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DESIGN PARAMETERS FOR A PILOT RESCUE SYSTEM

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1. Introduction

The German Federal Ministry of Transport (BMV) has commissioned the Fachhochschule Aachen to investigate the design parameters for a pilot rescue system (PRS). In the case of a mid-air glider accident, such as a collision or the loss of control, the pilot is pulled out of the cockpit by a parachute. Suspended beneath this parachute the pilot descends safely to the ground. This paper completes the fundamentals of the pilot rescue system [1] and more details are given in [2]. The design requirements for the parachute, the lines, and attachment points are identical to those of the glider recovery system described in [2]. The PRS uses a parachute with the size, mass and volume of the conventional personal parachute.

In the first rescue sequence the parachute is deployed by a lifting device such as a rocket or a mortar to carry the parachute clear of the tail. After opening, the parachute stabilizes the tumbling glider to a descent rate ranging from 13 to 18 meters/second, depending on total mass. After stabilization, the riser is disconnected from the glider and at the same time linked up to the pilots harness. Following this, the seat belts are automatically opened. Due to load reduction, the parachute decelerates to about 7m/s, and the free falling glider accelerates towards the ground. This differential movement pulls the pilot out of the cockpit.

Technical problems in such a pilot rescue system are the complex mechanism, the oscillation of the parachute, descending a damaged and possibly unstable glider, the hazard of injuring the pilot during the pull-out sequence, and a collision between the pilot and the tumbling glider.

2. Motion of parachute and glider

The parachute opens with a large shock in the direction of the airstream. This initiates a pitching moment due to the unavoidable distance between the attachment point of the riser and the c. of g. The pilot himself may withstand this load, but to avoid the disintegration or looping of the glider the parachute must be reefed.

During the steady state descent the angle of attack (AOA) is out of the normal flight range. To avoid oscillation of the parachute/glider system, dynamic and static stability of the lowered glider is necessary. Independently of the value of the angle of attack, the stabilizer always produces dynamic stability during a pitch rotation. Longitudinal static stability is only attained if an increasing angle of attack will lead to a nose-down

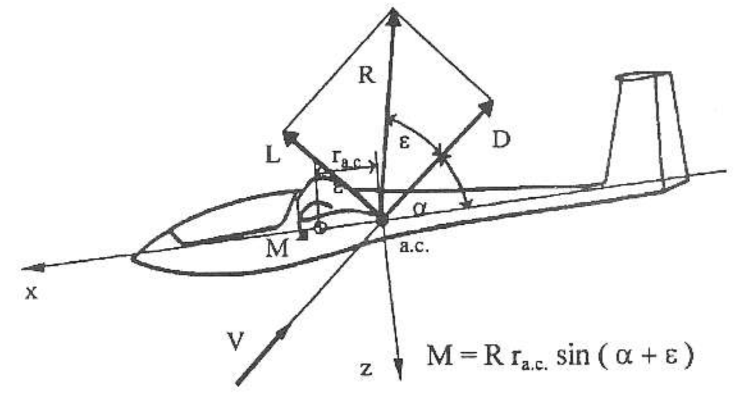

FIGURE 1.1: From Lift L and Drag D resultant aerodynamic for R and resultant pitching moment M.

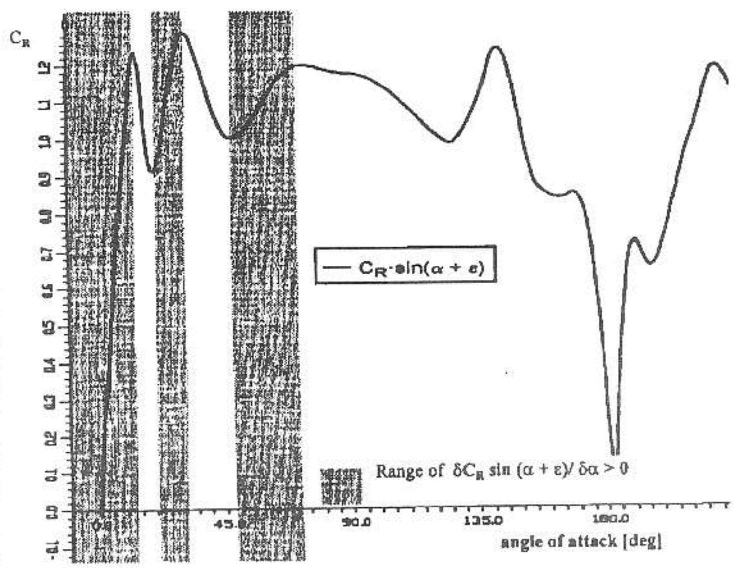

FIGURE 1.2: Resultant aerodynamic force coefficient CR versus angle of attack and ranges of static stability.

pitching moment. Figure 1 shows the resultant aerodynamic force coefficient C_R of an undamaged glider versus angle of attack. The values are related to the aerodynamic center (a.c.) which is situated behind the c. of g. C_m is nearly independent of the angle of attack, and therefore does not essentially influence the static pitch stability. In the case of a positive slope of C_R, an increasing angle of attack produces a nose-down pitching moment that gives static stability. For the chosen airfoil, static stability is only available in the normal flight range up to +13 degrees, and in the range of +20 to +30 degrees, and from +50 to +70 degrees AOA. To obtain +70 degrees AOA during the descent the glider must be kept at a pitch attitude of -20°. This may be realized by two attachment points in the fuselage x-axis, and a v-riser.

