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# RESEARCH MEMORANDUM

for the

Air Materiel Command, U. S. Air Force

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EPIN AND RECOVERY CHARACTERISTICS OF THE  
NORTHROP XF-89 AIRPLANE

By

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~~[Redacted]~~

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

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SPIN AND RECOVERY CHARACTERISTICS OF THE  
NORTHROP XF-89 AIRPLANE

By Theodore Berman

SUMMARY

The spin and recovery characteristics of the Northrop XF-89 airplane, as well as the spin-recovery parachute requirements, the control forces that would be encountered in the spin, and the best method for the crew to attempt an emergency escape are presented in this report. The characteristics were mainly estimated rather than determined by model tests because the XF-89 dimensional and mass characteristics were such as to make this airplane similar to several others, models of which have previously been tested. Brief tests were made on an available model of similar design to augment the estimation.

The results indicate that the recovery characteristics will be satisfactory for all airplane loadings if recovery is attempted by use of rudder followed by moving the elevator down. The rudder pedal forces will be within the capabilities of the pilot but the elevator stick forces will be beyond the pilot's capabilities unless a trim tab, or a booster is used. A 9.5-foot-diameter flat-type tail parachute or a 5.0-foot-diameter flat-type wing-tip parachute with a drag coefficient of 0.7 will be a satisfactory emergency spin-recovery device for spin demonstrations and if it is necessary for the crew to abandon the spinning airplane, they should leave from the outboard side of the cockpit.

INTRODUCTION

The Air Materiel Command, U. S. Air Force, requested that an investigation be conducted to determine the spin and recovery characteristics of the Northrop XF-89 airplane. The XF-89 is a two-place, midwing, jet-propelled fighter airplane. The dimensional and mass characteristics of the airplane were examined by the spin-tunnel section, and it was believed

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that because the XF-89 dimensional and mass characteristics were such as to make this airplane similar to several others, models of which have previously been tested, the spin and recovery characteristics of the airplane could be estimated and that construction of a model would, therefore, not be necessary. Accordingly, a prediction of the spin and recovery characteristics for three possible flight conditions of the XF-89 at an arbitrarily chosen altitude of 15,000 feet was made.

Because the study indicated the possibility of marginal results for one of the loadings, brief tests were made at this loading on an available model of similar design, modified to represent the XF-89. The tail assembly of the model chosen for the tests was rebuilt to simulate the XF-89 tail assembly and, although the remainder of the model was somewhat different from the XF-89, the differences were such that it was felt they would have little effect on the spin and recovery characteristics. Brief tests were also made at the two other loadings to check the accuracy of the prediction. In making the prediction, the values of dimensional and mass parameters which have been found to have a major effect on the spin and recovery characteristics of an airplane were considered. In addition, an estimate was made of the spin-recovery parachute requirements for demonstration spins, the control forces that would be encountered in a spin, and the best method for the crew to attempt an escape from the spin in an emergency.

#### SYMBOLS

b	wing span, feet
S	wing area, square feet
c	wing or elevator chord at any station along the span
$\bar{c}$	mean aerodynamic chord, feet
$x/\bar{c}$	ratio of distance of center of gravity rearward of leading edge of mean aerodynamic chord to mean aerodynamic chord
$z/\bar{c}$	ratio of distance between center of gravity and fuselage reference line to mean aerodynamic chord (positive when center of gravity is below fuselage reference line)
m	mass of airplane, slugs
$I_X, I_Y, I_Z$	moments of inertia about X, Y, and Z body axes, respectively, slug-feet <sup>2</sup>

$\frac{I_X - I_Y}{mb^2}$	inertia yawing-moment parameter
$\frac{I_Y - I_Z}{mb^2}$	inertia rolling-moment parameter
$\frac{I_Z - I_X}{mb^2}$	inertia pitching-moment parameter
$\rho$	air density, slugs per cubic foot
$\mu$	relative density of airplane $\left(\frac{m}{\rho S b}\right)$
$\alpha$	angle between fuselage reference line and vertical (approximately equal to absolute value of angle of attack at plane of symmetry), degrees
$\phi$	angle between span axis and horizontal, degrees
$V$	full-scale true rate of descent, feet per second
$\Omega$	full-scale angular velocity about spin axis, revolutions per second
$\sigma$	helix angle, angle between flight path and vertical, degrees (For the tests of this model, the average absolute value of the helix angle was approxi- mately 3°.)
$\beta$	approximate angle of sideslip at center of gravity, degrees (Sideslip is inward when inner wing is down by an amount greater than the helix angle.)
TDPF	tail-damping power factor

#### APPARATUS AND METHODS

##### Model

The dimensional and mass characteristics for the XF-89 airplane were furnished by Northrop Aircraft, Inc. A previously tested spin-tunnel model

of a similar design was modified to represent a  $\frac{1}{27}$ -scale model of the XF-89. A three-view drawing of the airplane is given in figure 1 and a comparison drawing of the XF-89 and the model as tested is given in figure 2. The dimensional characteristics of the airplane and model are given in table I. The mass parameters of the airplane and model are given in table II and are plotted in figures 3 and 4. The tail-damping power factor was computed by the method given in reference 1.

The model was ballasted with lead weights to obtain dynamic similarity to the airplane at an altitude of 15,000 feet ( $\rho = 0.001496$  slug per cu ft). A remote-control mechanism was installed in the model to actuate the controls and sufficient moments were exerted on the control surfaces during recovery tests to move them rapidly in the manner desired.

#### Wind Tunnel and Testing Technique

The model tests were performed in the Langley 20-foot free-spinning tunnel, the operation of which is generally similar to that described in reference 2 for the Langley 15-foot free-spinning tunnel, except that the model-launching technique has been changed. With the controls set in the desired position, the model is launched by hand with rotation into the vertically rising air stream. After a number of turns in the established spin, recovery is attempted by moving one or more controls by means of a remote-control mechanism. After recovery, the model dives into a safety net.

The data presented were determined by methods described in reference 2 and have been converted to corresponding full-scale values. The turns for recovery are measured from the time the controls are moved to the time the spin rotation ceases and the model dives into the net. For the spins which had a rate of descent in excess of that which can readily be attained in the tunnel, the rate of descent was recorded as greater than the velocity at the time the model hit the safety net, for example,  $>300$ . For these tests, the recovery was attempted before the model reached its final steeper attitude and while the model was still descending in the tunnel. Such model results are conservative, that is, recoveries will not be so fast as when the model is in the final steeper attitude. For recovery attempts in which the model struck the safety net while it was still turning, the result was recorded as greater than the number of turns observed from the time the controls were moved to the time the model struck the net, as  $>3$ . A  $>3$ -turn recovery, however, does not necessarily indicate an improvement over a  $>7$ -turn recovery. For recovery attempts in which the model did not recover, the result was recorded as  $\infty$ . When the model recovered without control movement, with the controls with the spin, the result was recorded as "No spin."

