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RESEARCH MEMORANDUM

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FREE-FLIGHT-TUNNEL INVESTIGATION OF THE DYNAMIC STABILITY AND CONTROL CHARACTERISTICS OF A CHANCE VOUGHT F7U-3 AIRPLANE IN TOWED FLIGHT

By David C. Grana and Robert E. Shanks

Langley Aeronautical Laboratory
Langley Field, Va.

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS
WASHINGTON

[redacted]

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SUMMARY

As part of a program to determine the feasibility of using a fighter airplane as a parasite in combination with a Consolidated Vultee RB-36 for long-range reconnaissance missions (project FICON), an experimental investigation has been made in the Langley free-flight tunnel to determine the dynamic stability and control characteristics of a 1/17.5-scale model of a Chance Vought F7U-3 airplane in several tow configurations. The investigation consisted of flight tests in which the model was towed from a strut in the tunnel by a towline and by a direct coupling which provided complete angular freedom. The tests with the direct coupling also included a study of the effect of spring restraint in roll in order to simulate approximately the proposed full-scale arrangement in which the only freedom is that permitted by the flexibility of the launching and retrieving trapeze carried by the bomber.

For the tow configurations in which a towline was used (15 and 38 feet full scale), the model had a very unstable lateral oscillation which could not be controlled. The stability was also unsatisfactory for the tow configuration in which the model was coupled directly to the strut with complete angular freedom. When spring restraint in roll was added, however, the stability was satisfactory. The use of the yaw damper which increased the damping in yaw to about six times the normal value of the model appeared to have no appreciable effect on the lateral oscillations in the towline configurations, but produced a slight improvement in the case of the direct coupling configurations. The longitudinal stability was satisfactory for those cases in which the lateral stability was good enough to permit study of longitudinal motions.

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INTRODUCTION

The U. S. Air Force has undertaken a program to determine the feasibility of using a fighter airplane as a parasite in combination with a Consolidated Vultee RB-36 in order to extend the range of the fighter for high-speed reconnaissance (project FICON). One part of the program is the development of a satisfactory method for launching and retrieving the parasite which in the preliminary tests will be a Republic F-84E airplane. Reference 1 presents the results of an experimental investigation to determine the stability and control characteristics of a simplified model of the F-84E airplane in several tow configurations. At the request of the Air Research and Development Command, this investigation has been extended to include a study of the stability and control characteristics of a 1/17.5-scale model of a Chance Vought F7U-3 airplane in towed flight.

The present investigation, like the investigation of reference 1, consisted of tow tests in which the model was towed from a strut in the tunnel to study its dynamic stability and control characteristics. Tests were made with the model towed by a towline, lengths of 15 and 38 feet full scale being used. The investigation also included tests of a direct-coupling configuration in which the model was coupled directly to the strut with complete angular freedom and with spring restraint in roll. This spring restraint simulated the flexibility in roll of the launching and retrieving trapeze when the fighter airplane is coupled to the trapeze with freedom only in pitch and yaw. For both the towline and direct-coupling configurations the effect of artificially increasing the damping in yaw was also studied.

APPARATUS AND MODEL

The model used in the investigation was approximately a 1/17.5-scale model of the Chance Vought F7U-3 airplane. Originally, it had been a scale model of the Chance Vought F7U-1, but it has been modified by increasing the nose length and enlarging the vertical tails to represent closely the F7U-3 airplane. A three-view sketch of the model is presented in figure 1 and the mass and dimensional characteristics of the model are presented in table I, together with a comparison between the full-scale and scaled-up model values.

The tests of the model were made in the Langley free-flight tunnel which is described in reference 2. All the tests were made in the power-off condition at an airspeed corresponding to a full-scale speed of about 210 mph at sea level for a fully loaded F7U-3 airplane having pylon tanks. At this speed the lift coefficient was about 0.56.

The model was towed from the lower end of a strut which extended downward from the top of the tunnel test section. The use of a rigid strut instead of a model of the bomber was felt to be justified because of the large difference in relative sizes of the two airplanes; that is, the motions of the bomber arising from the fighter motions are relatively small, so the assumption that the bomber maintains steady flight should give a reasonable first approximation of the actual fighter motions. No attempt was made to duplicate the possible effects of the turbulence of the flow around the bomber on the fighter. For the tests of the model on a towline, a 1/16-inch-diameter cotton line, representing a full-scale line about 1.1 inch in diameter, was used. The model was tested at towline lengths of 10 and 26 inches, which represented full-scale lengths of about 15 and 38 feet, respectively.

