NASA MEMO 3-12-59L

NASA MEMO 3-12-59L

NASA

MEMORANDUM

THE EFFECT OF LIFT-DRAG RATIO AND SPEED ON THE ABILITY TO POSITION A GLIDING AIRCRAFT FOR A LANDING ON A 5,000-FOOT RUNWAY

By John P. Reeder

Langley Research Center
Langley Field, Va.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WASHINGTON

April 1959

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MEMORANDUM 3-12-59L

THE EFFECT OF LIFT-DRAG RATIO AND SPEED ON THE ABILITY TO POSITION A GLIDING AIRCRAFT FOR A LANDING ON A 5,000-FOOT RUNWAY

By John P. Reeder

SUMMARY

Flight tests were made to determine the capability of positioning a gliding airplane for a landing on a 5,000-foot runway with special reference to the gliding flight of a satellite vehicle of fixed configuration upon reentry into the earth's atmosphere. The lift-drag ratio and speed of the airplane in the glides were varied through as large a range as possible.

The results showed a marked tendency to undershoot the runway when the lift-drag ratios were below certain values, depending upon the speed in the glide. A straight line dividing the successful approaches from the undershoots could be drawn through a lift-drag ratio of about 3 at 100 knots and through a lift-drag ratio of about 7 at 185 knots. Provision of a drag device would be very beneficial, particularly in reducing the tendency toward undershooting at the higher speeds.

INTRODUCTION

Several satellite vehicles have recently been proposed which will have the capability of gliding at lift-drag ratios comparable with those of present airplanes upon reentry into the earth's atmosphere. The uncertainty of predicting the exact reentry position has made it desirable that the vehicles be able to land on readily available prepared surfaces. The wing loading and lift-drag ratio of one such vehicle was chosen with the requirement that it be capable of landing on a 5,000-foot runway. This particular vehicle was to have a skid-type landing gear but no provision for lift- or drag-increasing devices.

It is anticipated that the approach and landing of such a vehicle will consist of perhaps three phases:

(1) Ground direction to a gate position with respect to some airport. Control to this point will insure passing the gate with a predetermined minimum altitude and speed.

(2) Visual control of the glide by the pilot to position himself for the flare and touchdown on the runway.

(3) Flare and touchdown maneuver.

The second phase or the ability of the pilot to adjust the glide of such an aircraft into position for a landing on a 5,000-foot runway with a fixed configuration seemed to warrant a simple investigation and is the subject of this paper. The objective was to determine the effects of such factors as lift-drag ratio and speed on the ability of the pilot to make successful approaches.

The scope of the tests was extended to include as high a speed and as low a lift-drag-ratio range as possible to simulate other vehicles that have been proposed. It is felt that the problem of positioning the aircraft for landing during the gliding phase is realistically simulated in these extended cases, although the excess lift and energy of the test airplane for performing the flare maneuver under the extended conditions greatly exceeded those for a more heavily loaded aircraft. For this reason the third phase or the flare and touchdown maneuver was considered outside the scope of this investigation.

AIRPLANE AND TEST METHODS

The airplane selected for the tests was a military training airplane which could cover a range of speeds and lift-drag ratios appropriate to the subject reentry vehicle. The airplane is shown in figure 1.

Test glides to determine the lift-drag-ratio characteristics of the airplane were made during which indicated speed and rate of descent were noted under steady conditions for the various configurations and desired speeds. The average altitude at which the lift-drag ratios were determined in these glides was 5,000 feet. Predetermined lift-drag ratios were selected in some cases by obtaining the proper rate of descent at a given speed by throttle or configuration adjustment. The power used in such an adjustment was only a little more than that at idle. However, the throttle setting was reduced during descents in these cases to maintain constant manifold pressure. No corrections for density were made to indicated speed in determining lift-drag ratios, although position-error corrections were necessary for flap-down configurations.