Spin-tunnel tests are made to determine the spin and recovery characteristics of the model for the normal spinning control configuration (elevator full up, ailerons neutral, and rudder full with the spin) and at various other aileron-elevator control combinations including zero and maximum deflections. Tests are also performed to evaluate the possible adverse effects on recovery of small deviations from the normal control configuration for spinning. For these tests, the ailerons are set at one-third of the full deflection in the direction conducive to slower recoveries and the elevator is set at two-thirds of its full-up deflection, or at its full-up deflection, whichever might lead to slower recoveries. Recovery is attempted either by rapidly reversing the rudder from full with the spin to two-thirds against the spin or by movement of the rudder to two-thirds against the spin in conjunction with moving the elevator below neutral. This control configuration and movement is referred to as the "criterion spin." The criterion for a satisfactory recovery from this spin in the spin tunnel has been adopted as  $2\frac{1}{4}$  turns or less. This value has been selected on the basis of spin-tunnel experience and on the basis of comparable full-scale spin-recovery data that are available.

PRECISION

The model test results presented herein are believed to be the true values given by the model within the following limits:

$\alpha$ , degrees . . . . .	$\pm 1$
$\phi$ , degrees . . . . .	$\pm 1$
V, percent . . . . .	$\pm 5$
$\Omega$ , percent . . . . .	$\pm 2$
Turns for recovery . . . . .	$\pm \frac{1}{4}$

The preceding limits may have been exceeded for certain spins in which it was difficult to control the model in the tunnel because of the high rate of descent or because of the oscillatory nature of the spin.

Comparison between model and airplane spin results (references 2 and 3) indicates that spin-tunnel results are not always in complete agreement with airplane spin results. The comparison in reference 3 showed that approximately 80 percent of the model recovery tests predicted satisfactorily the corresponding airplane recovery characteristics and that approximately 10 percent overestimated and approximately 10 percent underestimated the turns for recovery for the airplane.

The accuracy of measuring the weight and mass distribution is believed to be within the following limits:

••	Weight, percent . . . . .	±1
••	Center-of-gravity location, percent $\bar{c}$ . . . . .	±1
••	Moments of inertia, percent . . . . .	±5

The controls were set with an accuracy of  $\pm 1^\circ$ .

#### METHOD OF ESTIMATION

The estimation of the spin and recovery characteristics of the XF-89 airplane was deemed possible because, for two of three possible loadings, the dimensional and mass parameters which have a major effect upon spin-recovery characteristics were considered generally noncritical. The most important parameters affecting spin recovery, as indicated in reference 1, are tail-damping power factor, inertia yawing-moment parameter, and airplane relative density. The recovery characteristics of the airplane were estimated by consideration of these three factors in the manner indicated in reference 1. As previously indicated, because, for one loading, the values of these parameters were such that marginal results were indicated as possible, brief tests were made on an available model of similar design to augment the predictions.

Tail and wing-tip spin-recovery parachute sizes required for satisfactory recovery by parachute action alone were based on an analysis of spin-recovery parachute data obtained in the Langley 20-foot free-spinning tunnel (reference 4). The estimation of the parachute sizes was based on flat-type parachutes having a drag coefficient of 0.7 (based on the canopy area measured with the parachute spread flat).

In order to estimate the rudder pedal and elevator stick force, it was necessary to determine the rudder and elevator hinge moments. In each case, the control surface was considered an unsealed plain flap with no balance or trailing-edge bevel. In determining the rudder hinge-moment coefficient, reference 5 was used taking into account the location of the horizontal tail with respect to the vertical tail and the angles of attack and sideslip. It was felt that any way in which the airplane rudder varied from a plain flap would not adversely affect the resulting value of the hinge-moment coefficient. In determining the elevator hinge-moment coefficient, any deviation of the airplane elevator from a plain unsealed flap with no balance or bevel trailing edge can be corrected by use of references 6, 7, and 8. The hinge-moment coefficients were combined with the appropriate dimensional factors to compute the rudder pedal and elevator stick forces.

Inverted spin estimations were made on the basis of reference 9.

Crew-escape recommendations were made on the basis of a compilation and analysis of data obtained from numerous model tests (reference 10).

## RESULTS AND DISCUSSION

The estimation of the spin and recovery characteristics of the XF-89 airplane indicated that the spins would be somewhat oscillatory in pitch and that recoveries would be satisfactory by use of both rudder and elevator for all airplane loadings except possibly the minimum flying weight (loading point 3 in figs. 3 and 4). For this loading, it is indicated in figure 4 that unsatisfactory recoveries might be obtainable. As indicated in reference 1, the curves in figure 4 are conservative in that satisfactory models may fall in the unsatisfactory areas below the curves, although no unsatisfactory models fall in the satisfactory areas above the curves; and because point 3 is very close to the satisfactory area, it was felt that the recovery characteristics of the airplane at this loading would be difficult to predict. Accordingly, brief tests were made at this loading on the model modified to simulate the XF-89. As previously indicated, brief tests were also made at the two other loadings of the airplane to augment the prediction.

The results of the model spin tests are presented in charts 1 to 3. The model data are presented in terms of full-scale values for the airplane at a test altitude of 15,000 feet. The results obtained for right and left spins were similar and only right spins are arbitrarily presented.

Design gross weight.- Analysis of the dimensional and mass characteristics of the XF-89 design indicated that satisfactory recovery characteristics would result provided both rudder and elevator were reversed for recovery. Test results presented in chart 1 obtained with the model in the design gross weight (loading point 1 in table II and figs. 3 and 4) follow the expected pattern. Recoveries were satisfactory when attempted by movement of both the rudder and elevator but not satisfactory when attempted by rudder alone. Ailerons against the spin expedited recovery, whereas ailerons with the spin retarded recovery. Spins with the elevator neutral or down were generally oscillatory in pitch.