The strut and apparatus used to represent the launching and retrieving trapeze on the Consolidated Vultee RB-36 for the direct coupling tests are shown schematically in figure 2. A direct coupling which provided complete angular freedom was used to connect the model to the strut. The coupling consisted of a universal joint which provided freedom in pitch and yaw. The universal joint was mounted in a ball bearing in such a way that it was free in roll about the X wind axis but could be restrained in roll by a torsion spring. Three torsion springs were used in the tests to provide roll restraints which were equivalent to full-scale values of about 180,000, 235,000, and 490,000 ft-lb/radian. These values were intended to bracket the value for the full-scale trapeze. The stiffness of the actual trapeze is not known exactly although it is known that the original trapeze which provided a restraint of approximately 100,000 ft-lb/radian has been stiffened considerably. No attempt was made to simulate the flexibility of the full-scale trapeze in any other respect.

The model was equipped with rudder and aileron control but no elevator control. The ailerons were operated manually by the pilot for lateral control. The rudder was never used for manual control but was sometimes operated by a rate-gyro automatic stabilizing device (yaw damper). This stabilizing device consisted of a rate gyro which controlled a pneumatic servoactuator that operated the rudders to increase the damping in yaw. By means of this system the damping in yaw could be increased to about six times the normal value of the model.

RESULTS AND DISCUSSION

The results of the tests consist primarily of pilot's comments regarding the stability and controllability of the model and are illustrated in most cases by film records of the rolling motions of the model. These records are presented in figure 3 for the towline tests and in figures 4 and 5 for the direct-coupling configurations.

A motion picture containing film records of the flight behavior of the model in all the test configurations discussed herein is available on loan from the NACA Headquarters, Washington, D. C. The results of this investigation are illustrated more graphically by the flight scenes of this motion picture than is possible in the present paper.

Towline Tests

For the towline lengths covered in the tests (15 and 38 feet full scale), the model had a violently unstable lateral oscillation which could not be controlled for any extended period of time. This result is illustrated in figure 3 which shows time histories of the rolling motions of the model for flights in which the pilot was attempting to control the model. These records show that the pilot was sometimes able to control the oscillation for a short period of time but that it eventually built up in spite of his efforts. The use of a yaw damper which increased the damping in yaw of the model to about six times its normal value did not cause any noticeable improvement in the motions of the model.

It was not possible to determine whether the model was stable or unstable longitudinally because of the violent lateral oscillations of the model.

Direct Coupling Tests

Complete angular freedom.- The rolling motions presented in figures 4 and 5 show that, for the tests in which the model was coupled directly to the strut with complete angular freedom (no roll spring or yaw damper), the model had a violently unstable lateral oscillation. The data of figure 4(a) show that, for the uncontrolled case, the amplitude of the rolling oscillation of the model became very large in about $1\frac{1}{2}$ cycles. For the controlled case (fig. 4(b)), the oscillation diverged more slowly and reached large amplitudes after about $2\frac{1}{2}$ cycles. The pilot was unable to control the motion of the model successfully because of the short period (about 1 second) and high degree of instability of the oscillation. It might be possible to control this motion in the case of a full-scale fighter, however, since the period of the oscillation would be about 4 seconds.

It should be pointed out that the coupling for the case illustrated in figure 4(b) actually consisted of a very short towline connection instead of the universal joint connection (fig. 2) which was used in the cases illustrated in figures 4(a) and 5. These records are considered to be directly comparable, however, because this difference was found in some preliminary tests to have no appreciable effect on the motions of the model.

