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Brief Flight Tests of Crosswind Landings and Sidestep Manoeuvres on the BAC 221 Aircraft

by

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BRIEF FLIGHT TESTS OF CROSSWIND LANDINGS AND SIDESTEP MANOEUVRES ON THE BAC 221 AIRCRAFT

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SUMMARY

A brief flight study has been made of crosswind landings and sidestep manoeuvres in the BAC 221 slender-wing research aircraft. Using the crabbed approach for crosswind landings, and the coordinated S-turn for sidestep manoeuvres, pilots found both tasks straightforward.

The time required to complete a sidestep is little longer than for unswept aircraft, despite the oscillatory roll response to aileron inputs of the BAC 221.

Results of similar tests performed in a ground based simulator show good qualitative agreement.

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* Replaces RAE Technical Report 68251 - ARC 30959

CONTENTS

1 INTRODUCTION

The fundamental advantages of a slender wing compared with a conventional wing are its improved aerodynamic efficiency at supersonic speeds and the stable nature of the vortex flow on the upper surface leading to well-behaved aerodynamic characteristics over a wide speed and incidence range. However, compared with conventional aircraft, a slender wing aircraft has a low roll-to-yaw inertia ratio, and flies at a relatively high incidence in the approach and landing phase, and for these conditions, the handling characteristics are different from those of conventional aircraft. These differences have been well summarised by Barnes[1] and will only be briefly mentioned. They consist essentially of an oscillatory response to ailerons in which large angles of sideslip can easily be built up, and a sensitivity to lateral turbulence. These features might be expected to lead to a deterioration of the handling characteristics and an increase in the pilot work load.

Two particular conditions in which handling difficulties might be anticipated are: approaches and landings with strong crosswinds and the associated turbulence, and the sidestep manoeuvre required to align an aircraft with the runway when it breaks cloud laterally displaced from the runway. Tests in these conditions have been made previously on conventional (i.e. non-slender) aircraft[2,3] and the present Report describes some similar brief tests on the BAC 221 slender wing research aircraft made at R.A.E. Bedford during a preliminary handling assessment[1]. These tests were made to see if slender wing aircraft presented any particular problems. In the event pilots reported no unusual difficulties although the flight records suggested that the pilot work-load may have been increased.

In addition to the flight tests, some comparative tests[4] have been made simulating the BAC 221 on the Aero Flight Division moving-cockpit simulator. The comparison between the simulator and flight tests on the BAC 221 provides a valuable basis for assessing the significance of simulator tests on other slender-wing aircraft such as the Concorde, although the differences in the time scale of the dynamic modes of the two aircraft is quite large and must be borne in mind when making these assessments.

2 DESCRIPTION OF AIRCRAFT AND INSTRUMENTATION

2.1 The aircraft

The BAC 221 aircraft was built to explore the characteristics of slender wings over a considerable proportion of their potential flight envelope. The aircraft is a conversion of the Fairey Delta 2, with a slender, ogee wing of 65 degrees minimum sweep and aspect ratio of 1.28; a 6 foot fuselage extension; and a new, longer undercarriage, to permit landing at very high incidences.

The cockpit and nose portion is hinged, and can be lowered 8 degrees to improve the pilot's view during approach and landing.

A photograph of the aircraft is shown in Fig.1, and a general arrangement in the landing configuration, in which the present tests were made, is shown in Fig.2. Table 1 lists the leading particulars of the aircraft, and Table 2 presents the principal aerodynamic derivatives, again in the landing configuration, as measured in wind tunnel tests[5].

The flying controls are fully powered, irreversible surfaces, consisting of inboard elevators on the wing trailing edge, outboard ailerons, and a conventional rudder. For a variety of reasons already described by Barnes[1], the conversion of the aircraft aggravated existing deficiencies of the mechanical linkages between the control column and the aileron and rudder operating jacks. In the case of the ailerons, which were fitted with new, larger jacks, a combination of high valve operating forces of the jacks with flexible control linkages made the achievement of precise aileron inputs very difficult.

2.2 Flight instrumentation

The following quantities, relevant to the tests, were recorded in the aircraft on SFIM A22 trace recorders running at a nominal paper speed of 1 inch per second,

Quantity

aileron angle
rudder angle
elevator angle
angle of bank
sideslip
nose-boom pitot pressure
nose-boom static pressure.

For some tests, ground-based kine-theodolites recorded the flight path of the aircraft, so that the aircraft's height, lateral displacement and longitudinal distance from the runway threshold could be determined.

3 SIMULATION

A detailed report[4] on the simulator study made in the Aero Flight Division moving cockpit simulator is available. A brief account of the tests is given here.

The tests were made after the completion of the flight programme, and were arranged to represent typical flight tasks with similar crosswind and turbulence conditions.

Visual cues to the aircraft's position and velocity were provided by a closed-circuit television display. A television camera was driven over a scale model of the airfield and surrounding countryside in response to the computed aircraft position and attitude, and the picture so produced was projected on to a flat screen mounted ahead of the dummy cockpit. The aircraft's windscreen structure was not represented.

Motion cues in roll and pitch only were available, and the cockpit instrument display was similar in content to that of the aircraft, although the disposition of the instruments was not identical. Pilot's airspeed and altitude indications did not include the effects of pressure lag.

The principal aerodynamic derivatives used to set up the simulation are collected in Table 2.

Pen recorders were used to obtain continuous time histories of the quantities listed below:-

aileron, rudder and elevator angles
angle of bank
sideslip
airspeed
altitude
lateral displacement from runway centre-line.

4 FLIGHT TESTS

4.1 Crosswind landings

Two methods of performing crosswind approaches and landings may be used, the sideslipping and the "crabbing" approach. In both cases the aircraft's track lies along the extended runway centre-line, but in the sideslipping method, the pilot maintains a steady straight sideslip with the aircraft heading identical to the runway heading. The sideforce, rolling and yawing moments due to sideslip are balanced by angle of bank, aileron and rudder deflections.

Just prior to touchdown the wings must be levelled and the landing completed before any appreciable lateral, or "drift", velocity has developed.

During the crabbing approach, on the other hand, the aircraft heading is adjusted so that the sideslip is zero, and in the steady state, bank, aileron and rudder angles are also zero. In this case the angle of drift, the difference between heading and track angle, is removed just prior to touchdown by applying rudder, and aileron is then required to counteract the resulting rolling moments due to sideslip, rate of yaw and rudder deflection. Again the landing must be completed before the aircraft drifts appreciably across the runway.

Earlier work[3] has suggested that of these two techniques, the crabbing approach is less tiring for the pilot, and moreover, is compatible with existing instrument landing systems, whereas the sideslipping technique is not.

The seven crosswind landings reported in the present tests were performed using the crabbing approach.

The approaches were made, with undercarriage and nose lowered, and elevator and aileron gear ratios* of 2:1 at speeds between 153 and 170 knots, leading to touchdowns between 138 and 148 knots. The maximum crosswind during the tests was 12 knots. Table 3a summarises the test conditions. The aircraft has a crosswind limitation of 20 knots which is imposed by directional control limitations on the runway. Records were made from about 30 seconds prior to

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*The elevator and aileron circuits have a variable gearing between the stick and control surfaces which may be selected by the pilot in flight. A 2:1 gear ratio halves the control surface deflection for full stick travel.

touchdown, and during the first part of the ground roll. Analysis of the records is confined to the airborne and touchdown phase only.

4.2 Sidestep manoeuvres

Two techniques are available for correcting lateral displacement errors during a landing approach; the flat slipping turn, and the banked turn. In the first method, the transverse forces required to align the aircraft with the runway centre-line are generated by sideslip alone, whereas in the banked turn, a component of the aircraft lift force is generated in the desired direction.

It has been demonstrated[2] that, for conventional straight-winged aircraft, the more effective method of the two is the banked turn. It might be expected therefore, that this method will also be more effective for the slender aircraft, especially since the large rolling moment due to sideslip and potentially oscillatory response to aileron inputs[1] characteristic of such aircraft, would demand large and rapidly varying aileron deflection to maintain wings level during the flat turn. In the short time available for the present tests, it was therefore decided to concentrate on the banked turn manoeuvre.

Twelve such manoeuvres were performed; the test conditions are tabulated in Table 3b. The aircraft was flown, with undercarriage and nose lowered, and elevator and aileron gear ratios of 2:1, at speeds between 160 and 175 knots along an approach path parallel to the runway, but offset either side from the runway centre-line by distances between 150 and 400 feet. The sidesteps were begun at arbitrary heights of 300 or 600 feet above ground, and were considered complete when the aircraft was aligned with the runway centre-line at a height less than 50 feet, without necessarily completing the landing. Records were made from a few seconds before initiation of the sidestep until completion.

For some tests, ground-based kine-theodolite cameras recorded the flight path of the aircraft, enabling its position and velocity to be determined, in a system of earth axes.

5 RESULTS AND DISCUSSION

5.1 Crosswind landings

During a landing approach, considerable control activity is required to counteract disturbances due to turbulence, and to make flight path corrections to achieve a desired touchdown point. It has also been suggested[6] that a pilot introduces continuous elevator inputs as a means of monitoring the pitching response available during the approach. There is nevertheless, a trim state, appropriate to the instantaneous flight conditions, about which all this control activity takes place.