Wing-tank loading.- Spin-recovery results with the wing-tip tanks installed (loading point 2 in table II and figs. 3 and 4) are presented in chart 2. These data show, generally, the same pattern as for the design gross weight; that is, simultaneous reversal of the rudder and elevator are necessary for satisfactory recovery, deflecting ailerons against the spin is beneficial, and deflecting ailerons with the spin is detrimental to recovery. These results are consistent with the prediction based on reference 1. The spins were quite oscillatory in pitch indicating that,



as the loading along the wings increased  $\left( \frac{I_X - I_Y}{mb^2} \text{ becoming more positive} \right)$ ,  
the spins became more oscillatory in pitch.

Minimum flying weight.- Test data for the minimum flying weight loading (loading point 3 in table II and figs. 3 and 4) are presented in chart 3. The recovery characteristics were found to be satisfactory. For this loading, ailerons against the spin retarded recovery, whereas ailerons with the spin expedited recovery.

Inverted spins.- Based on the results in reference 9 and spin-tunnel experience gained with other models, satisfactory recovery can be expected from all inverted spins obtained with this airplane by full rudder reversal followed by stick neutralization.

#### Landing Condition

The landing condition is not considered critical inasmuch as the current specifications usually require airplanes to demonstrate satisfactory recoveries in the landing condition from only 1-turn spins. At the end of 1 turn the airplane will probably still be in an incipient spin from which recoveries are more readily obtained than from fully developed spins. An analysis of full-scale and model tests of many airplanes to determine the effect of flaps and landing gear (reference 11) indicates that the XF-89 airplane will recover satisfactorily from a 1-turn spin in the landing condition but that recoveries from fully developed spins in the landing condition may be unsatisfactory. It is recommended, therefore, that the flaps be neutralized and recovery be attempted immediately upon inadvertently entering a spin in the landing condition.

#### Control Forces

The discussion of recovery characteristics so far has been based on control effectiveness without regard to the forces required to move the controls. Sufficient force must be applied to the airplane controls to move them rapidly in the manner indicated to obtain the indicated results.

Estimations of the forces required to move the controls for satisfactory recovery indicate that the rudder pedal and elevator stick forces will be of the order of magnitude of 150 and 400 pounds, respectively. The rudder force is considered within the capabilities of the pilot but the stick force is not. It therefore appears that to move the elevator as needed for recovery, trim tabs or some booster arrangement will be necessary.

### Emergency Crew Escape

Results of spin-tunnel tests on approximately 20 models (reference 10) indicate that, if necessary to escape from an uncontrollable spin of this airplane, the crew should jump from the outboard side of the cockpit (left side in a right spin).

### Emergency Spin-Recovery Parachute Requirements

Tail parachute.- For recovery from spins by tail-parachute action alone, a 9.0-foot-diameter flat-type parachute with a drag coefficient of 0.7 attached to the airplane with a 30-foot to 50-foot towline will be satisfactory. It is recommended that a positive ejection mechanism be used to throw the parachute clear of the tail and to assure rapid opening. The pack and attachment point must be so located that the parachute will not foul the tail surfaces. Reference 12 describes various practical methods of tail-parachute installations.

Wing-tip parachute.- For recovery by wing-tip-parachute action alone, a 5.0-foot-diameter flat-type parachute with a drag coefficient of 0.7 opened on the outer wing tip will be satisfactory. The length of the towline should be such that the parachute, when fully extended, just misses the horizontal tail. It is recommended that wing parachute packs be installed within the wing with a positive ejection device to throw the parachute clear.

If parachutes of different drag coefficients are used, corresponding changes in the diameters should be made.

In several instances during level-flight check tests of the operation of spin-recovery parachute equipment, the instability and the erratic behavior of the conventional flat-type parachute used caused the airplane to make uncontrollable gyrations. Investigation has shown (reference 13) that this condition can be alleviated by the use of stable-type parachutes. Therefore, in selecting a parachute for use on the XF-89 for possible spin demonstrations, consideration should be given to the use of an equivalent stable-type parachute rather than the flat-type parachute usually used.

### CONCLUSIONS

Study of the dimensional and mass characteristics of the Northrop XF-89 airplane and analysis of test results of a model of similar design leads to the following conclusions regarding the spin and recovery characteristics of the airplane at an altitude of 15,000 feet:

1. Recovery will be satisfactory for all loadings if recovery is attempted by rapid full rudder reversal followed, approximately 1/2 turn

later, by movement of the stick forward of neutral while maintaining it laterally neutral. The spins may be somewhat oscillatory in pitch.

2. If a spin is inadvertently entered in the landing condition, the flaps should be neutralized and recovery attempted immediately.

3. The rudder pedal forces will be within the capabilities of the pilot but the elevator stick forces will be beyond the pilot's capabilities unless some type of trim tab or booster is used. The pedal and stick forces to move the controls for satisfactory recovery will be of the order of magnitude of 150 and 400 pounds, respectively.

4. If it is necessary for the crew to abandon the spinning airplane, they should attempt escape from the outboard side of the airplane.

5. A 9.5-foot-diameter flat-type tail parachute or a 5.0-foot-diameter flat-type wing-tip parachute with a drag coefficient of 0.7 will be a satisfactory emergency spin-recovery device for spin demonstrations.

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TABLE I.- DIMENSIONAL CHARACTERISTICS OF THE NORTHROP XF-89

AIRPLANE AND THE  $\frac{1}{27}$ -SCALE MODEL TESTED

	Model (full-scale values)	Airplane
Length, over-all, ft . . . . .	50.4	50.5
Wing:		
Span, ft . . . . .	55.0	52.0
Area, sq ft . . . . .	523.0	606.2
L.E. wing at root to elevator hinge, ft . . . . .	33.3	33.4
Incidence, deg . . . . .	1.0	1.5
Aspect ratio . . . . .	5.8	4.5
Leading edge of $\bar{c}$ rearward of L.E. of wing, in. . . . .	11.3	12.0
Mean aerodynamic chord, in. . . . .	104.9	145.6
Dihedral, deg . . . . .	2.0	1.0
Ailerons:		
Span, ft . . . . .	9.7	10.9
Area aft hinge line, sq ft . . . . .	32.3	42.4
Chord, percent c . . . . .	25.0	21.8
Full aileron deflection, deg . . . . .	±13	±13
Horizontal tail:		
Span, ft . . . . .	22.3	22.3
Total area, sq ft . . . . .	114.6	114.6
Elevator area aft hinge line, sq ft . . . . .	26.8	26.8
Incidence, deg . . . . .	0	0
Full elevator-up deflection, deg . . . . .	40	40
Full elevator-down deflection, deg . . . . .	20	20
Vertical Tail:		
Total area, sq ft . . . . .	44.4	44.4
Total rudder area aft hinge line, sq ft . . . . .	7.4	7.4
Full rudder deflection, deg . . . . .	±40	±40
Tail-damping ratio . . . . .	0.05012	0.0476
Unshielded rudder-volume coefficient . . . . .	0.01027	0.0093
Tail-damping power factor . . . . .	0.000514	0.000443