Effect of spring restraint in roll.- Figure 5 presents the results for the direct-coupling configurations which had spring restraint in roll to simulate approximately the flexibility in roll of the launching and retrieving trapeze when the fighter airplane is coupled to the trapeze with freedom only in pitch and yaw. With the weakest roll spring (fig. 5(c)), the lateral oscillation was stable but was still only lightly damped; however, the model could easily be steadied by use of the controls following a disturbance. The small-amplitude residual oscillation can probably be attributed to the turbulence in the tunnel airstream rather than to an inherent condition of neutral stability. Reference 3 indicates that, for an airplane having a lightly damped lateral oscillation, atmospheric turbulence can initiate and maintain a pronounced lateral hunting oscillation of fairly regular amplitude and frequency. The stronger roll spring (fig. 5(e)) increased the initial damping, reduced the period of the oscillation, and made the model more difficult to disturb in roll. As in the case of the weakest roll spring, however, a small-amplitude residual oscillation appeared to persist. The use of the strongest roll-spring restraint (fig. 5(f)) resulted in a well-damped oscillation with a period about half that found for the weakest spring configuration. The residual oscillation in this case was of such small amplitude as to be barely discernible to the observers. The model was found to be longitudinally stable for all direct-coupling configurations having spring restraint in roll.

Effect of artificially increased damping in yaw.- For the model having complete angular freedom, the instability of the lateral oscillation was not markedly improved by the use of a yaw damper which increased the damping in yaw to six times the normal value of the model (see figs. 5(a) and 5(b)). Analysis of the record presented in figure 5(b) indicates that the yaw damper provided more damping at small amplitudes than at large amplitudes. (The rate of divergence from 2 to 4 seconds is about twice that from 0 to 2 seconds.) This nonlinearity can be attributed to the fact that, because of the high gearing used, maximum available rudder deflection was obtained at rather small yawing velocities so that the value of yawing moment due to yawing angular velocity (damping in yaw) could not be maintained at the higher yawing velocities associated with the larger amplitude motions.

The addition of artificial damping to the condition with the weakest spring restraint caused a slight improvement in the motion (figs. 5(c) and 5(d)).

SUMMARY OF RESULTS

The results of an experimental investigation of the dynamic stability and controllability of a 1/17.5-scale model of the Chance Vought F7U-3 airplane in towed flight may be summarized as follows:

1. For tow configurations in which a towline was used (towline lengths of 15 and 38 feet full scale), the model had a very unstable lateral oscillation which could not be controlled. The stability of this lateral oscillation was not noticeably improved by increasing the damping in yaw to about six times the normal value of the model.

2. For direct-coupling tow configurations, the lateral stability was satisfactory when the model was directly coupled to the strut with complete angular freedom in pitch and yaw but restrained in roll by a torsion spring. With no spring restraint in roll, however, the lateral oscillation was very unstable and uncontrollable. Increasing the damping in yaw to six times the normal value of the model produced only a very small improvement in the behavior of the model for these direct-coupling configurations.

3. The longitudinal stability was satisfactory for those cases in which the lateral stability was good enough to permit study of the longitudinal motion.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va.

David C. Grana
Aeronautical Research Scientist

Robert E. Shanks
Aeronautical Research Scientist

Approved: Thomas A. Harris
Chief of Stability Research Division

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REFERENCES

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2. Shortal, Joseph A., and Osterhout, Clayton J.: Preliminary Stability and Control Tests in the NACA Free-Flight Wind Tunnel and Correlation With Full-Scale Flight Tests. NACA TN 810, 1941.

3. Bird, John D.: Some Calculations of the Lateral Response of Two Airplanes to Atmospheric Turbulence With Relation to the Lateral Snaking Problem. NACA RM L50F26a, 1950.