In the case of the "crabbing" approach, as described in section 4.1, the trim states for bank, sideslip, aileron and rudder angles are all zero. Thus apart from small heading corrections which may be required to compensate for wind shear near the ground, it would be expected that trim states for approaches with and without crosswind would be indistinguishable, and only during the "kicking-off drift" manoeuvre, just prior to touchdown would differences become apparent.

5.1.1 Approach

Figs.3 and 4 show time histories of control positions, bank angles, sideslip and airspeed during approaches made with nominally zero crosswind, and with a 12 knot crosswind component, respectively. Records of simulated landings, under nominally similar conditions of crosswind and turbulence, are also presented for comparison. The histories have been constructed from points plotted at $\frac{1}{2}$-second intervals.

Fig.3 shows that both in flight and simulator considerable control activity was required about all three axes. In flight the ailerons were used at frequencies in the order $\frac{1}{2}$ to 2 Hz, at typical amplitudes of ±2 degrees, maximum ±4 degrees, while maximum rudder inputs were about ±2 degrees applied infrequently. It is worth noting however, that these amplitudes constitute only one-half of the total aileron, and less than one quarter of the total rudder movement available during the approach, whereas almost full aileron and rudder was required in tests[3] in similar conditions on the Avro 707A, a 50 degree delta-winged aircraft. Elevator inputs, in terms of excursions from the steady trim state, varied from about ±1 degree at 168 knots airspeed to ±2$\frac{1}{2}$ degrees at 153 knots airspeed, at a frequency of about 2/3 Hz.

The simulator records of control activity correspond well with the flight records, although control inputs are in general of slightly smaller amplitude and at lower frequency. The greater use of aileron in flight may be due in part to the deficiencies of the aircraft's aileron control circuit, which were not represented in the simulator. These deficiencies may have led, in flight, to some overcontrolling in roll, necessitating corrective aileron movements.

Angles of bank and sideslip, which provide some indication of the success with which the pilot controlled the manoeuvre, indicate that no particular difficulties were experienced. In flight, bank angles were held within ±7 degrees for most of the recorded part of the approach, and at touchdown, the wings were level within ±2 degrees. Sideslip was held within 3 degrees of zero. The mean values of bank and sideslip angles are slightly displaced from zero. It is thought that this may be due to the pilot's desire to see round the central pillar of the windscreen; with zero crosswind the aircraft heading and track coincide, and the pillar may thus obstruct the pilot's view of the runway. The simulator records are generally of similar form, but more symmetrical, possibly because the windscreen structure was not reproduced in the simulator.

Speed holding appears to be rather smoother in flight than in the simulator. Although pressure lag in the aircraft A.S.I. system may have masked short period speed fluctuations due to turbulence. The simulation did not include lag effects, and the "high"-frequency speed excursions shown in Fig.3 were almost certainly imposed by the simulation of turbulence.

Fig.4 shows time histories for a landing with a nominal 12 knot crosswind, on the port side, (13 knot total wind), this is the maximum crosswind component recorded to date. As expected, the results are similar to those of Fig.3, for zero crosswind, except for three inputs of right rudder in flight, which may have been required to correct the drift angle for the effects of wind shear near the ground. Agreement with simulator results is again reasonable.

It is apparent from Figs.3 and 4 that at least up to a 12 knot crosswind the technique used by the pilot, even to the touchdown point, is not materially affected by the crosswind. The most notable feature is the amount of general control activity recorded during the approach. Fig.5 shows the ranges of aileron, rudder, bank and sideslip angles used during the recorded approaches (including touchdowns) as functions of crosswind component and total wind speed. It is seen that there is little correlation with crosswind or total wind speed, apart from a tendency for sideslip, and to a lesser extent, aileron angle amplitudes to increase with total wind speed.

Although these tests were not exhaustive they show that no unexpected problems were encountered during the approach of the aircraft in crosswinds up to 12 knots and total winds of 20 knots. Pilots commented that they experienced no difficulty in controlling the aircraft, although they were perhaps more aware than usual of the lateral sensitivity of the aircraft to turbulence.

5.1.2 Touchdown

As has already been mentioned pilots normally kick off the drift just prior to touchdown following a crabbing approach. Using the derivatives given in Table 2 it has been calculated that a rudder angle of 2^{o} would be required for an approach speed of 150 knots and a crosswind of 12 knots (equivalent to a drift angle of $4\frac{1}{2}$ degrees). In addition an aileron angle of 6^{o} would be required to maintain the wings level at touchdown.

The flight records have been examined to see how pilots removed drift before touchdown. It has not been possible to establish this from the records because of the general control usage noted in Fig.5. Pilots reported that they either removed the drift with gentle rudder application, or accepted the relatively small drift angle of up to $4\frac{1}{2}$ degrees at the maximum crosswind of 12 knots. Adverse pilot comment was directed mainly at the difficulty of ground handling of the aircraft, which may have been accentuated by the undercarriage geometry. The manufacturers limit the aircraft to a 20 knot crosswing due to directional control on the runway.

It must be emphasised that these tests were made as part of a handling programme and consequently are limited in their scope. A fuller investigation would require at least measurements of wind velocity on the approach path, aircraft heading and track.

5.2 Sidestep manoeuvres

Figs.6 and 7 show time histories recorded in flight and the simulator of control positions, bank and sideslip angles, airspeed, height and lateral displacement from the runway centre-line during sidestep manoeuvres.

For Fig.6 the crosswind during the flight record was nominally zero although the headwind was 18 knots. The sidestep was commenced at 300 ft altitude from approximately 400 feet to the right of the runway centre-line;

conditions for the simulator tests were approximately the same. The records have been synchronised at the instant of starting the manoeuvres. Both for flight and the simulator, although the sidestep manoeuvre was completed, it was not followed by an actual landing.

Bearing in mind the nature of the tests the agreement between the flight and simulator record is very good. The variation of bank angle with time shows an approximately sinusoidal form. The initial bank reduces the lateral displacement and the opposite bank aligns the aircraft with the runway. This is similar to records obtained for conventional aircraft[2]. However the control inputs required to achieve the manoeuvre for the BAC 221 are less well defined than for conventional aircraft. This is probably because the roll power needed to neutralise the effects of turbulence is high compared with that required to manoeuvre. In addition, the aileron angle input required to produce a sinusoidal bank angle output is complex because of the oscillatory rolling response of the aircraft. Fig.8 shows the aircraft response to an approximate step input of aileron. For a conventional aircraft a steady rate of roll is quickly obtained after an aileron input, whereas for the BAC 221 a steady rate of roll was not achieved.

For the flight results shown in Fig.7 the crosswind was 8 knots from the right and the sidestep was commenced at 300 feet altitude from 120 feet to left of the runway centre-line. In the case of the simulator results for the same crosswind the closest comparable sidestep was initiated from 220 feet lateral displacement. The agreement between the flight and simulator records is quite good. Compared with the results shown in Fig.6 the relative magnitude of the random bank angle variations distorts the smaller sinusoidal input chosen by the pilot. During the simulator test, the pilot opened the throttle before touchdown,causing the increase of airspeed shown at 27 seconds. This is of no signficiance in the sidestep manoeuvre. The flight test was followed by a full landing.

Pilots commented that the sidestep manoeuvre was easy to perform using aileron control alone, although small co-ordinating rudder inputs were usually applied. This comment is rather unexpected in view of the oscillatory roll response of the aircraft.

Fig.9 shows the maximum bank angles ϕ_1 and ϕ_2 chosen by the pilot during the entry to and recovery from the sidestep manoeuvre. The results show a trend of increasing bank angle with lateral displacement and a slightly larger angle for the entry to the manoeuvre. The greatest bank used was slightly less than the limit of 35 degrees suggested by Perry et al[2] for fighter type aircraft. Three of the ϕ_1 values are significantly smaller than the remaining points. Kine-theodolite records are available for two of these points and show that there was a small initial tracking error of about 1° towards the runway, consequently the pilot chose to use less initial bank in these cases.

Fig.10 shows that the time taken from the start of the sidestep to regaining wings level flight was about 10 to 15 seconds for lateral displacements of 100 to 400 feet, a further 8 or 10 seconds was usually available before reaching the touchdown point. Based on a simple sinusoidal bank angle variation the time for the sidestep manoeuvre has been calculated[2] using measured values of ϕ_1 and ϕ_2. There is very good agreement with the measured values of time required, suggesting that the simple theory[2] based upon conventional aircraft experience is applicable to slender-wing aircraft. The full line in this figure gives the minimum time required assuming that both ϕ_1 and ϕ_2 are 35 degrees. Also, results from earlier tests[2] on the Avro 707 (a 50 degree delta-wing aircraft) are shown in Fig.10 and these times are larger than for the BAC 221: this is interesting to note as, although the maximum rates of roll available at the approach speed of the two aircraft are similar (about 35 degrees/second), it is contrary to the suggestion of Perry et al[2] that the more complex rolling characteristics of a slender wing aircraft may increase the manoeuvre time. In fact the manoeuvre time was only slightly longer than that for the Meteor[2], an unswept-wing fighter aircraft.

Figs.11 and 12 compare the maximum bank angles and the times to complete the sidestep manoeuvres as measured in flight and in the simulator. These show that rather smaller bank angles were attained in the simulator, and that this correspondingly increased the time of the manoeuvre. The restricted field of view afforded by the simulator, or the false lateral acceleration cues (due to bank angle) sensed by the simulator pilot, may have inhibited his use of large bank angles and so given rise to this result.