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TABLE II.- MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR LOADINGS POSSIBLE ON THE

NORTHROP XF-89 AIRPLANE AND TESTED WITH THE SIMULATED  $\frac{1}{27}$ -SCALE MODEL

[Model values are converted to corresponding full-scale values]

Number	Loading	Weight (lb)	$\mu$ Sea level	$\mu$ 15,000 feet	Center-of-gravity location		Moments of inertia, slug-feet <sup>2</sup>			Mass parameters		
					$x/\bar{c}$	$z/\bar{c}$	$I_X$	$I_Y$	$I_Z$	$\frac{I_X - I_Y}{mb^2}$	$\frac{I_Y - I_Z}{mb^2}$	$\frac{I_Z - I_X}{mb^2}$
Airplane values												
1	Design gross weight	31,000	12.8	20.4	0.301	-0.050	82,207	65,700	141,636	$63 \times 10^{-4}$	$-292 \times 10^{-4}$	$229 \times 10^{-4}$
2	Maximum alternate weight	43,000	17.8	28.3	0.302	-0.056	334,748	70,022	397,492	733	-907	174
3	Minimum flying weight	23,010	9.5	15.2	0.287	-0.030	47,834	61,505	103,389	-71	-216	287
Model values												
1	Design gross weight	29,098	13.2	21.0	0.308	-0.048	84,463	68,274	145,030	$59 \times 10^{-4}$	$-281 \times 10^{-4}$	$222 \times 10^{-4}$
2	Maximum alternate weight	40,027	18.2	28.9	0.301	-0.045	324,197	76,090	410,686	660	-890	230
3	Minimum flying weight	20,259	9.2	14.6	0.282	-0.009	46,592	60,231	99,390	-72	-206	278

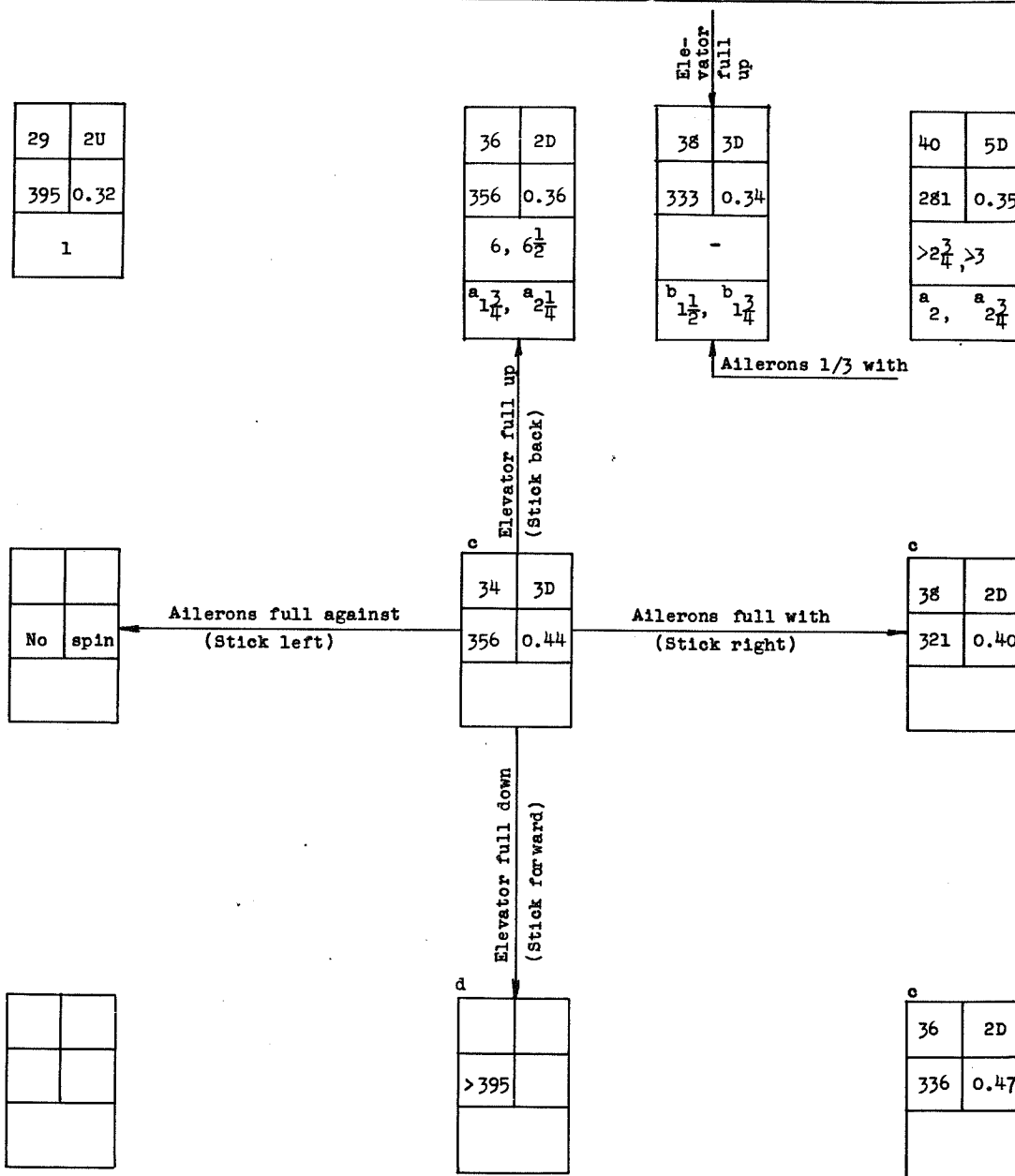
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CHART 1.- SPIN AND RECOVERY CHARACTERISTICS OF THE SIMULATED  $\frac{1}{27}$ -SCALE MODEL OF THE NORTHROP XF-89 IN THE DESIGN-GROSS-WEIGHT LOADING

[Loading point 1 on table II and figures 3 and 4; cockpit closed; landing gear retracted; flaps neutral; recovery by rapid full rudder reversal except as noted (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); right erect spins]



<sup>a</sup>Recovery attempted by simultaneous full reversal of the rudder and elevator.

<sup>b</sup>Recovery attempted by simultaneous reversal of the rudder to  $\frac{2}{3}$  against the spin and the elevator to  $\frac{1}{3}$  down.