TABLE I.- MASS AND DIMENSIONAL CHARACTERISTICS OF THE MODEL AND

COMPARISON WITH THE CHANCE VOUGHT F7U-3 AIRPLANE

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	Model	Model scaled up	[a]Full scale
Weight, lb	6.33	33,925	33,998
Wing loading, lb/ft^2	3.91	68.43	63.51
Radius of gyration about X body axis, ft	0.344	6.02	6.09
Radius of gyration about Y body axis, ft	0.440	7.70	7.05
Radius of gyration about Z body axis, ft	0.547	9.57	9.11
Wing:			
Span, ft	2.2	38.5	39.72
Area, sq ft	1.62	496	535.3
Aspect ratio	3.01	3.01	2.94
Taper ratio	0.60	0.60	0.66
Mean geometric chord, ft	0.746	13.06	13.69
Sweepback, quarter-chord line, deg	35	35	35
Airfoil section	CVA 4-(00)-(12)(40)-(1.1)(1.0)		
Ailavator:			
Span, ft	0.521	9.12	9.37
Total area, sq ft	0.176	53.9	74.36
Vertical tail:			
Height, ft	0.697	12.2	-----
Total area, sq ft	0.448	137.2	156.3
Rudder area, sq ft	0.046	14.1	12.9
Sweepback, quarter-chord line, deg	45.0	45.0	45.0
Airfoil section	NACA 64-008.9 Mod.		
Center-of-gravity location, percent mean geometric chord	12	12	11.9
Over-all length, ft	2.297	40.2	43.79
Towline attachment point:			
Horizontal distance from nose, ft	0.117	2.04	-----
Vertical distance from centerline, ft	0.104	1.82	-----

[a]Mass parameters represent approximate maximum loading conditions with pylon tanks.

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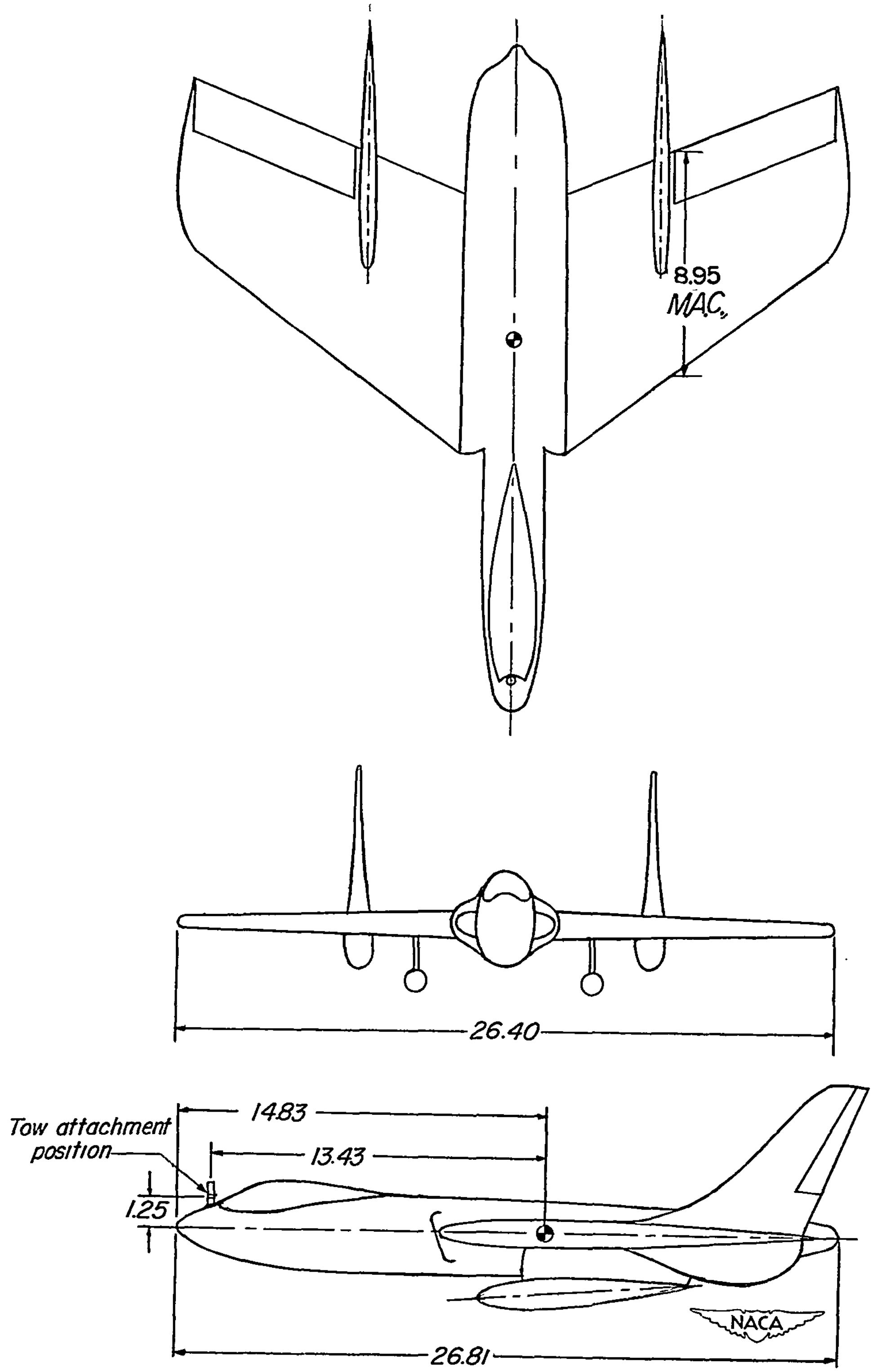