6 CONCLUSIONS

Brief flight tests have been made to investigate crosswind landings and sidestep manoeuvres on the BAC 221 aircraft. A simulator study has also been made, and some results have been included for comparison.

Landings have been made in crosswinds up to 12 knots, with a total wind of 20 knots, using the crabbing technique. Pilots reported no particular difficulty, and although considerable control activity was required throughout the range of test conditions, this constituted a smaller proportion of the available lateral control than was required for the Avro 707A under similar conditions. No systematic variation with crosswind component was observed; there was, however, a tendency for sideslip excursions and aileron activity to increase with total wind speed, which may have resulted from the aircraft's sensitivity to lateral turbulence.

Because of the aircraft's relatively high approach speed, the maximum drift angle at touchdown was only $4\frac{1}{2}$ degrees, and the results show that pilots either removed the drift by gentle rudder application, or landed without correcting the drift.

Sidestep manoeuvres were made with initial displacements of up to 400 feet from runway centre line, starting at 300 feet, or, in a few cases at 600 feet altitude, in crosswinds up to 10 knots. Pilots found the co-ordinated 'S'-turn easy to perform, despite the oscillatory roll response to aileron inputs. The largest bank angle used was about 30 degrees, and the time required to complete a sidestep varied between 10 and 15 seconds. This time is only slightly greater than that required for a straight wing fighter aircraft.

In general, the simulator results showed qualitative agreement with the flight tests.

Table 1

BAC 221 LEADING DIMENSIONS

Length	57.6 ft
Span	25.0 ft
Mean aerodynamic chord	25.0 ft
Wing area	490 ft^2
Aspect ratio	1.28
Minimum sweep	65°
Weight, zero fuel	16454 lb
Weight, full fuel	19998 lb

Mean centre of gravity position (approach configuration) 169 inches forward of wing root trailing edge

Inertia data for weight = 18500 lb in approach configuration (principal axes)

i_A	0.101
i_B	0.150
i_C	0.660

Inclination of principal axes to fuselage datum in approach configuration

1° 18' nose down

Available control angles in control gearing recommended for approach

$$\left.\begin{array}{l}\text{Elevator } 13^{\circ} \text{ up, } 8\tfrac{1}{2}^{\circ} \text{ down}\\ \text{Aileron } 10^{\circ} \text{ up, } 11^{\circ} \text{ down}\end{array}\right\}\text{gearing 2:1}$$

Rudder $\pm 15^{\circ}$

Nominal aileron rigged-up angle 2°

Table 2

AERODYNAMIC DATA FOR BAC 221 AIRCRAFT[5]

Stability wind axes		Body datum axes	
$C_{L_{TRIM}}$	0.514	$C_{L_{TRIM}}$	0.514
α	14.25°	α	14.25°
l_v	-0.108	l_{v_B}	-0.115
l_p	-0.223	l_{p_B}	-0.237
l_r	+0.041	l_{r_B}	+0.086
l_ξ	-0.087	l_{ξ_B}	-0.089
l_ζ	-0.010	l_{ζ_B}	0
n_v	+0.042	n_{v_B}	+0.016
n_p	+0.027	n_{p_B}	+0.018
n_r	-0.424	n_{r_B}	-0.410
n_ξ	+0.017	n_{ξ_B}	-0.004
n_ζ	-0.041	n_{ζ_B}	-0.043
y_v	-0.276	y_{v_B}	-0.276
y_ξ	0	y_{ξ_B}	0
y_ζ	+0.026	y_{ζ_B}	+0.026
μ_2	40.6	μ_2	40.6
$\hat{t}$	2.0 sec	$\hat{t}$	2.0 sec
i_A	0.138	i_{A_B}	0.107
i_B	0.150	i_{B_B}	0.150
i_C	0.622	i_{C_B}	0.663
i_E	-0.130	i_{E_B}	-0.012

Inclination of principal axis of inertia to body datum, 1° 18' nose down

Table 3

SUMMARY OF TESTS MADE

a Crosswind landings

Test No.	Wind velocity °T/kn	Touchdown speed kn	Runway heading	Crosswind kn*
1	260/8	145	270	+1.5
2 (Fig.3)	270/15	140	270	0
3	320/9	148	270	-7.0
4	260/9	144	270	+1.5
5	290/20	142	270	-6.8
6 (Fig.4)	200/13	144	270	+12
7	130/19	138	090	-12

b Sidestep manoeuvres

Test No.	Wind velocity °T/kn	Nominal start height (ft)	Nominal+ offset distance (ft)	Measured+ offset distance (ft)	Crosswind kn*
1	240/12	600	-150	-	-6
2	240/12	600	-300	-	-6
3	330/10	600	+300	-	+8.5
4	330/10	300	+150	-	+8.0
5	240/20	600	-300	-	-10
6 (Fig.7)	240/16	300	-150	-120	-8
7	270/15	300	-150	-112	0
8	270/15	300	-300	-316	0
9	270/15	300	-300	-407	0
10	270/18	300	+400	+343	0
11 (Fig.6)	270/18	300	+400	+386	0
12	270/18	300	-300	-292	0

*Crosswind defined as positive from port side of aircraft.

+Lateral displacement defined as +ve when aircraft is to right of runway centre-line.

SYMBOLS

d	aircraft lateral displacement from runway centre-line, feet
T	time required to complete a sidestep manoeuvre, seconds
V_W	crosswind component, knots
ϕ_1	maximum bank angle for first half of sidestep manoeuvre, degrees
ϕ_2	maximum bank angle for second half of sidestep manoeuvre, degrees

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Fig.1 View of BAC221 in approach configuration