. The landing-approach test glides were made to a relatively unused airport which has three 5,000-foot concrete runways surrounded by trees. Most of the glides were begun directly over the center of the field at 10,000 feet and in the direction of landing for the runway selected. Some glides were also made from 5,000 feet. In addition, a few approaches were made from 10,000 feet over gate positions at 8, 10, and $12\frac{1}{2}$ nautical miles from the field. At the initial point or gate, the conditions were set to obtain the desired lift-drag ratio at the preselected speed, and the glide was commenced. In all cases the pattern was varied as necessary by the pilot to have the glide path intersect the desired runway at about 0.4 of the runway length from the approach end. Manifold pressure was held constant with throttle as noted to maintain the selected lift-drag ratio. Generally the speed was held constant as closely as possible until the touchdown point was determined. In cases where the shape of the curve of lift-drag ratio against indicated speed of the subject reentry vehicle could be approximately simulated, glides were made to note the effects of being at a speed higher or lower than that for the best lift-drag ratio. In these cases, at gliding speeds higher than that for the best lift-drag ratio, it was considered realistic to reduce speed to flatten the glide path where necessary to complete an approach.

RESULTS AND DISCUSSION

The glides, including explanatory remarks, are enumerated in table I. Wind data for the period of the tests are included in table II. In 28 glides there were 9 misses, all of them undershoots. The data are presented in figure 2 as plots of the lift-drag ratio against the calibrated airspeed V_c in knots. The solid symbols indicate undershoots; the open symbols indicate successful approaches. The curve drawn through the data points for the test airplane in the upper left of the figure approximate the lift-drag-ratio variation with speed for the reentry vehicle under consideration.

It was the pilot's consistent and strong impression that speed was the primary factor in his ability to attain the desired touchdown area. Speed is very important because all turn and maneuver radii increase as the square of the speed. Therefore, the distance through which the pilot is trying to judge the touchdown point and the distance required for corrections to his path increase rapidly with speed. The errors in the touchdown point increase in a similar manner. Also, it was apparent that the tendency to undershoot became very strong at the lower lift-drag ratios. It was felt that a line could be drawn on figure 2 separating the lift-drag ratio and speed combinations which could be judged for successful approaches from those which resulted in consistent undershoots. This line passes through a lift-drag ratio of roughly 3 at

100 knots and 7 at 185 knots. Although the rate of descent did not appear to the pilot to be a primary factor in his ability to hit the selected touchdown spot, there is a surprising correlation between the boundary line determined from the test glides and the line on the figure representing a constant rate of descent of 3,000 feet per minute.

Although the flare-out capabilities from these glides did not simulate properly more heavily loaded aircraft and, consequently, were not within the scope of this study, it was the pilot's opinion that the vertical velocity could have been readily checked in all cases encountered.

An initial position or gate over the field was felt to be undesirable to some extent in that the airport could not be seen from 10,000 feet for setting up the approach pattern until more than 90° of a pattern turn had been made. A gate position at 8 nautical miles was selected for trial on the basis that the airport could be seen ahead and could be reached against a 50-knot headwind at either a lift-drag ratio of 11 and a speed of 104 knots or at a lift-drag ratio of 7 and a speed of 165 knots. The gate position at 8 nautical miles proved to be satisfactory from 10,000 feet for speeds from 90 knots to 140 knots for the configuration simulating the subject vehicle. Headwinds for these runs varied from 40 knots at 10,000 feet to 20 knots at 6,000 feet and 10 knots at the ground. Although it was expected that more difficulty would be experienced in gliding at or below the speed for the best lift-drag ratio than at higher speeds, it was found that judgment was appreciably easier for the lower speeds and the point of touchdown was controlled without the necessity of reducing the speed. In the case of the glides having the excess speed, however, part of the excess was used to reach the field because of a tendency to undershoot. The airport was reached from 8 nautical miles either for a circling pattern or for a straight-in approach by using S-turns to adjust the altitude. It might have been better to have had the gate position even closer to the field than 8 nautical miles in order to relieve the pilot of the decision as to which type of approach it would be best to make. The gate should not be so close to the field that the pilot cannot see to establish the radius of his pattern before reaching the field, however. Approaches from 10 and $12\frac{1}{2}$ nautical miles against lighter winds of 10 to 15 knots were successful, but the first impressions were that the airport was too far to be reached. This situation could involve considerable psychological stress.