Figure 1.- Three-view sketch of model used in tests. All dimensions are in inches.

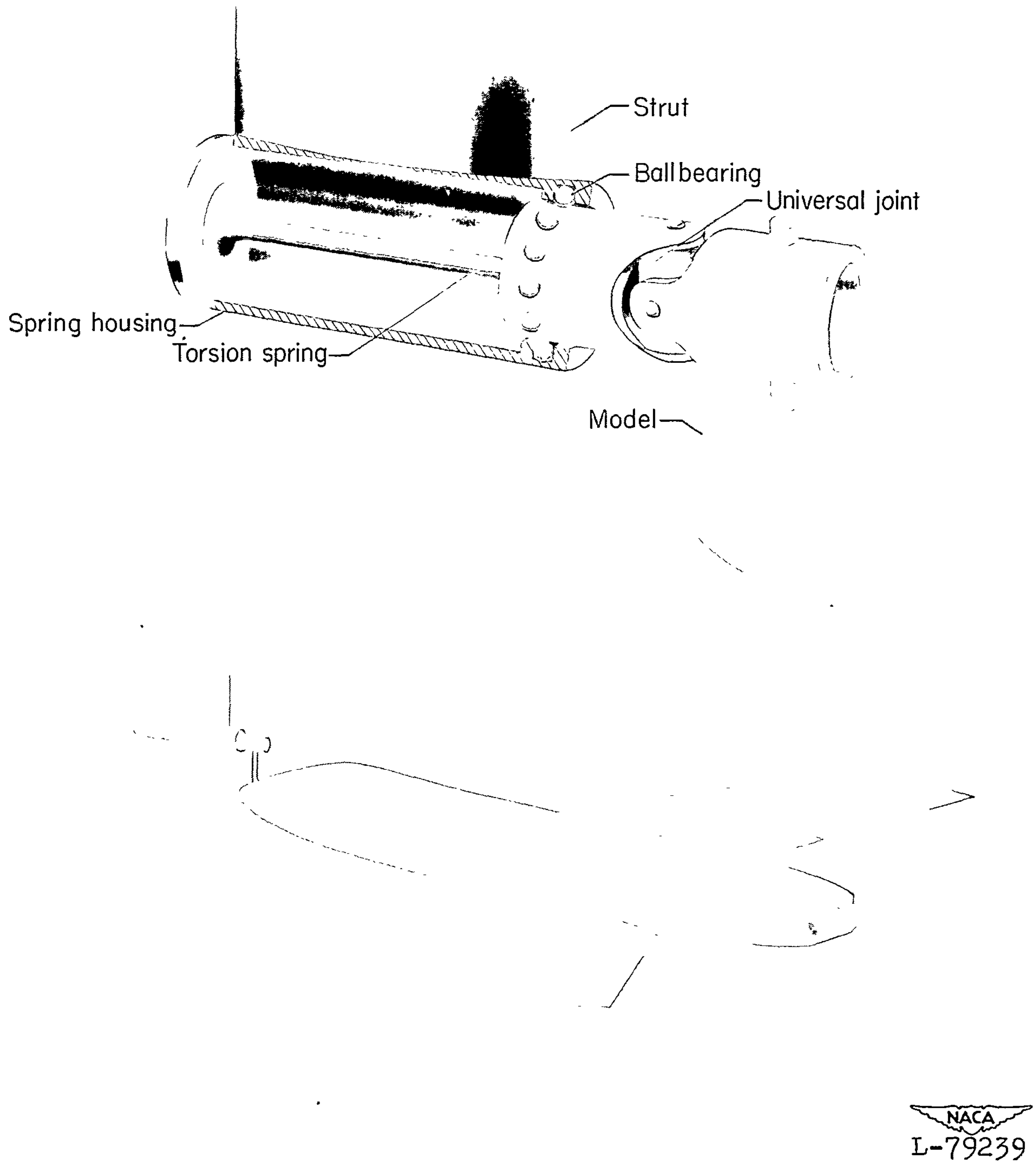

Figure 2.- Sketch of model on tow showing direct-coupling details.