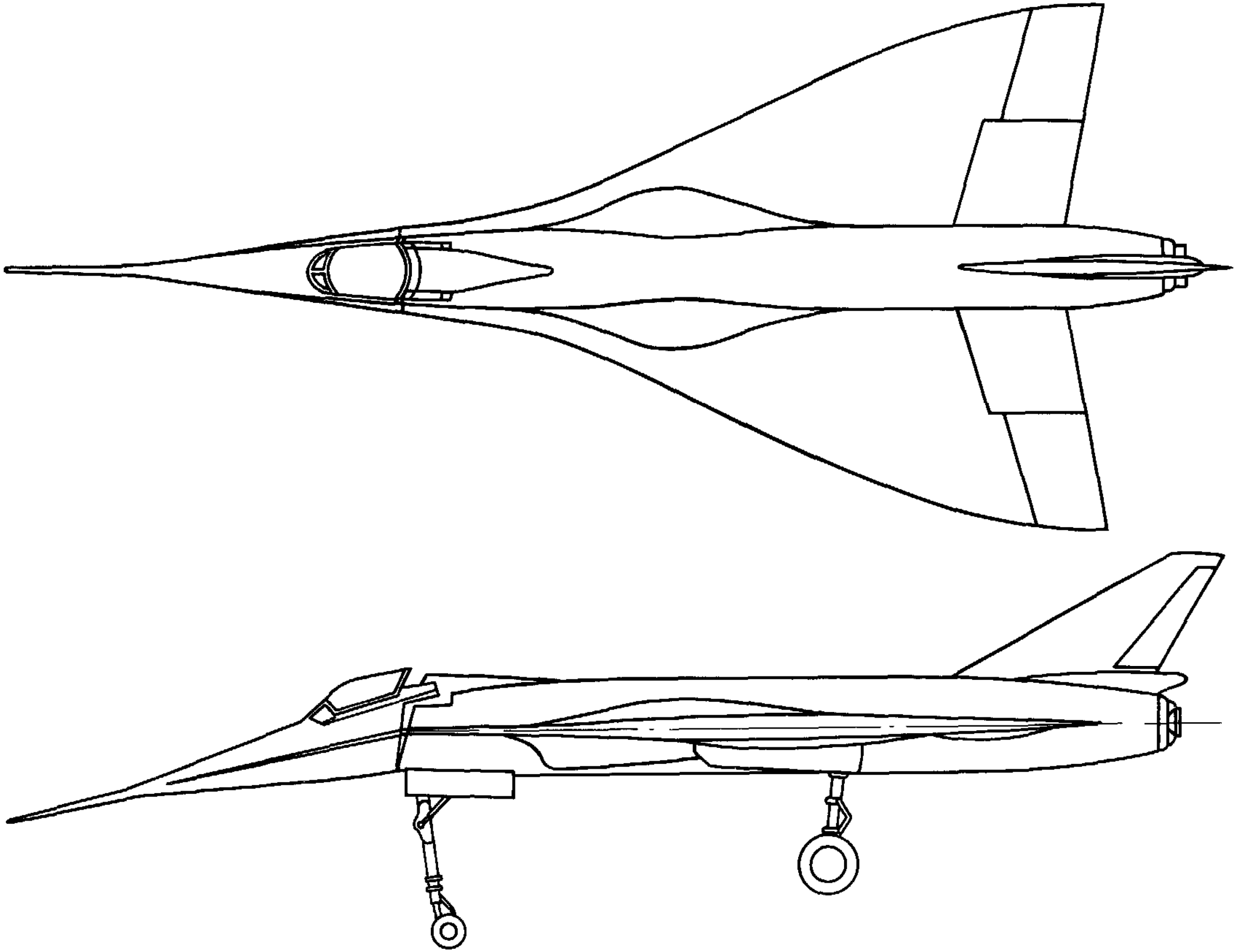


Fig.2 General arrangement of BAC 221 in approach configuration

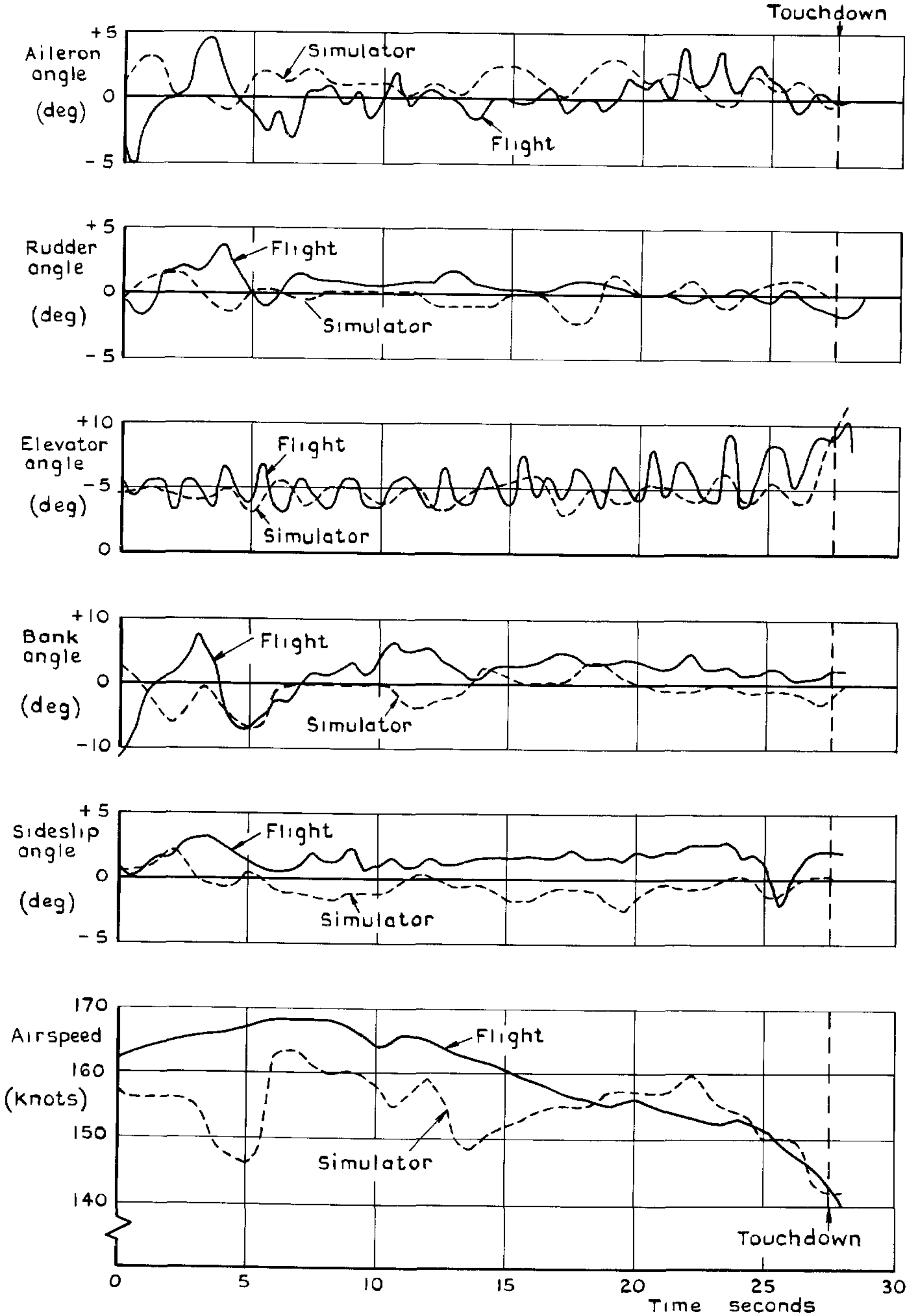


Fig 3 Time history of approach in 15 knot headwind Flight and simulator

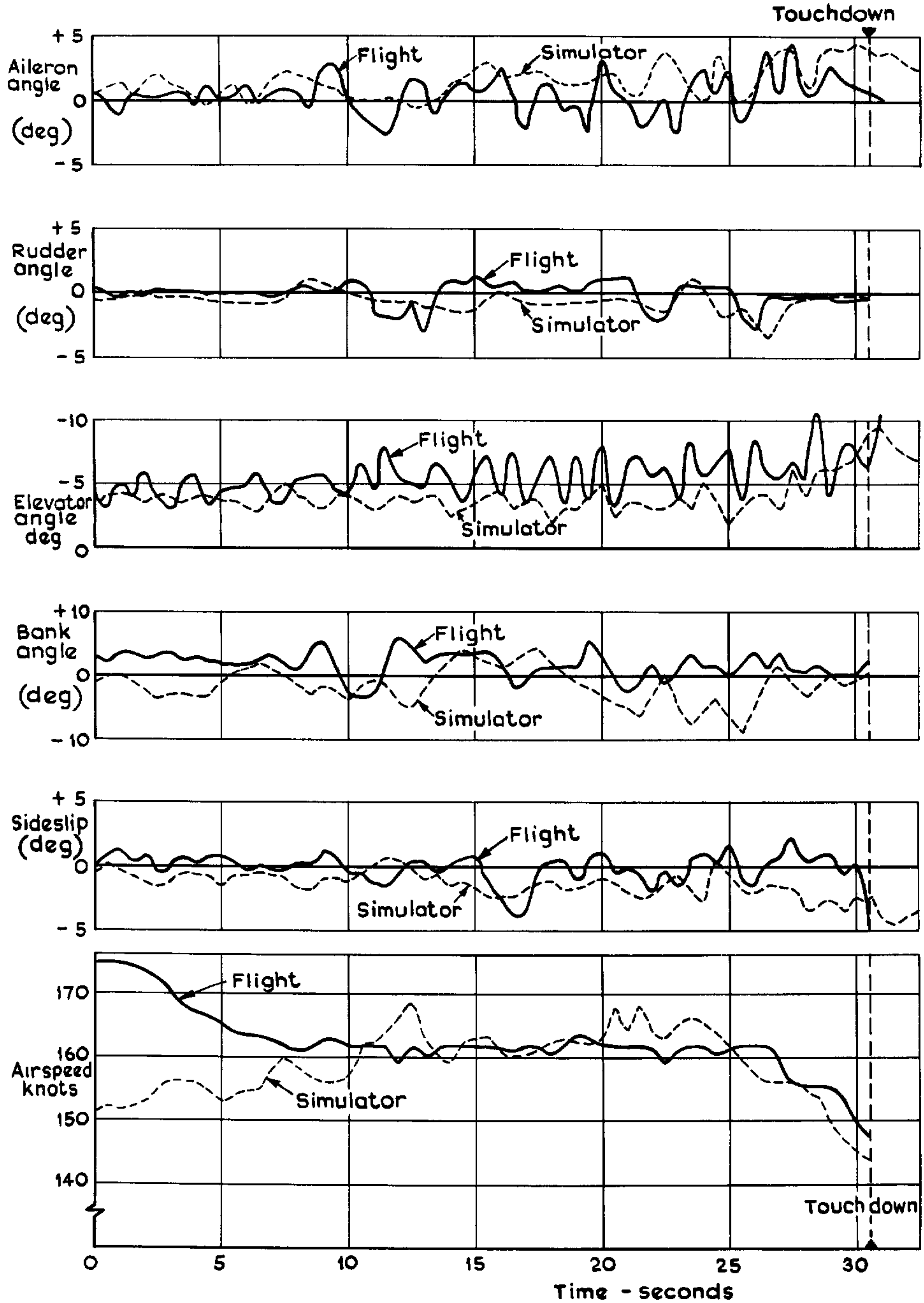


Fig.4 Time history of approach in 12 knot crosswind. Flight and simulator