The bank angles used in the circling patterns were normally 10° to 20° except for the steeper descents and those at the higher speeds for which 30° banks were frequently used. In S-turns to reduce altitude, 60° banks were frequently used at the higher speeds.

At high lift-drag ratios, difficulty was experienced in judging when to stop the circling type of pattern and plan the final approach. Practice is highly recommended for judging and timing the rate of altitude loss to determine whether another circuit of the airport is desirable or possible and for executing S-turn maneuvers either for a straight-in or the final-approach phase of a circling pattern. It would appear that S-turns on the final approach can be used very effectively for losing excess altitude but require planning in themselves. Judgment of the touchdown point is strongly subject to error at the higher speeds used, however, regardless of the type of pattern.

The effects of winds on the approach are very pronounced at the speeds used in this study. On one day a wind which varied from 50 knots at 10,000 feet to 28 knots at 6,000 feet and 10 to 15 knots at the ground was experienced. The circling-type patterns are lengthened considerably in time by wind and there can be about a 30-percent increase in altitude loss per circuit with a 50-knot wind at a glide speed of 104 knots. The time required for a 360° pattern varied between 2 and 4 minutes depending on speed, altitude, lift-drag ratio, and wind. The wind gradient in the lower 1,000- to 2,000-foot level results in loss of speed and in lowering of the glide-path level if speed is regained. This effect would appear to be more serious at the higher speeds. The effect can, of course, be offset by flying at a speed greater than that for best lift-drag ratio since this speed provides the capability of flattening the glide path by reducing speed.

One important point is that any diversion of attention due to traffic while in the final stages of a gliding approach is very critical. Also, although the word "easier" can be used in a relative manner for comparison of the different approaches, none of these approaches is really easy. On the contrary, utmost concentration and effort in judgment must be used at all times.

It is the firm opinion of the pilot that, of the successful approaches, those at the lower speeds were considerably easier to judge and control than those at the higher speeds. Also, the glides with the higher lift-drag ratios, particularly at the lower speeds, were not as readily judged as those with intermediate values of lift-drag ratio, although this conclusion is not apparent from figure 2.

A drag device would be very beneficial for adjusting the glide at the lower speeds. Even more important, however, would be the benefits at higher speeds. At the higher speeds the drag device would reduce the strong tendency to undershoot by permitting the pilot to carry excess speed and/or altitude until reaching the runway is assured. The excess of either could then be dissipated for landing by use of the drag device.

CONCLUSIONS

Tests to simulate the landing-approach glide of general, winged-type satellite vehicles of fixed configuration during maneuvering for a landing on a 5,000-foot runway have been made with a military training airplane. The results showed a marked tendency to undershoot the runway when the lift-drag ratios were below certain values, depending upon the speed in the glide. A straight line dividing the successful approaches from the undershoots could be drawn through a lift-drag ratio of about 3 at 100 knots and through a lift-drag ratio of about 7 at 185 knots.

It was the pilot's strong impression that speed was a primary factor in the ability to hit the desired touchdown area; that is, the higher the speed the greater the difficulty in judgment. The tendency to undershoot became very strong at low lift-drag ratios. However, the glides with high lift-drag ratios, particularly at low speeds, were not as readily judged as those with intermediate lift-drag ratios.

Provision of a drag device would be very beneficial, particularly in reducing the tendency toward undershooting at the higher speeds.

The choice of a gate position from which to establish a visual approach should be far enough away that the airport can be readily seen in time to establish an approach pattern to it but not so far as to make it difficult to decide as to the type of maneuver required.