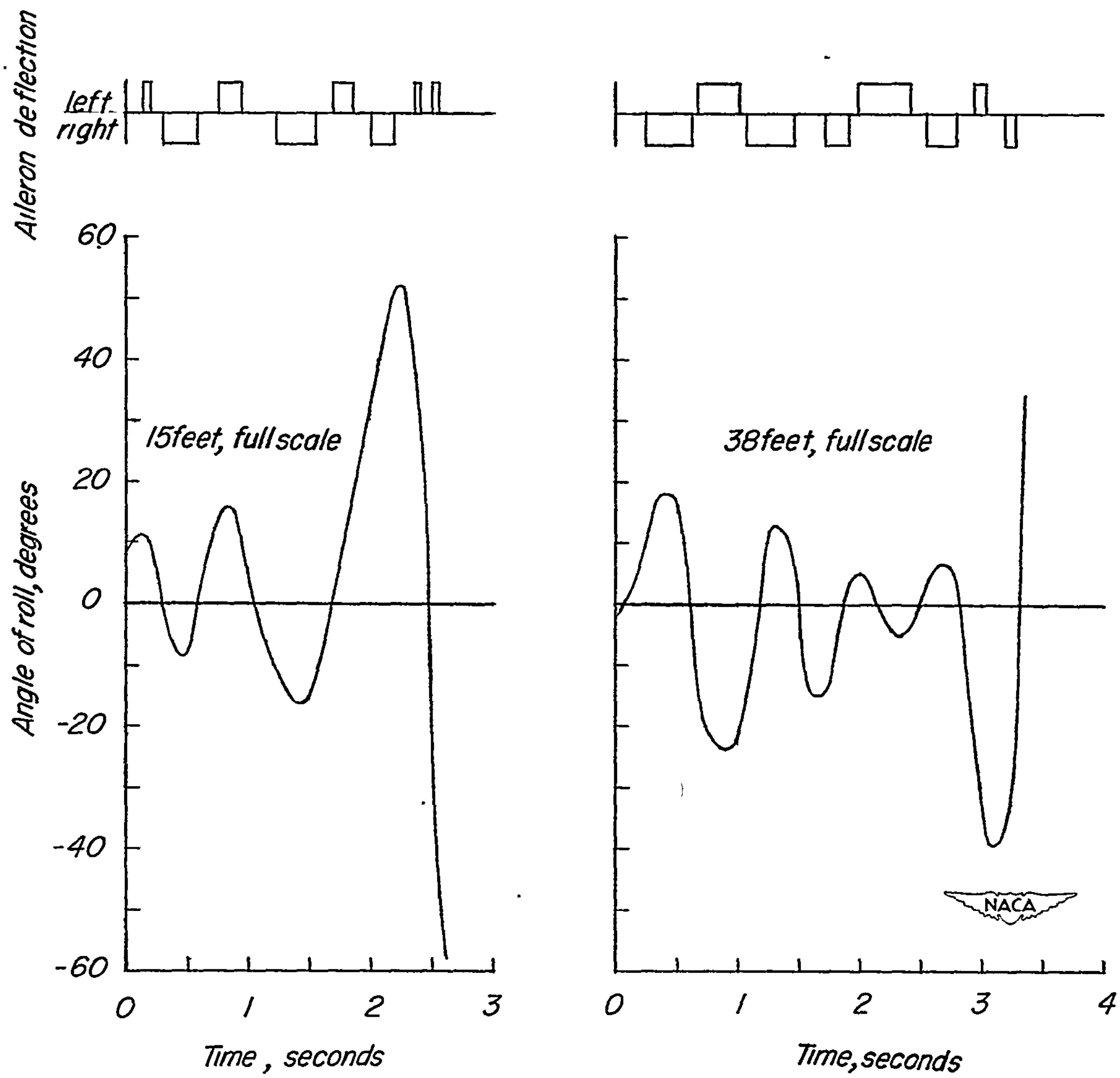

Figure 3.- Controlled rolling motions of model for full-scale towline lengths of 15 feet and 38 feet.