<sup>c</sup>Oscillatory in pitch, average values given.

<sup>d</sup>Very steep spin.

Model values converted to corresponding full-scale values.

U inner wing up  
D inner wing down

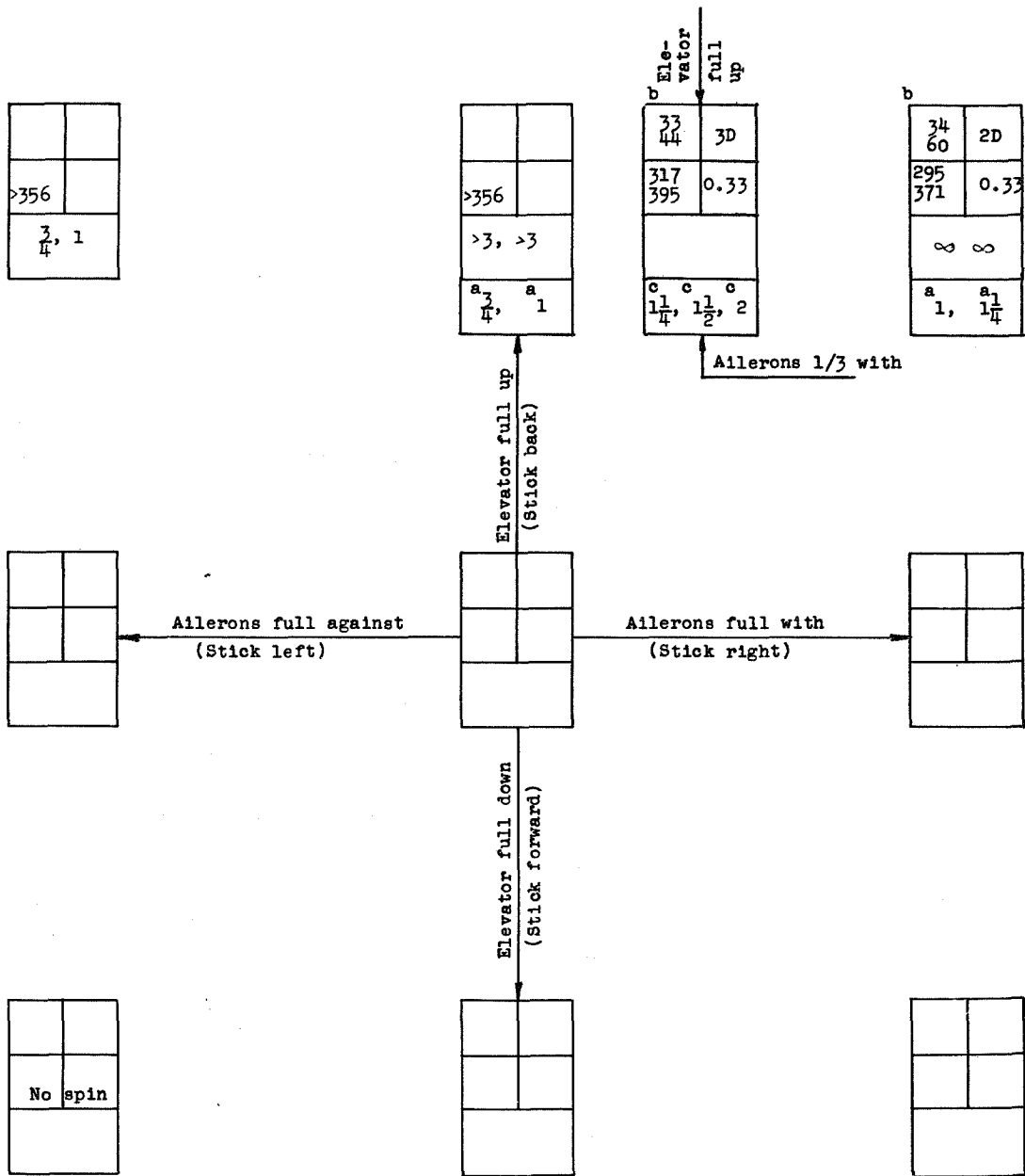
a (deg)	$\phi$ (deg)
V (fps)	$\Omega$ (rps)
Turns for recovery	



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CHART 2.- SPIN AND RECOVERY CHARACTERISTICS OF THE SIMULATED  $\frac{1}{27}$ -SCALE MODEL OF THE NORTHROP XF-89 WITH THE FULL WING-TIP FUEL TANKS INSTALLED

[Loading point 2 on table II and figures 3 and 4; cockpit closed; landing gear retracted; flaps neutral; recovery by rapid full rudder reversal except as noted (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); right erect spins]



<sup>a</sup>Recovery attempted by simultaneous full reversal of the rudder and elevator.

<sup>b</sup>Oscillatory in pitch, range of values or average value given.

<sup>c</sup>Recovery attempted by simultaneous reversal of the rudder to 2/3 against the spin and the elevator to 1/3 down.

Model values converted to corresponding full-scale values.  
 U inner wing up  
 D inner wing down