The most critical situation is the loss of the stabilizer. In this case the a.c. of the glider is identical with the a.c. of the wing and close to the c. of g. The damaged glider has lost its dynamic as well as its static pitch stability. The loss of the fuselage tail cone moves the c. of g. in front of the a.c. and this guarantees static stability in the ranges of positive slope of C_R.

The motion of the glider and parachute system was calculated by a computer simulation [4], and tested with a scale model glider of 1:4.8 [5]. In the case of a missing stabilizer, Figure 2 clearly illustrates the simulated pitch oscillation of the lowered glider with a steady state pitch attitude angle of -45 degrees. Figure 3 shows the motion of the glider model with loss of the stabilizer and an attitude of about -45 degrees. The measured accelerations of the c. of g. show the nearly undamped oscillation.

During descent, the period of oscillation depends on the length of the lever arm from parachute drag to the center of gravity. If the riser is attached near the c. of g., the value will be about 6 seconds, and with an increasing distance the period decreases. For example, a position two meters away from the c. of g. results in a value of about 1 to 2 seconds.

3. Pull-out acceleration

Shortly after the parachute/glider system reaches a steady state descent speed, the riser is linked to the pilots harness. This reduces the load of the parachute, for example from 400 to 80 kilogram. The parachute decelerates and this deceleration is also influenced by the airmass dragged along the parachute's flight path. Experiments [6] with small parachutes (up to a nominal diameter of 3 meters) at the parachute test rig of the FH Aachen show the value of deceleration depends on the gliders mass, the relation of the pilot to the glider mass, and the

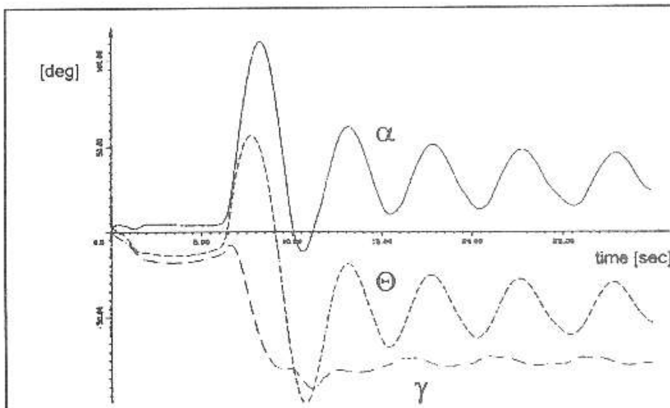

FIGURE 2. Time history of angle of attack α, pitch attitude Θ and glide path angle γ during dive and parachute deployment of a glider with the loss of the stabilizer (t=0s mid-air accident, t=3.5s initiation of the rescue procedure).

