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AN ANALYTICAL INVESTIGATION OF LANDING FLARE MANEUVERS OF A PARAWING-CAPSULE CONFIGURATION

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An analytical study is being made to determine the capabilities of various parawing configurations for executing satisfactory flared landing maneuvers, and to investigate the factors which influence this capability. This study was initiated because doubt existed as to whether a parawing could perform a flare from trimmed glide conditions at max $^{L}/D$, especially at low wing loadings.

For this study, a cone-shaped capsule having a weight of 5000 pounds is used for a payload. Control is achieved by varying the position of the payload with respect to the wing. A time history of the motion during the flare is obtained by utilizing three-degree-of-freedom equations of motion and a high-speed digital computer.

SLIDE NO. 1

The static aerodynamic characteristics of the wing used are shown as a function of angle of attack. This data is for a wing having rigid keel and leading edge members and a conical shape when deployed. This wing had a basic sweep angle of 45 degrees laid out flat and a deployed sweep angle of 55 degrees. The aerodynamic data show is pitching moment coefficient, lift coefficient, and $^L/_D$. The pitching moment coefficients are for the three vertical payload positions investigated; 1/2, 3/4, and 1 keel length below the wing. For each of these vertical payload positions, you will note that a stable pitching moment curve exists. The maximum lift-coefficient is approximately 1.0; the maximum $^L/_D$ is 4.7. The symbols on the C_L and $^L/_D$ curves indicate the trimmed glide conditions from which flares were attempted. These trimmed glide conditions are for lift coefficients of .2, .3 and .45. The .45 condition is where the maximum $^L/_D$ occurrs. For all motions encountered during the flare attempts, the lift coefficient was never allowed to exceed a value of .8.

<u>SLIDE NO. 2</u>

From each trimmed glide contion, flares were attempted as follows: At some position along the flight path, indicated here by the arrow, the control movement for the flare was begun. The control movement used was a <u>single</u> shift of the payload longitudinally, made at a constant rate. As shown by the solid and dotted lines, respectively, a maximum and a minimum control rate were determined which would give a satisfactory flare without exceeding the C_L limit of .8. A flare initiated below the altitude used for the maximum control rate cannot, of course, be completed before ground contact. Flares initiated above the altitude used for the minimum control rate can be satisfactorily completed, but the completion will occur somewhere above ground level. The altitude range between these two limits is the range available to the pilot during which he must decide when he is at the proper altitude and begin his control movement. The pilots' decision <u>time</u> will be a function of this altitude range and the rate of descent.

SLIDE NO. 3

The altitude used during the flare is presented as a function of wing loading and trimmed glide lift coefficient. A wing loading range of 3 to 20 pounds per square foot was investigated. The maximum $^L/D$ and the C_L limit are listed. Again, the solid lines are for the maximum control rate, and the dotted lines are for the minimum control rate. For this particular wing, it was found that a satisfactory flare maneuver could be obtained from all combinations of wing loadings, vertical payload positions, and trimmed glide lift coefficients investigated. Larger pilot decision times come with the higher wing loadings and lower C_L's. At the same time, flares made in this region must be initiated at relatively high altitudes, which may become difficult for the pilot to judge accurately. Conditions with low wing loadings and higher C_L's can be flared from altitudes which are closer to the ground and which are therefore easier for the pilot to judge, but the decision time is greatly reduced. The decision times encountered herein varied from 6 seconds to 1 second. The time from the flare initiation to the flare completion at touch-down varied from 2 seconds (for ____ $\overset{w/s=3}{C_L=.45}$) to 21 seconds (---- $\overset{w/s=20}{C_L=.2}$). G-loads encountered by the pilots are normally less than 1 1/2-g's. It was found that all the flares shown here were made without exceeding this value, so the g-loads encountered are well within the range of the pilot's present experience.

SLIDE NO. 4

The rates of descent for the trimmed glide conditions used are presented as a function of wing loading and trimmed glide C_L. These rates of descent are compared with the rates presently encountered by pilots. The first dotted line is at 10 feet per second, a rate normally used by aircraft making an IFR type landing. The next dotted line, at 40 feet per second, represents the rates encountered by helicopter pilots making auto-rotative landings. The last dotted line, at 50 feet per second, indicates a descent rate encountered when a T-28 airplane was modified for low $^{L}/D$ landings. (NASA Memo 3-12-59L). The X-15 (NASA TM X-195) has a descent rate of 120 feet per second, but it also has a wing loading of 66, so it cannot be directly compared with the parawing values shown. The rates of descent for the parawing configuration are therefore within the range of present pilot experience. However, the pilots are not used to encountering these rates at the relatively low wing loadings shown here.

The landing flare parameters just presented have been discussed with several Langley pilots. It is felt that additional pilot experience is necessary due to the relatively high descent rates and the small pilot decision times associated with the lower wing loadings. It should be mentioned that one of the Langley pilots has recently made some flared landings in an aircraft with an $^{L}/D$ of 3 and a wing loading of 11. The flare portion of the landings was accomplished successfully, but some difficulty was encountered in making the touch-down at a predetermined spot on the runway.

Among the factors which should receive additional study are the capabilities of different wing shapes, the effects of flexibility in the leading edge sweep angle when no spreader bar is present, control rigging set-ups and their corresponding power requirements, and pilot capabilities.