a (deg)	φ (deg)
V (fps)	Ω (rps)
Turns for recovery	

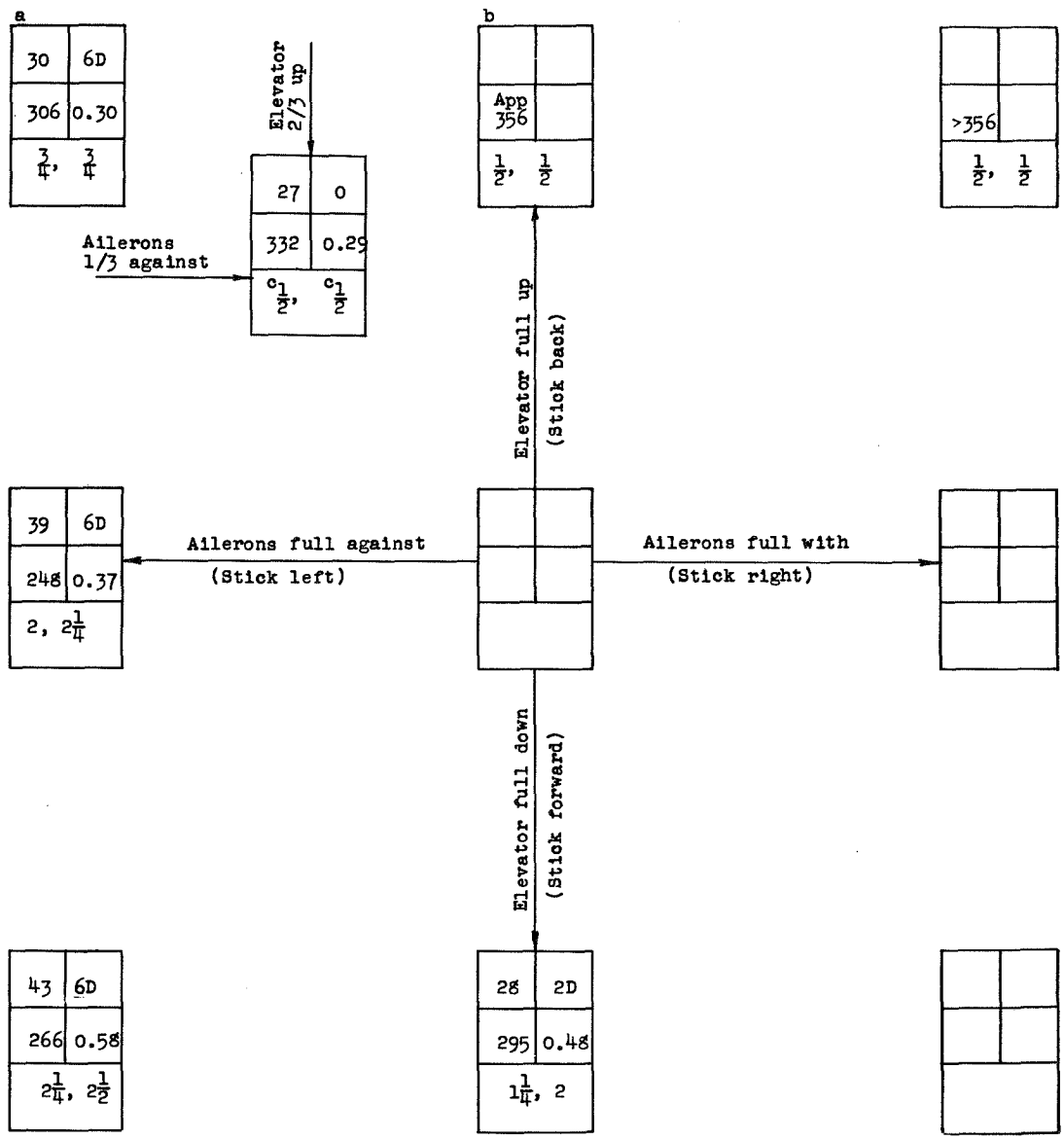




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CHART 3.- SPIN AND RECOVERY CHARACTERISTICS OF THE SIMULATED  $\frac{1}{27}$ -SCALE MODEL OF THE NORTHROP XF-89 IN THE MINIMUM-FLYING-WEIGHT LOADING

[Loading point 3 on table II and figures 3 and 4; cockpit closed; landing gear retracted; flaps neutral; recovery by rapid full rudder reversal except as noted (recovery attempted from, and steady spin data presented for, rudder full with spins); right erect spins]



<sup>a</sup>Very wandering spin.  
<sup>b</sup>Wandering and whipping spin.  
<sup>c</sup>Recovery attempted by reversal of the rudder from full with to 2/3 against the spin.

Model values converted to corresponding full-scale values.  
 U inner wing up  
 D inner wing down

$\alpha$ (deg)	$\phi$ (deg)
V (fps)	$\Omega$ (rps)
Turns for recovery	



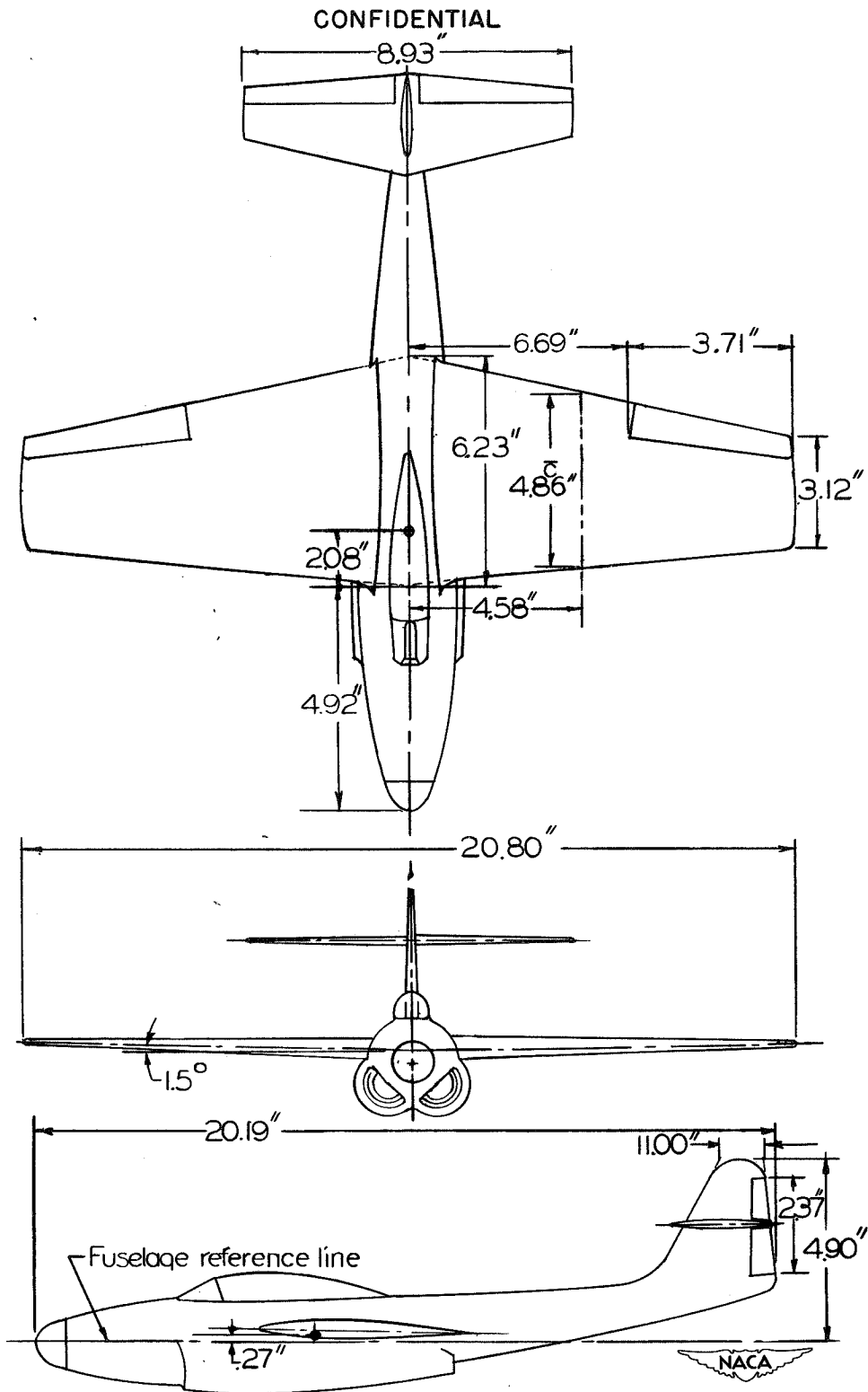


Figure 1. Three-view drawing of the Northrop XF-89 airplane. Dimensions are for  $\frac{1}{27}$ -scale model