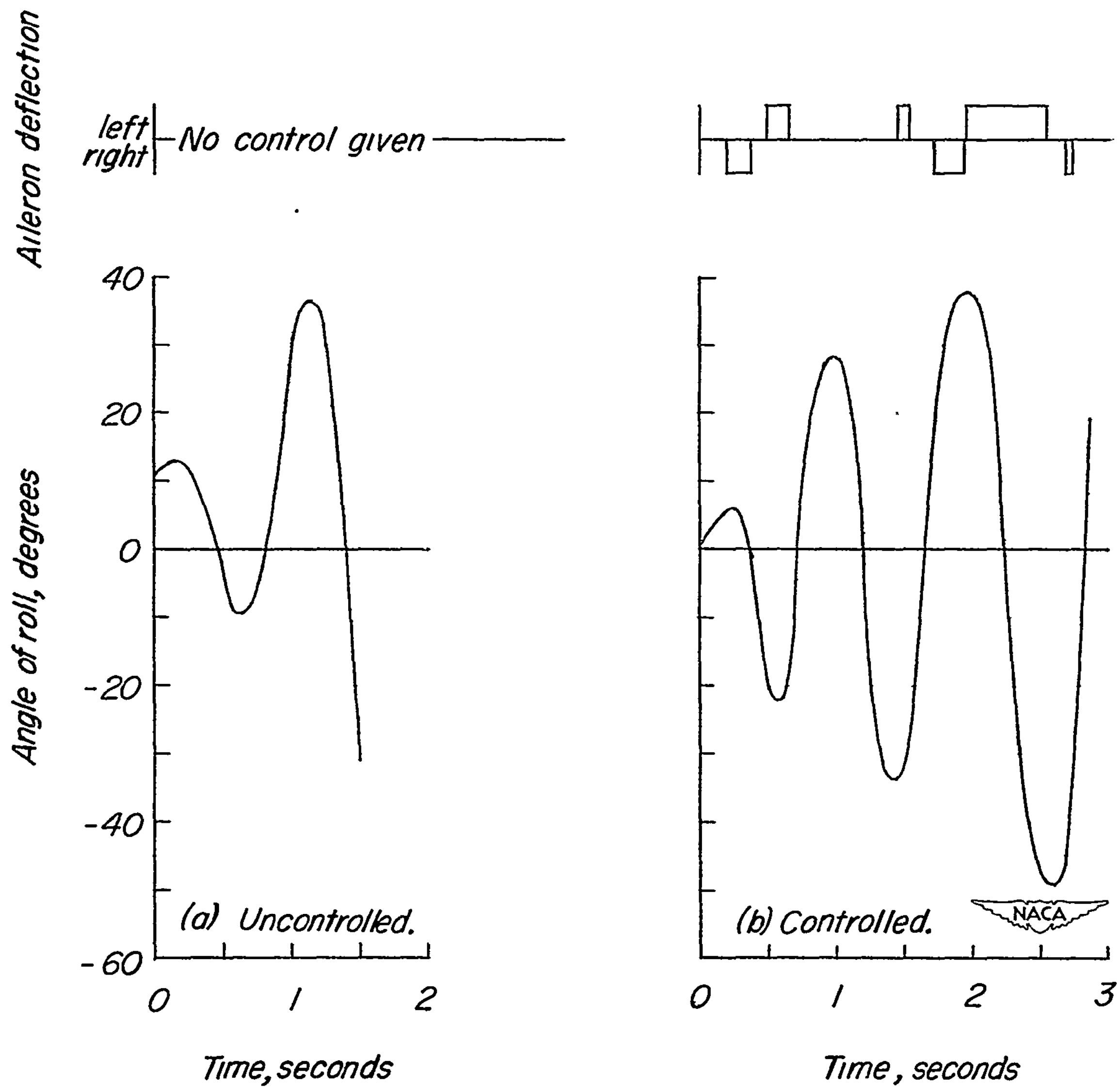

Figure 4.- Comparison of controlled and uncontrolled rolling oscillation of model for direct-coupling configuration having no roll-spring restraint or damping in yaw.