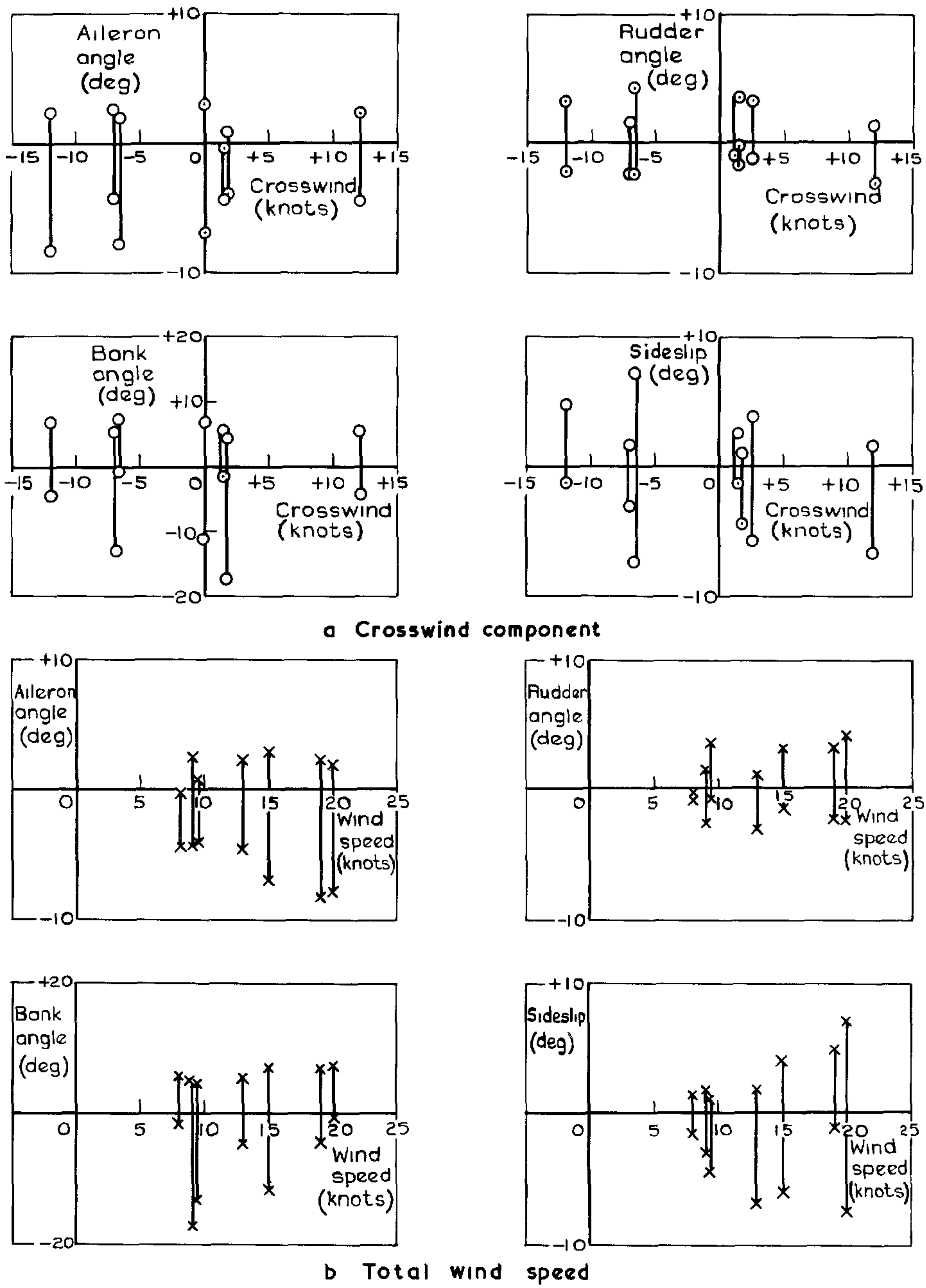


Fig. 5 a & b Maximum amplitudes of rudder and aileron angles, bank and sideslip during approach as functions of crosswind and total wind speed

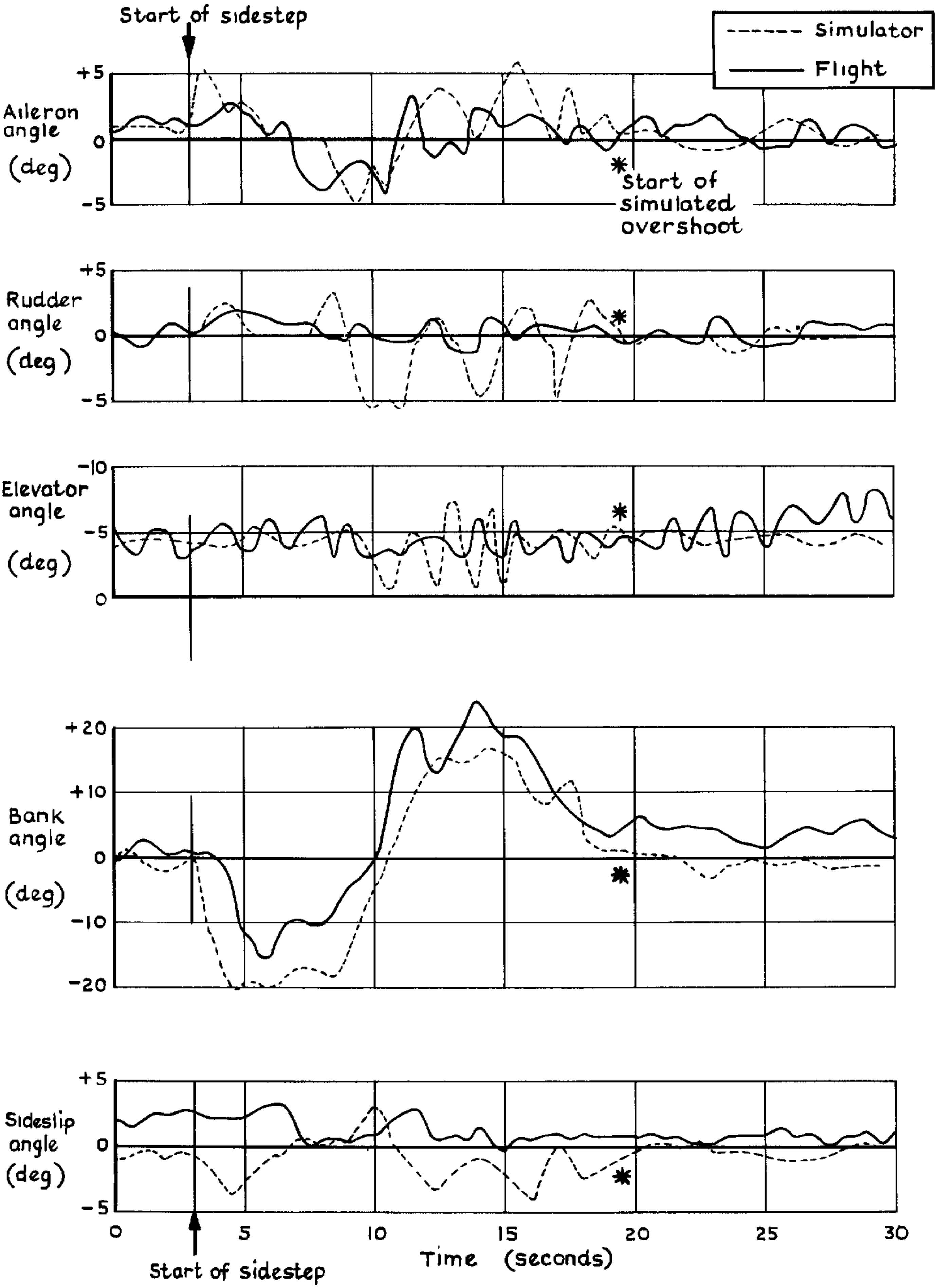


Fig.6 Time history of 385 ft sidestep to left, initiated at 300 ft altitude. No crosswind Flight and simulator