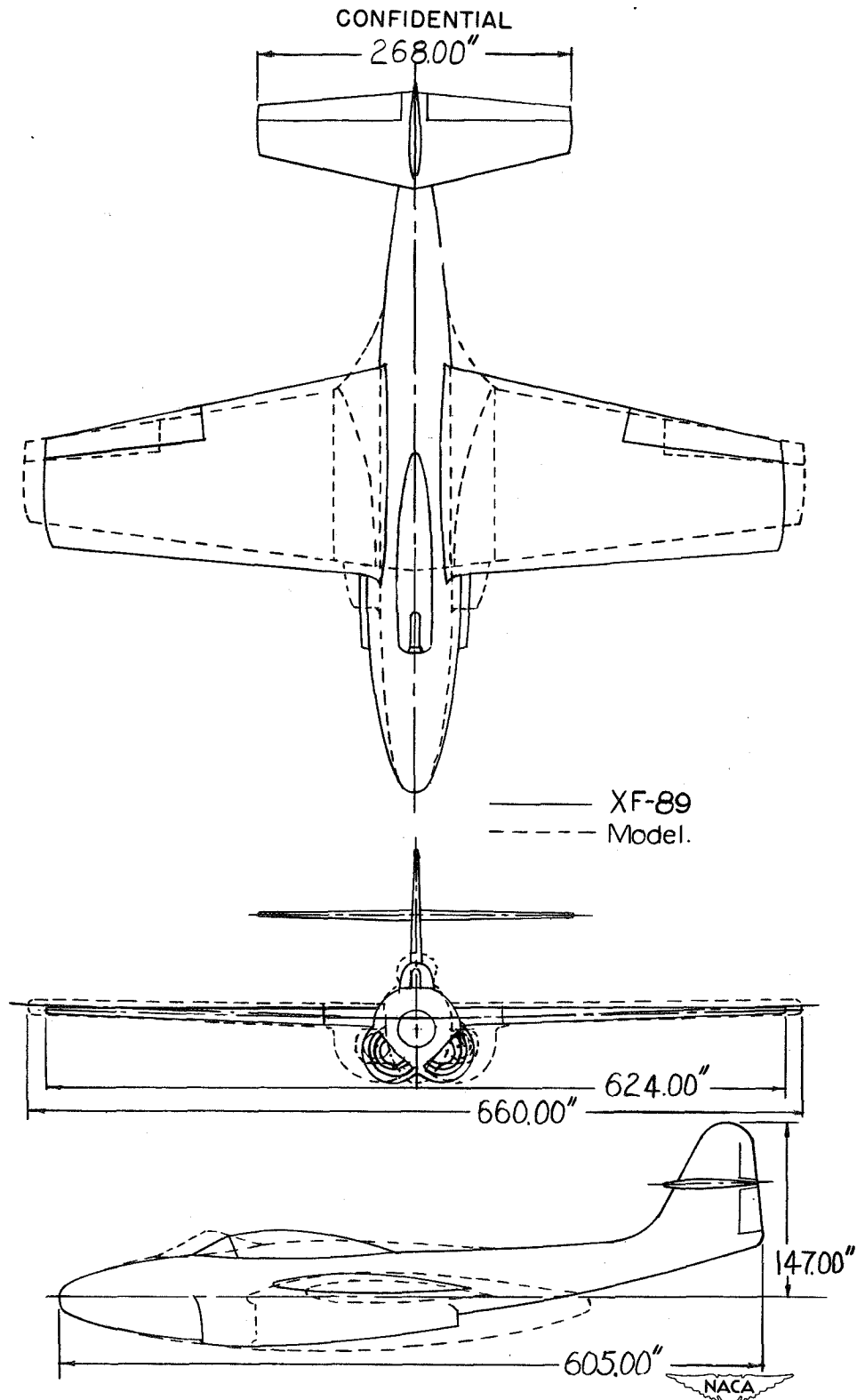


Figure 2. Comparison drawing of the Northrop XF-89 airplane and the simulated  $\frac{1}{27}$ -scale model.