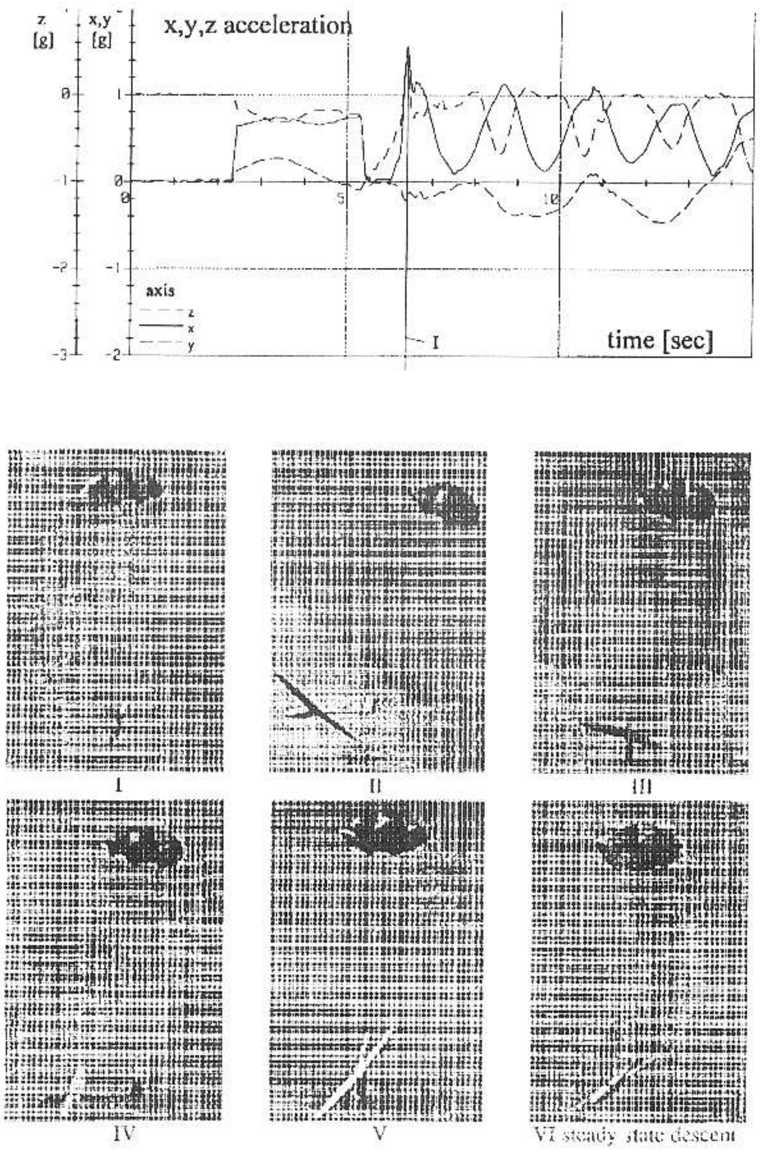

FIGURE 3. Motion of the glider model with loss of stabilizer, accelerations curves in c. of g. (steady state pitch attitude about -45°).

diameter of the parachute. For single seaters, the initial deceleration ranges from 1.5 g to 5 g and the pilot is pulled out off the cockpit within about 0.7 seconds. The values of the deceleration are far below those during the opening sequence of a conventional parachute.

4. Pull-out movement of the body

A "pull-out" test rig was built at the FH Aachen. The first tests with dummies [1, 7] did not show any danger of a collision between the pilot and parts of the seat or the cockpit. Therefore, the tests were extended to "pull-out" tests with human beings.

It was found that the accelerations in the human body are tolerable, and overstretching of the joints (for example in the knees) does not happen. At a nose-up pitch attitude angle of more than +20°, the head is jerked backwards due to the initial nosewards snatching of the body. The instrument panel should be raised, or better, jettisoned with the canopy.

5. Glider motion after pull-out

After "pull-out" of the pilot, the c. of g. of the free falling glider shifts rearwards, and the aerodynamic forces and moments acting at the glider determine the motion. The glider starts to rotate and the rate as well as its direction depends on the kind of damage and on the angle of attack. Large nose-up, nose-down or roll movements may result in a collision between the pilot and the glider during the pull away sequence. In the case of an undamaged glider (Figure 4a), the resultant aerodynamic force of the wing initiates a nose-up rotation against the nose-down pitching moment of the wing and the resultant aerodynamic force of the stabilizer. Only a small rotation may occur. The loss of the stabilizer (Figure 4b) results in a nose-up pitching due to the missing counter rotation of the tail. The loss of the fuselage cone (Figure 4c) induces a larger nose-down rotation due to the pitching moment and the resultant aerodynamic force of the wing. A missing wing (Figure 4d) produces a lift-up rolling moment due to lift and drag of the remaining wing.

A computer simulation and tests with a scaled glider and dummy (1:4.8) were carried out to show the relative movement of glider and pilot. Figure 5 presents the calculated time history of pitch attitude angle, glide path angle and angle of attack. One second after a straight and level flight the glider looses the fuselage cone in an accident and starts to dive. After a further 2.5 seconds, the pilot initiates the rescue system and the parachute deploys and stabilizes the glider. Because the riser is attached at the c. of g. the glider maintains the attitude of dive. After reaching a steady state descent (15 seconds), the parachute pulls the pilot out off the cockpit and the glider immediately starts to pitch nose down. It