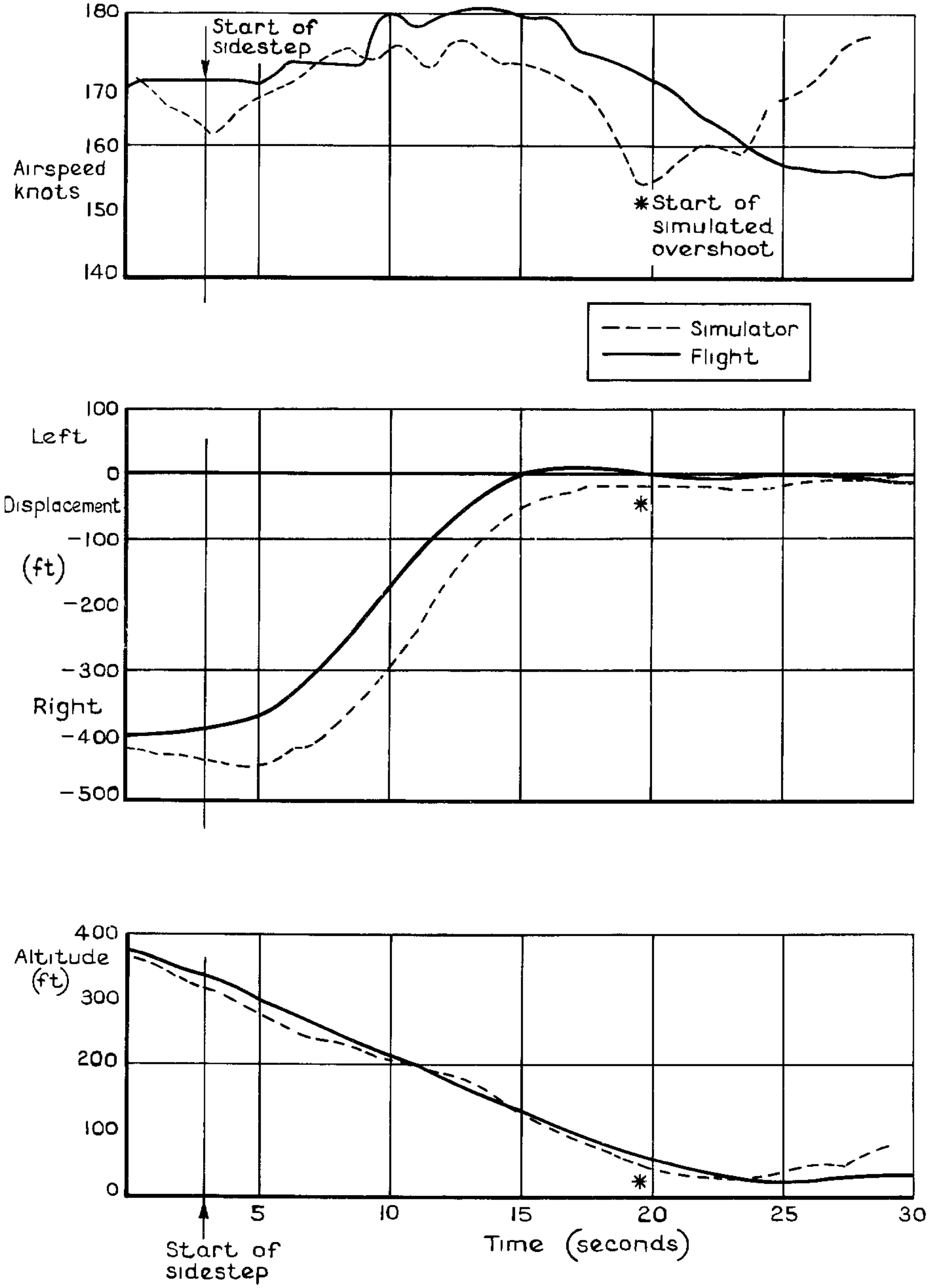

180
170
160
150
140
Airspeed knots
Start of sidestep
*Start of simulated overshoot
Simulator
Flight
100
Left
0
Displacement
-100
(ft)
-200
-300
Right
-400
-500
400
Altitude (ft)
300
200
100
0
5
10
15
20
25
30
Time (seconds)
Start of sidestep

Fig 6 contd

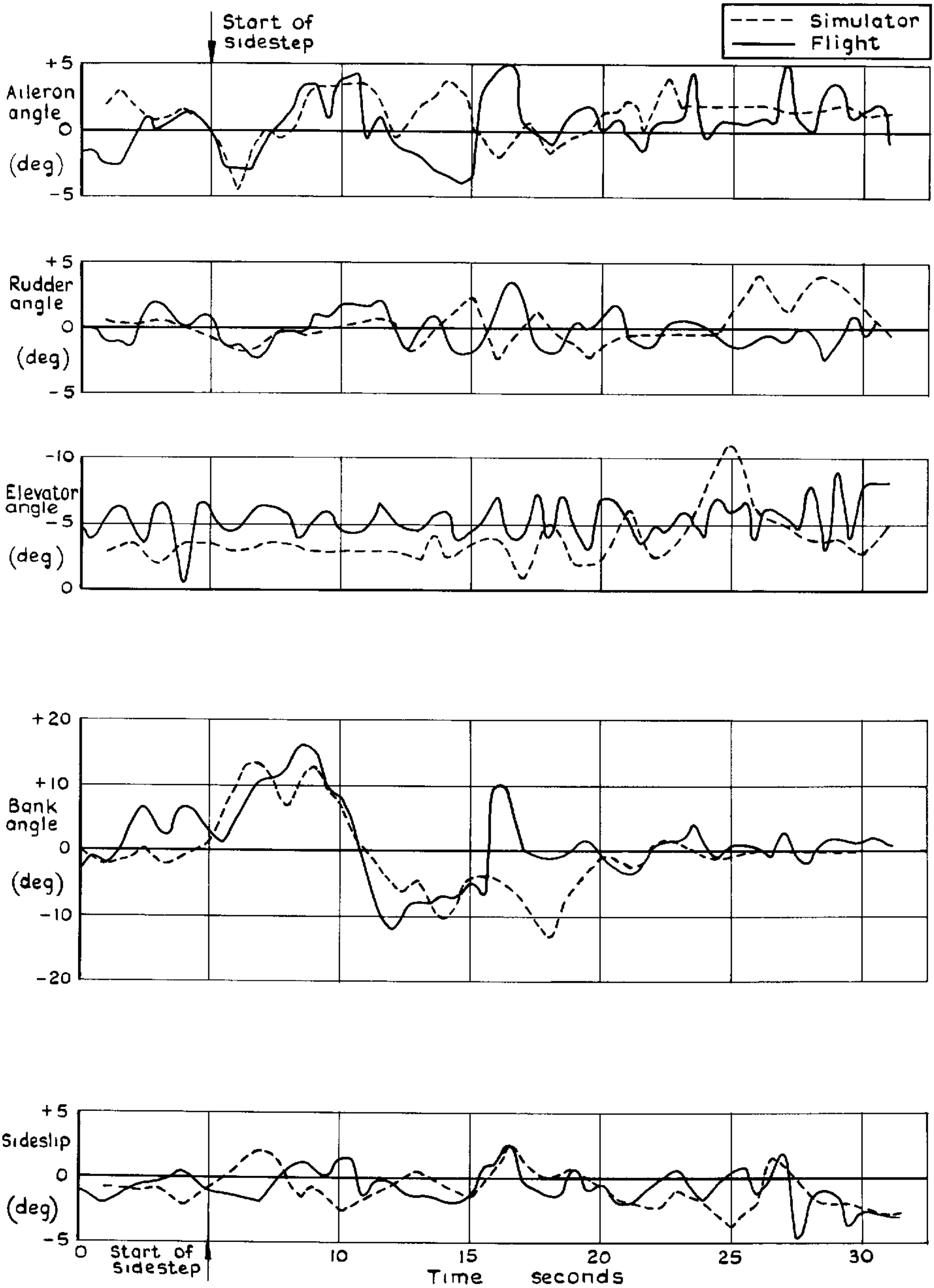
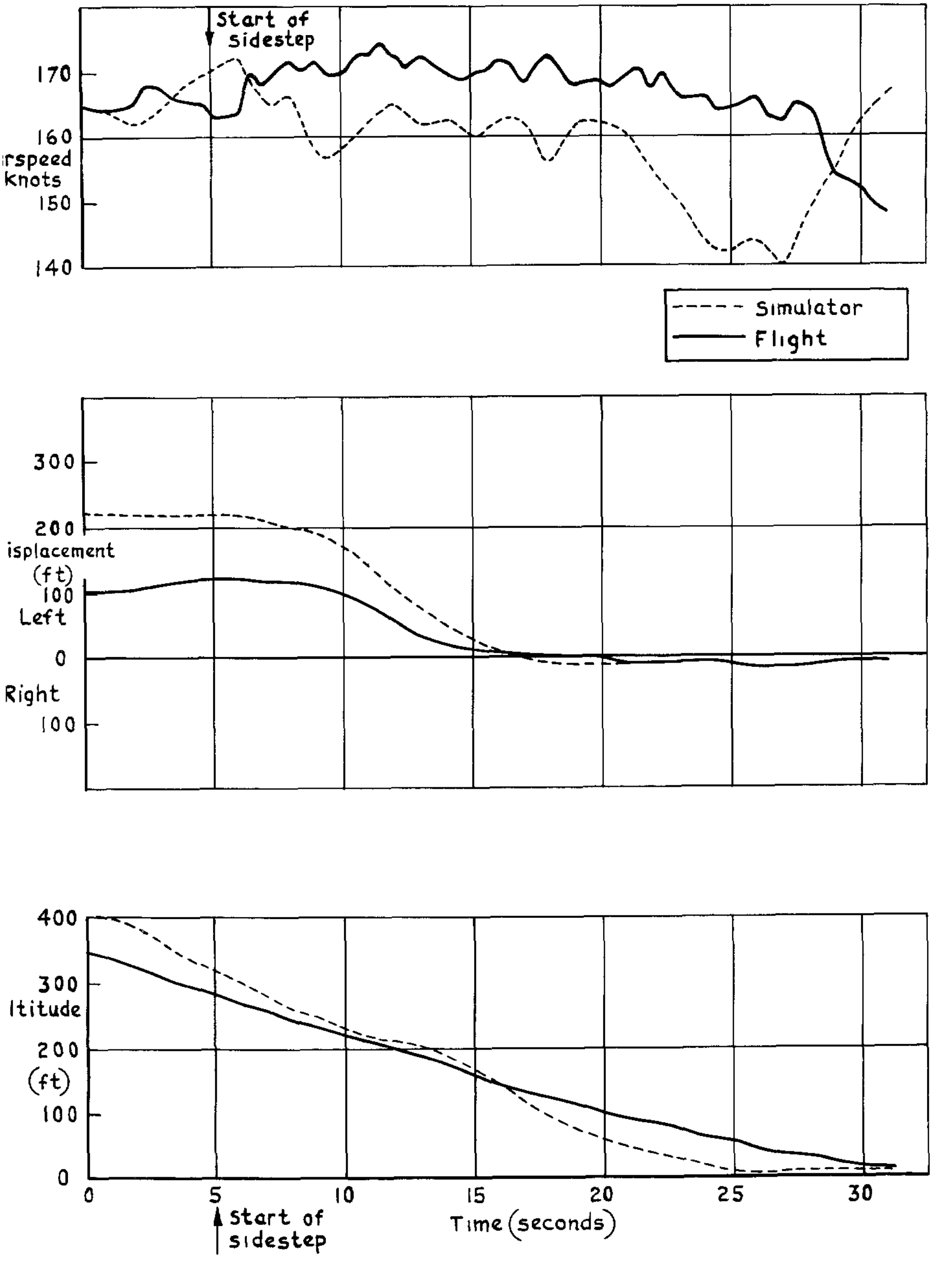