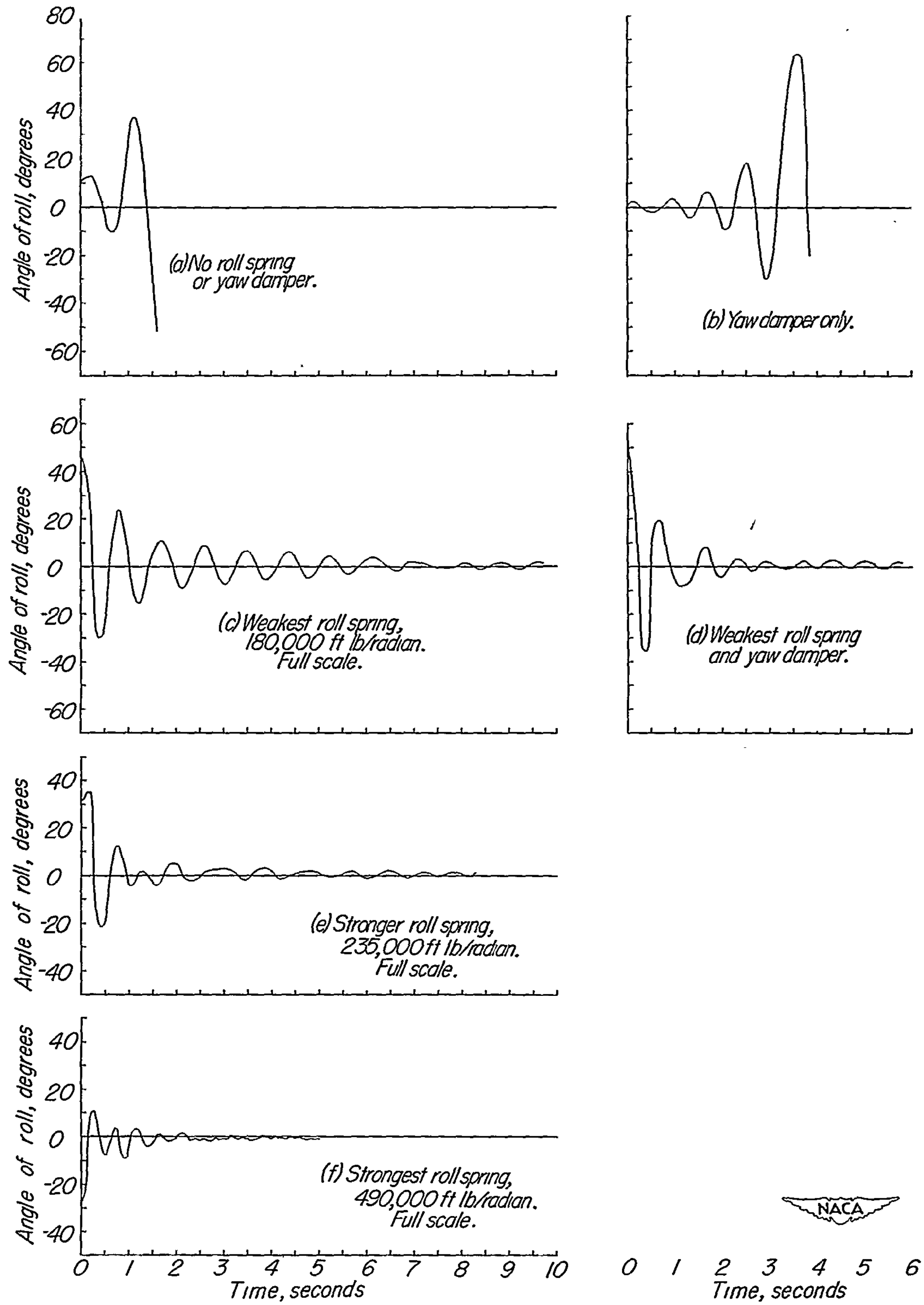

Figure 5.- Uncontrolled rolling motion of model in various direct coupling configurations.