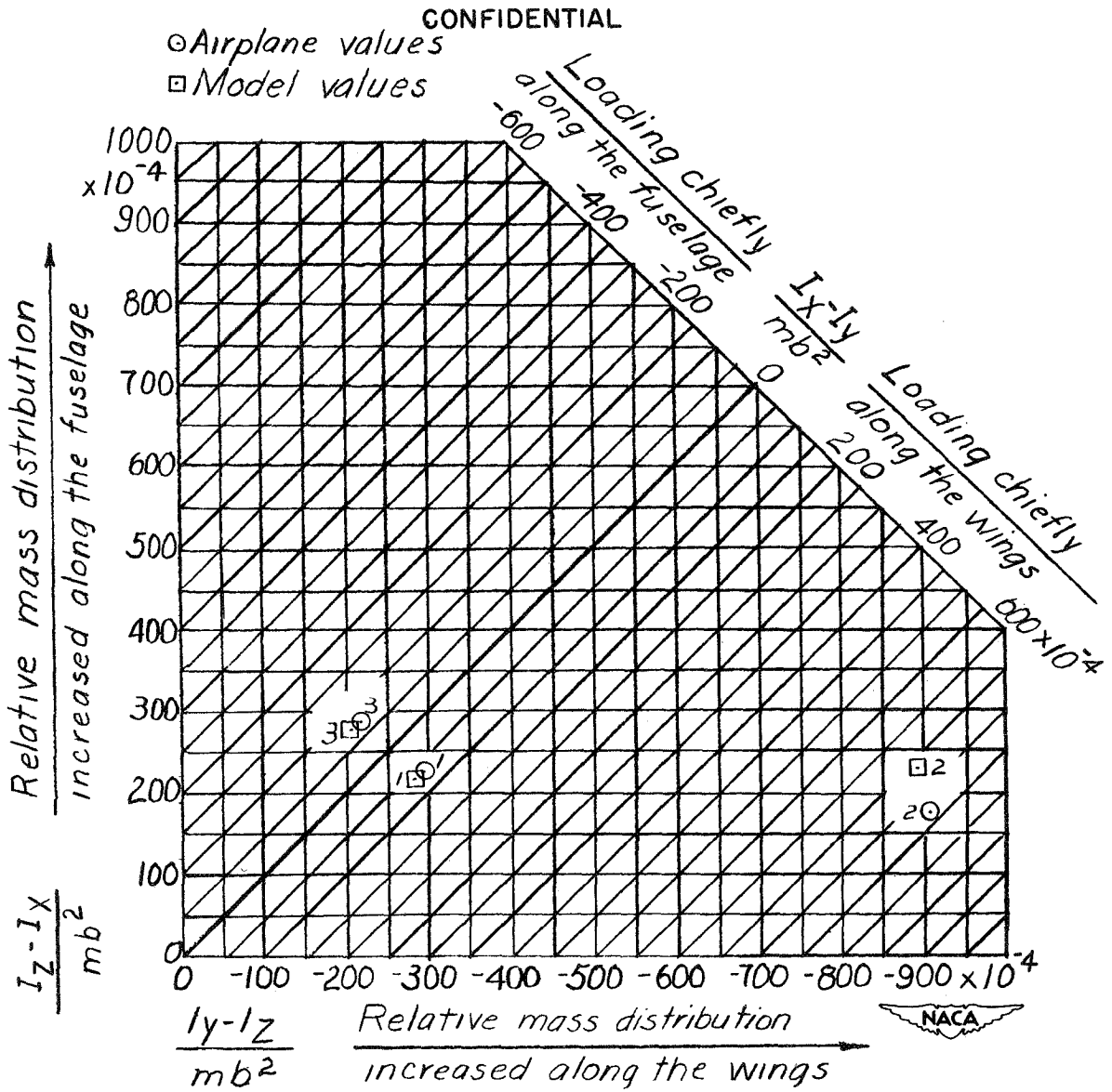


Figure 3.-Mass parameters for loadings possible on the XF-89 airplane and for the loadings tested on the model. (Numbers refer to the loadings listed on table II.)

Restriction/Classification Cancelled

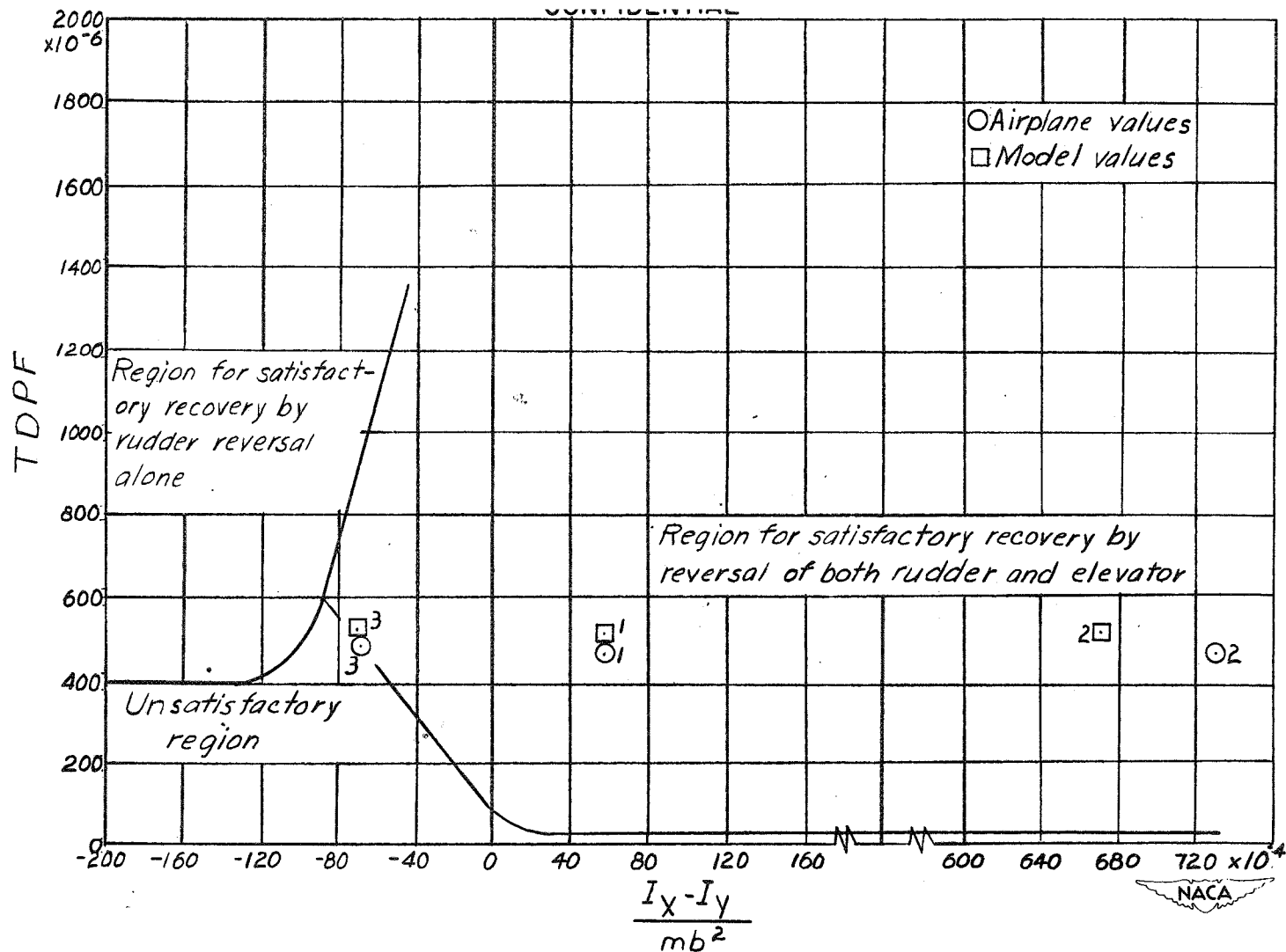


Figure 4. Spin-recovery design requirements for the XF-89 airplane.

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