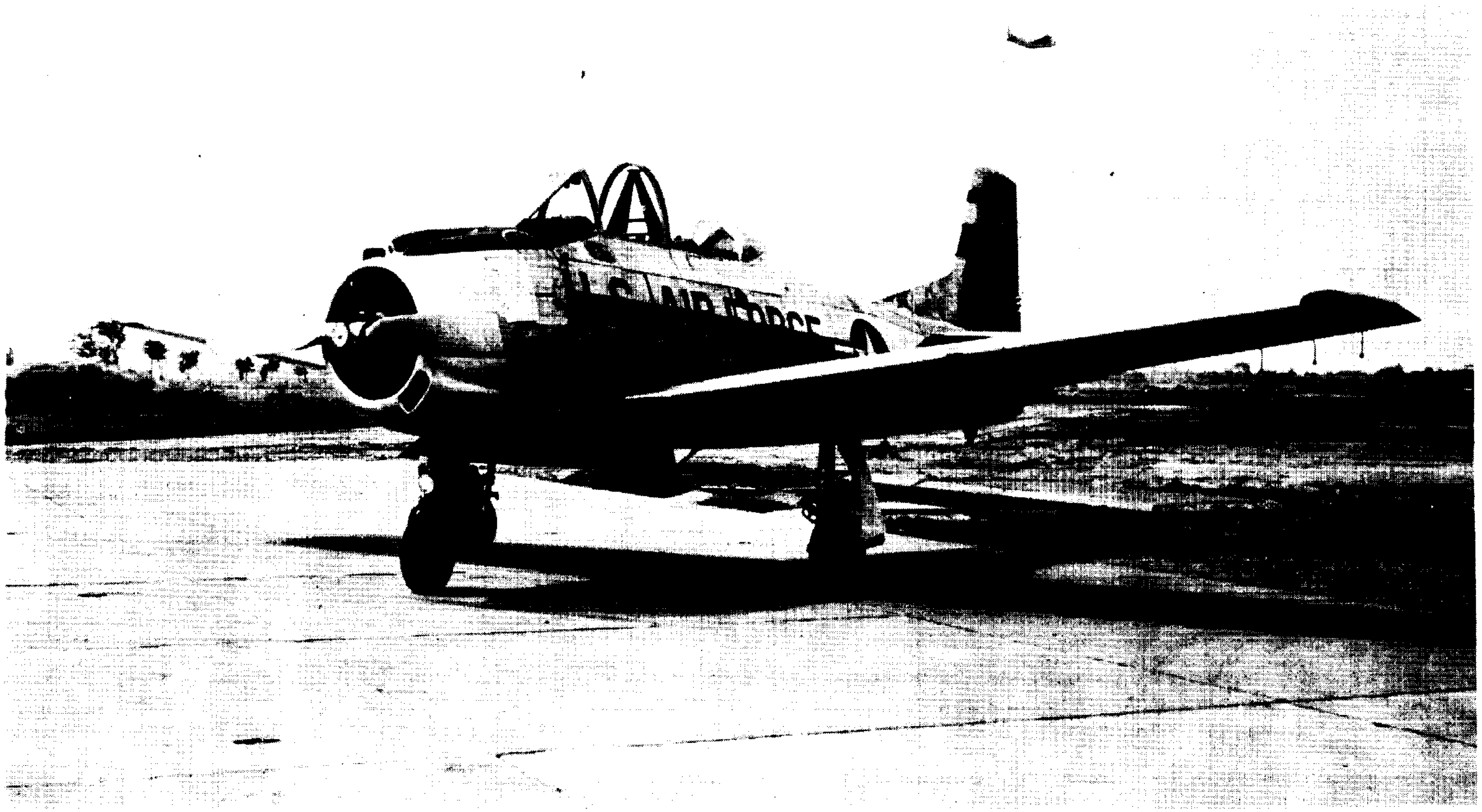
Langley Research Center,
National Aeronautics and Space Administration,
Langley Field, Va., January 7, 1959.