Fig 7 Time history of 150 ft sidestep to right, initiated at 300 ft altitude, 8 knot crosswind from right. Flight and simulator



Start of sidestep
170
160
rspeed knots
150
140
Simulator
Flight
300
200
isplacement (ft)
100
Left
0
Right
100
400
300
ltitude
200
(ft)
100
0
0
5
10
15
20
25
30
Start of sidestep
Time (seconds)

Fig. 7 contd

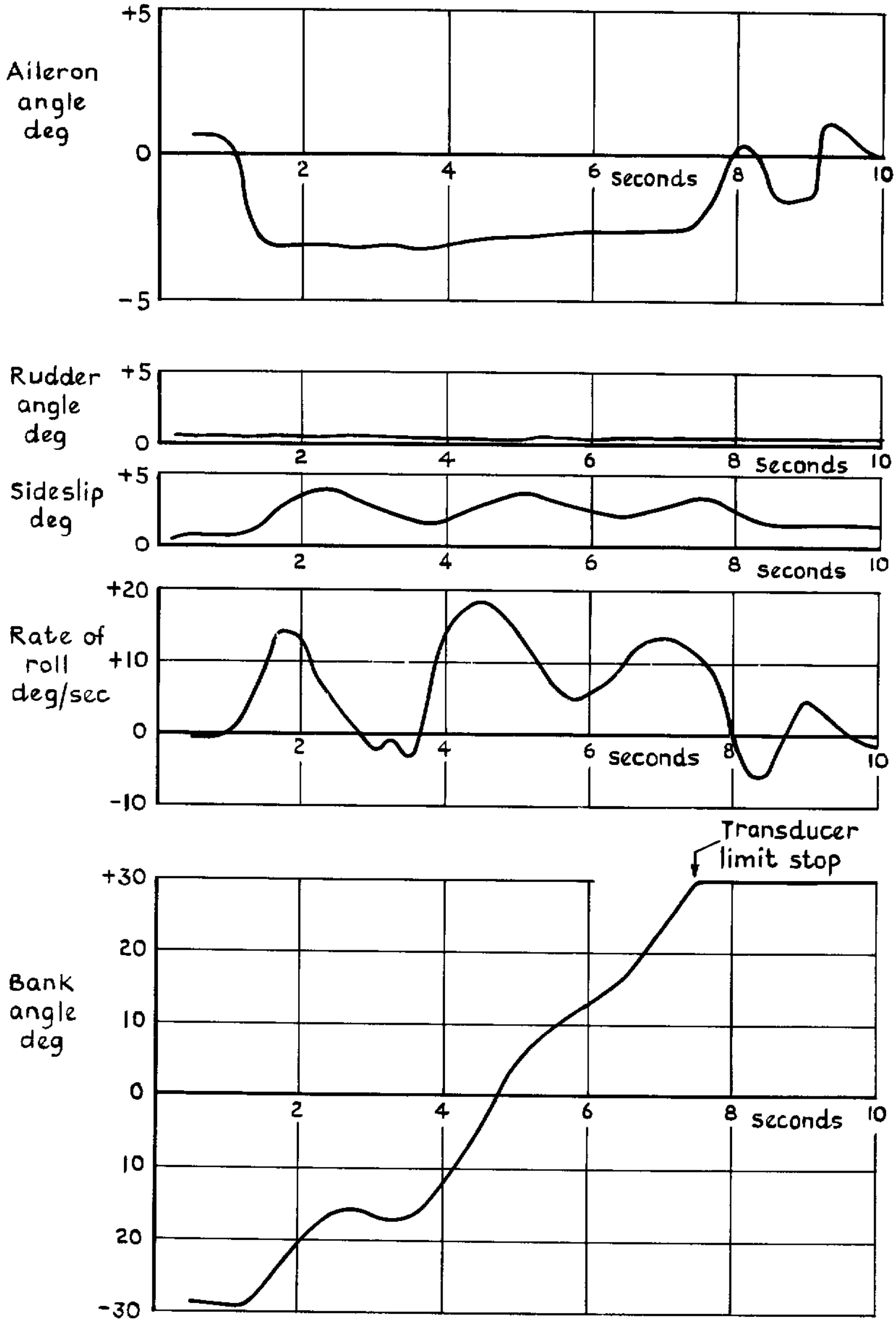


Fig. 8 Response of clean aircraft to step aileron input 150 knots at 20000 ft

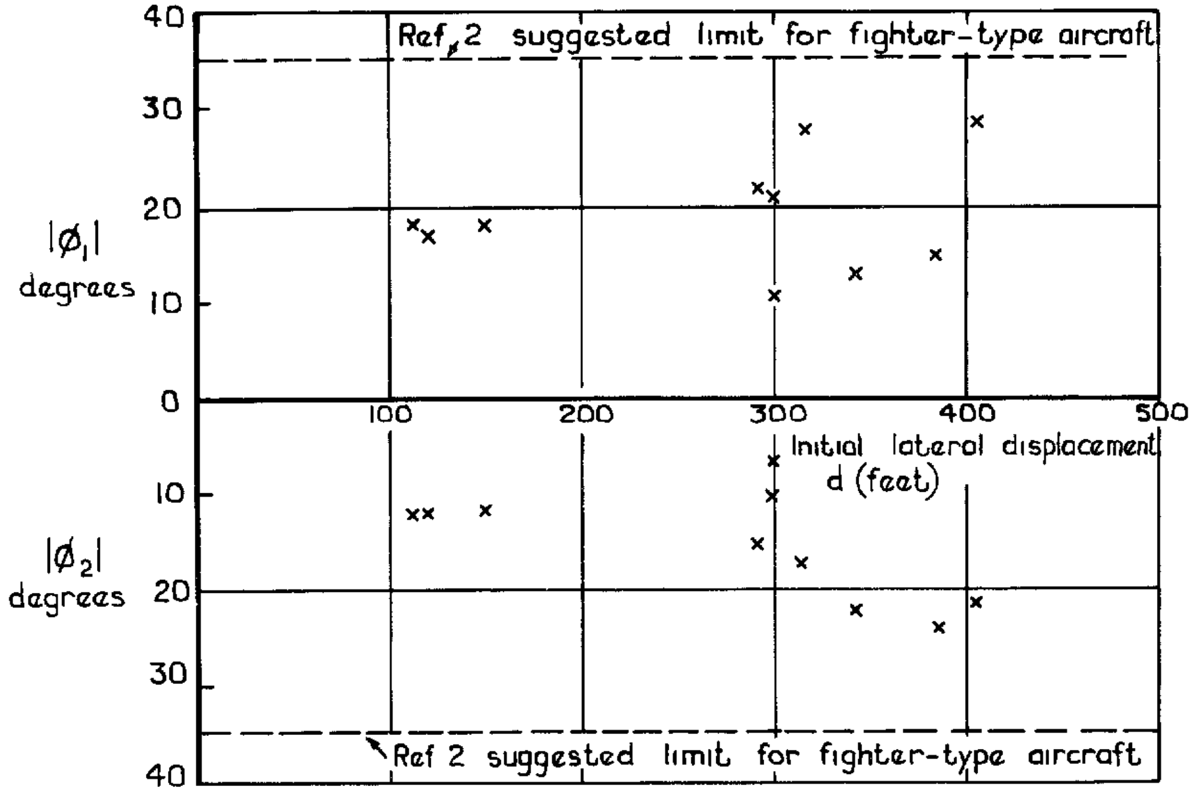


Fig.9 Max. bank angles used during sidestep manoeuvre. Flight

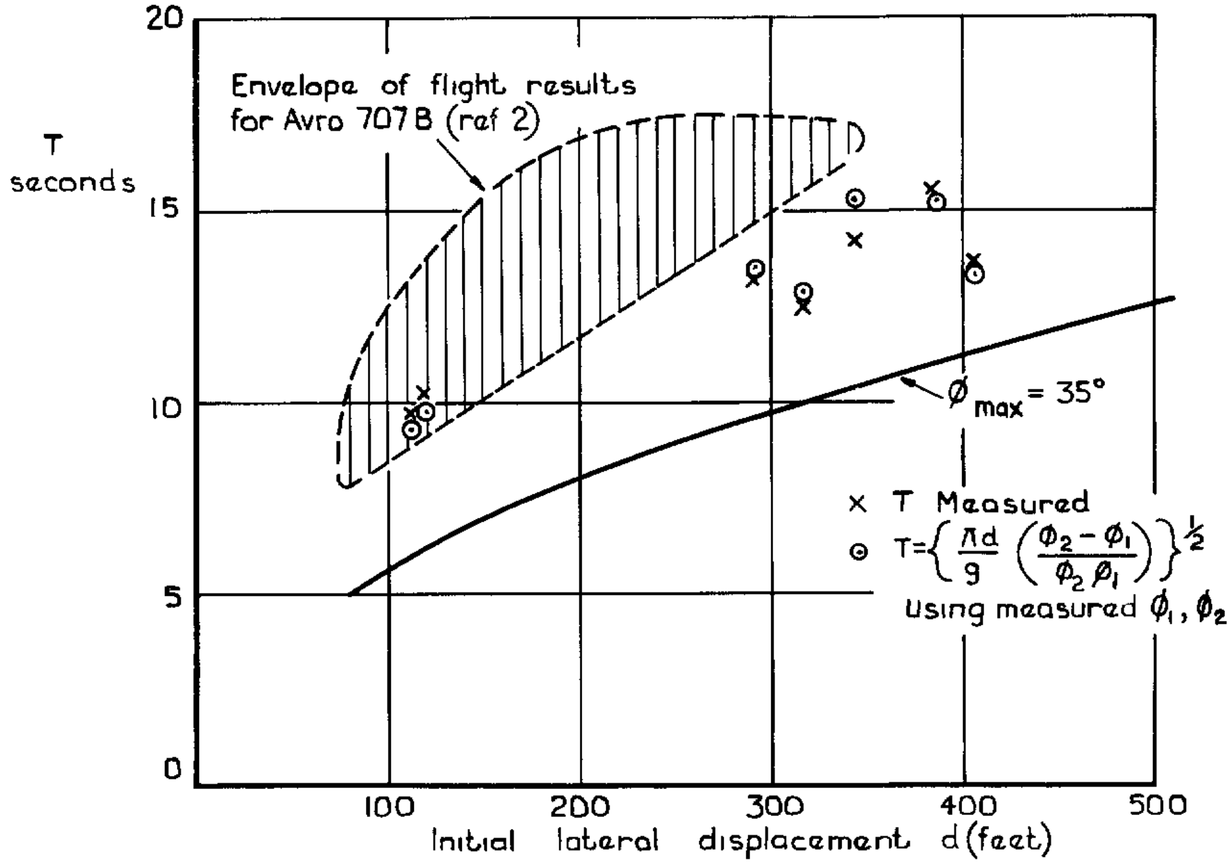


Fig.10 Time required to perform sidestep manoeuvre. Flight

