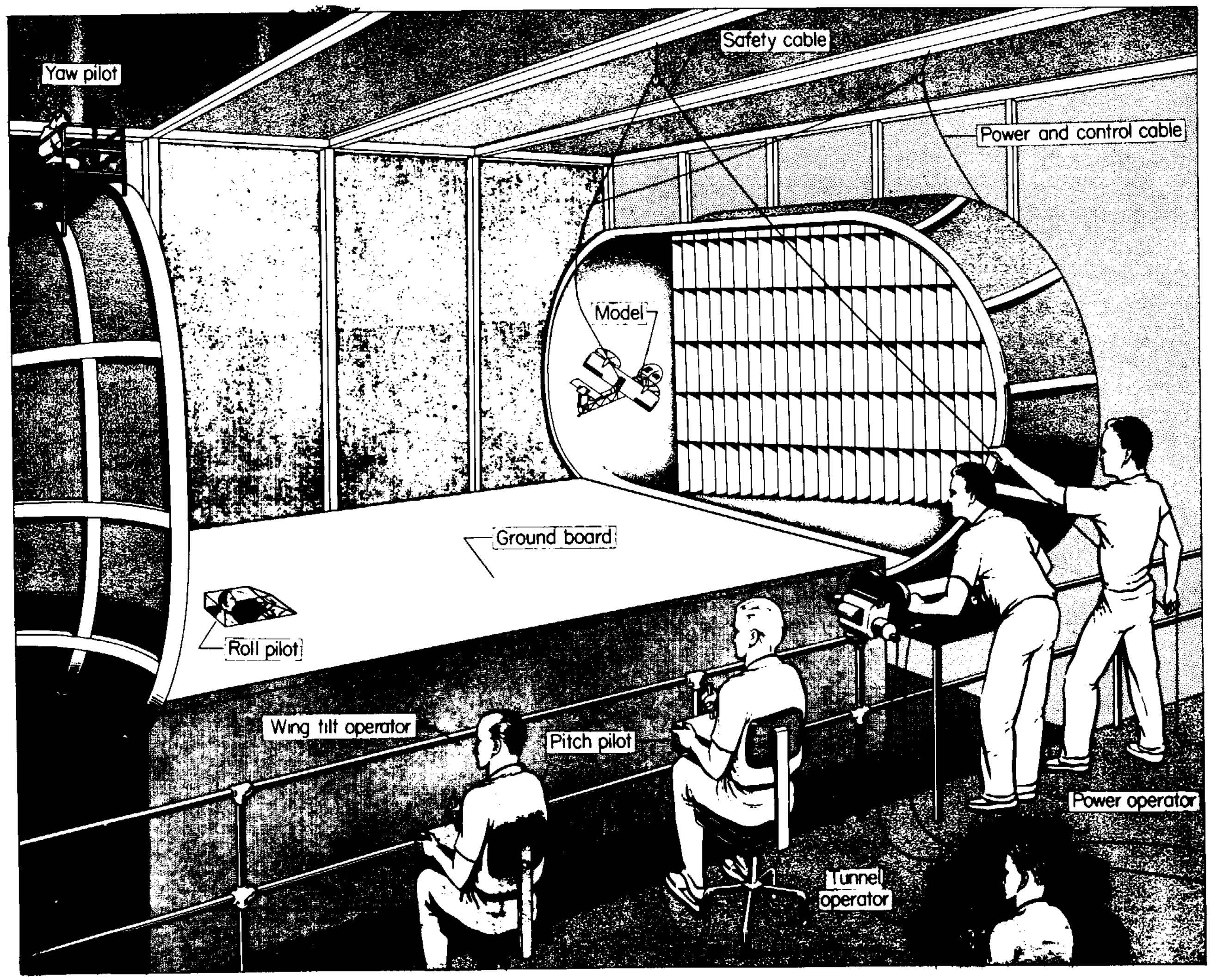

Figure 3.- Sketch of the test setup for the slow constant-altitude transition tests in the Langley full-scale tunnel.

NASA - Langley Field, Va.

A motion-picture film supplement is available on loan. Requests will be filled in the order received. You will be notified of the approximate date scheduled.

The film (16 mm., 18 min., color, silent) shows hovering flights of the model in still air, vertical take-offs and landings, and slow constant-altitude transitions from hovering to forward flight.

Requests for the film should be addressed to the

Division of Research Information
National Aeronautics and Space Administration
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NASA MEMO 11-4-58L
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FLIGHT INVESTIGATION OF THE STABILITY AND CONTROL CHARACTERISTICS OF A 1/4-SCALE MODEL OF A TILT-WING VERTICAL-TAKE-OFF-AND-LANDING AIRCRAFT. Louis P. Tosti. January 1959. 17p. diagr., photo., tabs., film suppl. available on request.
(NASA MEMORANDUM 11-4-58L)

The model had two propellers with hinged (flapping) blades mounted on the wing which could be tilted up to an incidence angle of nearly 90^{0} for vertical take-off and landing. The model had conventional aileron, rudder, and elevator controls for forward flight. For hovering flight, jets at the tail provided pitch and yaw control and differential total pitch of the propellers provided roll control. The investigation consisted of hovering flights in still air, vertical take-offs and landings, and slow constant-altitude transitions from hovering to forward flight.

Copies obtainable from NASA, Washington

1. Airplanes - Specific Types (1.7.1.2)
2. Stability, Dynamic (1.8.1.2)
3. Control, Longitudinal (1.8.2.1)
4. Control, Lateral (1.8.2.2)
5. Control, Directional (1.8.2.3)
6. Flying Qualities (1.8.5)
I. Tosti, Louis P.
II. NASA MEMO 11-4-58L

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NASA MEMO 11-4-58L
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FLIGHT INVESTIGATION OF THE STABILITY AND CONTROL CHARACTERISTICS OF A 1/4-SCALE MODEL OF A TILT-WING VERTICAL-TAKE-OFF-AND-LANDING AIRCRAFT. Louis P. Tosti. January 1959. 17p. diagr., photo., tabs., film suppl. available on request.
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6. Flying Qualities (1.8.5)
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II. NASA MEMO 11-4-58L

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