TABLE I.- GLIDE CONDITIONS

Gate position	Flight	Run	Calibrated airspeed, V_c, knots	Lift-drag ratio, L/D	Rate of descent, ft/min	Pattern	Result of glide	Remarks
Altitude, 5,000 feet								
Over field	2	1	104	11.0	960	2 circles	Good	
Over field	2	2	104	5.0	2,100	2 circles	Undershot	Could land on crossing runway.
Over field	2	3	104	5.0	2,100	1 circle	Good	Almost undershot.
Over field	2	5	99	3.3	3,000	1 circle	Good	Easier to judge than glide at 165 knots and L/D of 11; used up to 30° bank.
Over field	2	4	165	11.0	1,500	2 circles	Good	More difficult than glide at 104 knots; used up to 30° bank.
Over field	6	3	165	9.8	1,700	1 circle	Good	Lost 5 knots before over runway, definitely easier than glide at 185 knots and L/D of 7.8 or 6.
Over field	6	4	165	5.8	2,900	1 circle	Undershot	Undershot badly; turn uncomfortably tight; couldn't be judged readily.
Over field	6	1	185	7.8	2,400	1 circle	Good	Lost 5 knots before over runway.
Over field	6	2	185	6.0	3,100	1 circle	Undershot	Lost 15 knots to get in; definitely greater tendency to misjudge than glide at 185 knots and L/D of 7.8.
Altitude, 10,000 feet								
Over field	3	1	104	11.0	960	3 circles	Good	Field not visible at start; 10° to 15° bank maximum; pattern smaller as descend.
Over field	4	1	104	5.0	2,100	2 circles	Good	
Over field	4	5	99	3.3	3,000	1 circle	Good	Easier than higher speed for judging.
Over field	3	3	140	5.0	2,850	2 circles	Undershot	Some traffic distraction.
Over field	4	2	140	5.0	2,850	1 circle + 1 S-turn	Good	Traffic distraction.
Over field	3	4	136	2.8	5,000	1 circle	Undershot	Pattern tight and banks over 30°; must study wind closely; traffic distraction.
Over field	4	3	136	2.8	5,000	1 circle	Undershot	Appear easy to position but great care necessary to prevent undershoot.
Over field	3	2	165	11.0	1,500	2 circles	Good	Undershot aiming point but reached runway.
Over field	4	6	180	11.0	1,700	2 circles	Good	Easier to misjudge than glide at lower speed.
Over field	3	5	180	4.8	3,800	2 circles	Undershot	Undershot badly
Over field	4	4	180	4.8	3,800	1 circle + 1 S-turn	Undershot	Safety factors must be applied in judging glide.
10 nautical miles Southwest	3	6	165	11.0	1,500	3 S-turns	Good	Looked too low for circle; used S-turns; good technique.
10 nautical miles Southwest	3	7	180	4.8	3,800	1 S-turn	Undershot	Appeared to be satisfactory but undershot; wind gradient below 2,000 feet critical, mild traffic distraction.
8 nautical miles South	5	1	104	11.0	960	S-turns	Good	
8 nautical miles South	5	2	104	11.0	960	1 circle + 1 S-turn	Good	Better to start with circle of field for this case.
8 nautical miles South	5	3	125	10.5	1,200	1 circle	Good	Easier to misjudge than lower speed; stretched glide by slowing to 110 knots.
8 nautical miles South	5	4	140	9.5	1,500	1 circle + 1 S-turn	Good	Looked easy but had to stretch by slowing to 120 knots.
8 nautical miles South	5	5	90	10.7	850	1 circle + 1 S-turn	Good	Excruciatingly slow descent; easy because of close pattern; no speed loss.
$12\frac{1}{2}$ nautical miles South	6	5	125	10.5	1,200	1 circle + 1 S-turn	Good	Looked too far at start; easy to judge.

TABLE II.- WIND CONDITIONS DURING GLIDES

Flight	Altitude, ft	Wind direction, deg	Velocity, knots
2	5,000 1,000 Surface	300 330 300 to 330	30 20 10 to 15, gusts to 25
3 and 4	10,000 5,000 1,000 to Surface	320 340 290 to 360	50 28 8 to 15
5	10,000 5,000 1,000 Surface	300 300 300 Variable	40 15 10 Light
6	5,000 1,000	320 350	10 10



L-58-3581
Figure 1.- Military training airplane used for glide tests.