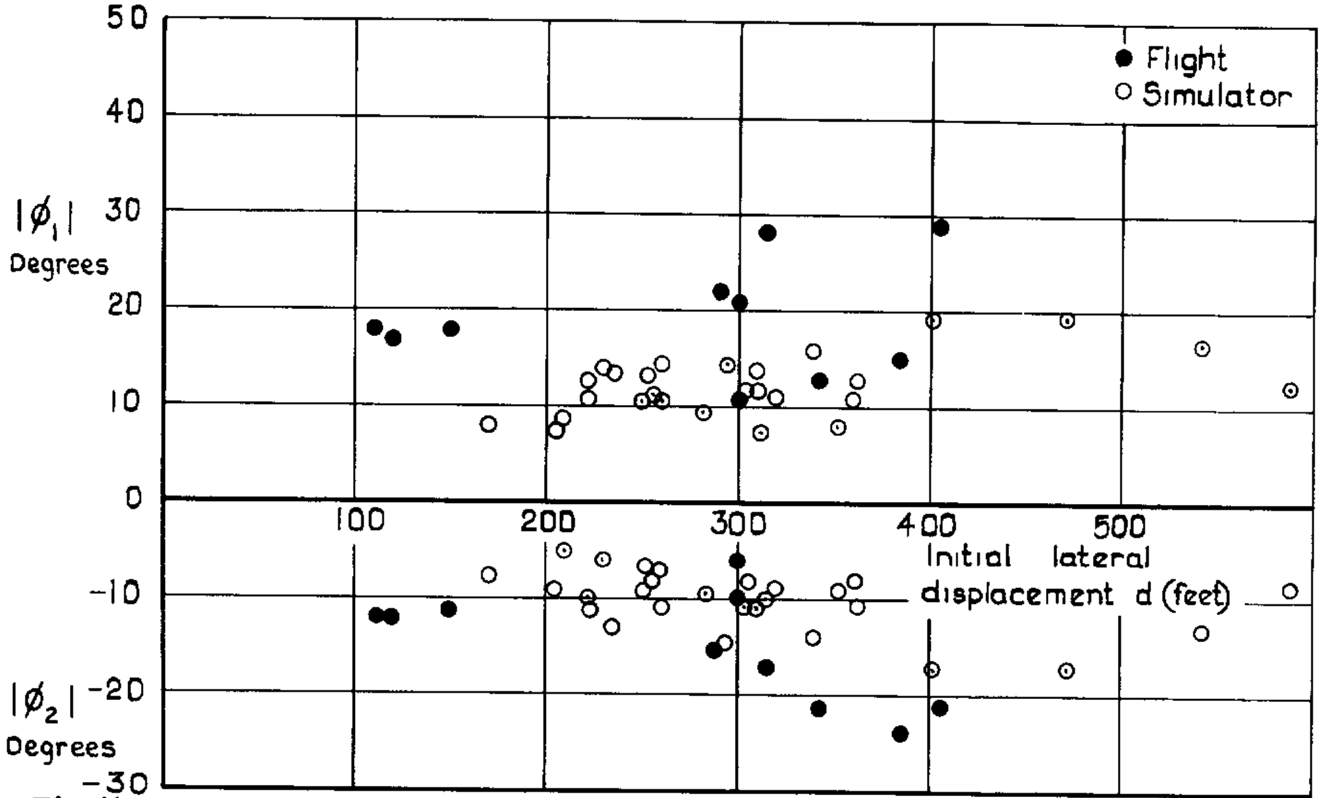


Fig. 11 Maximum bank angles used during sidesteps, flight & simulator

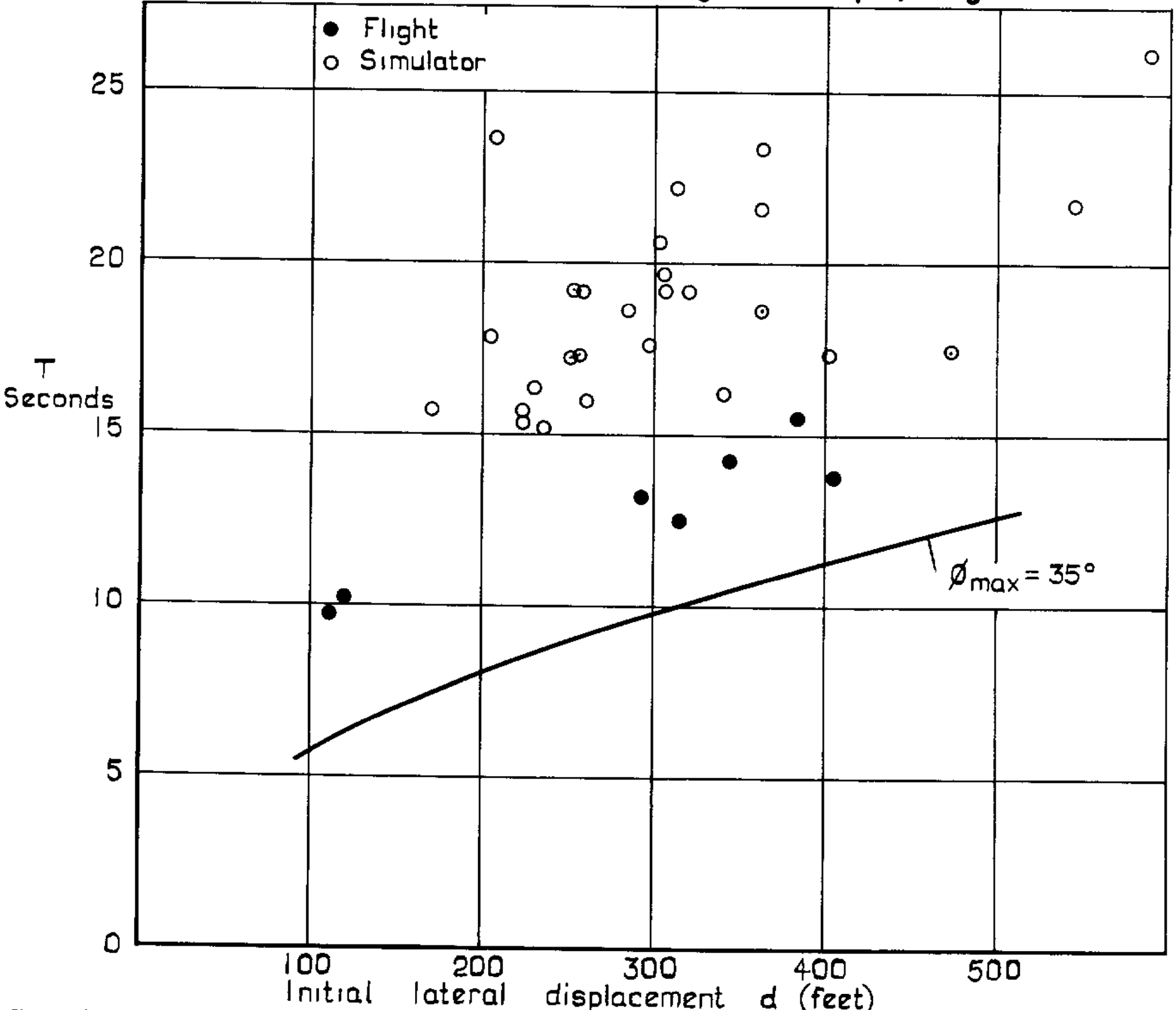


Fig. 12 Time required to perform sidesteps, flight and simulator

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Nicholas, O P

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The time required to complete a sidestep is little longer than for unswept aircraft, despite the oscillatory roll response to aileron inputs of the BAC 221

Results of similar tests performed in a ground based simulator show good qualitative agreement

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