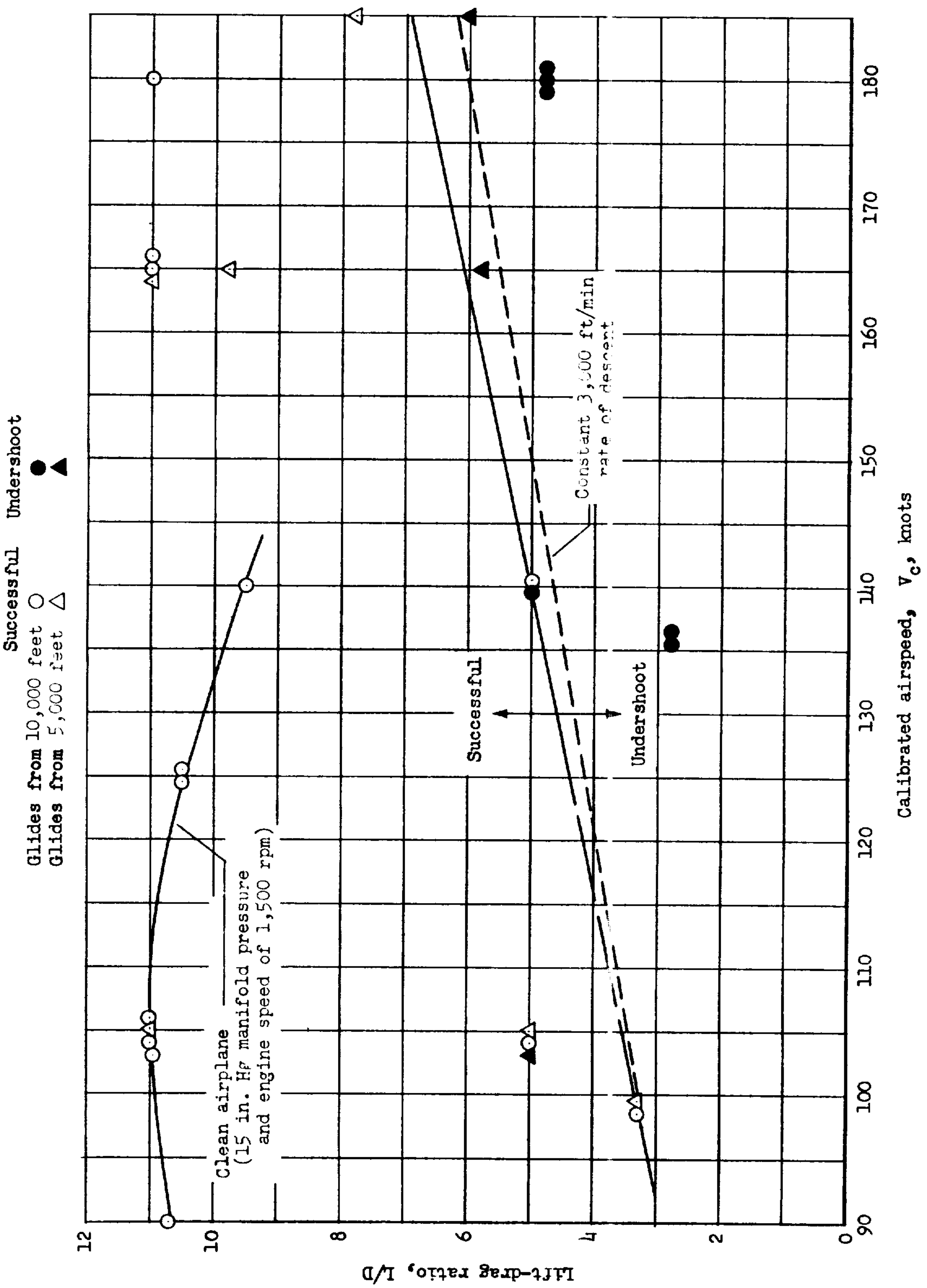


Figure 2.- Summary plot of gliding approaches to a 5,000-foot runway.