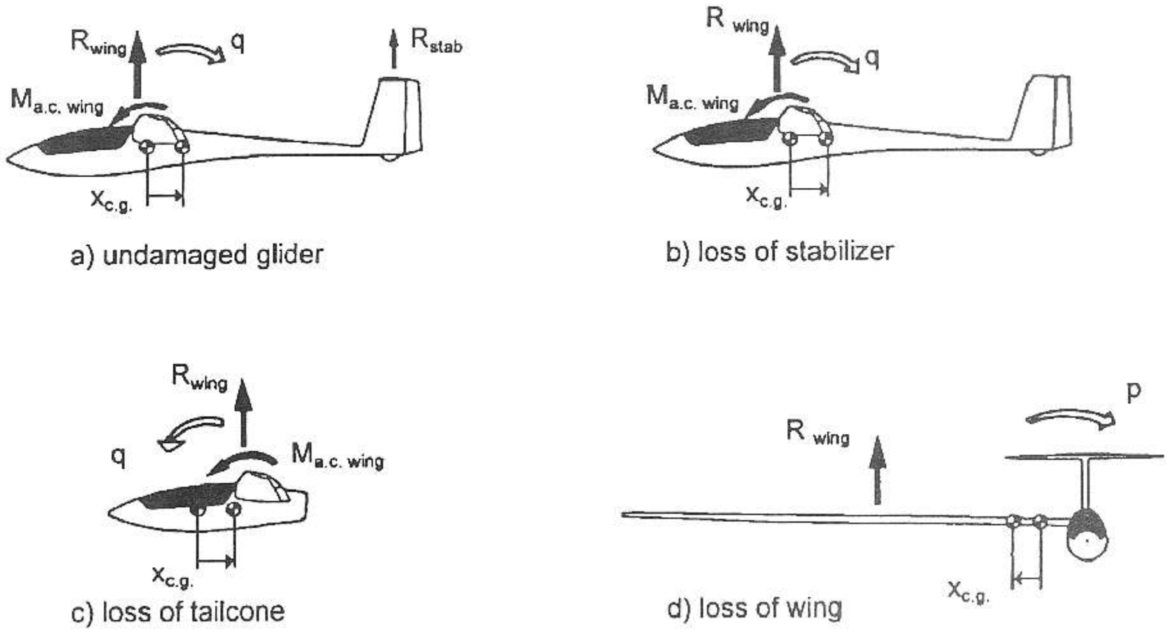

FIGURE 4. Shift of c. of g. resultant airforces R, pitching moment M and initiated rotation q after pilot pull-out.

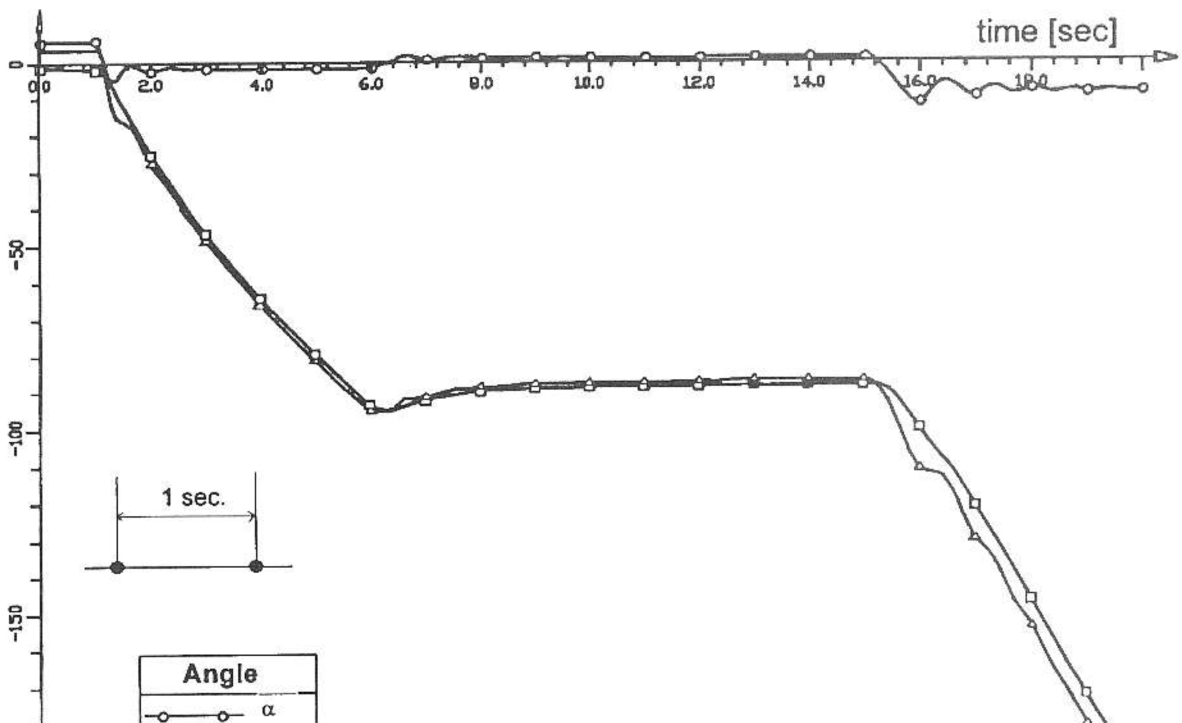

FIGURE 5. Angle of attack α, pitch attitude Θ and flight path angle γ during the rescue procedure (t=1s mid-air fatality, t=3.5s initiation of rescue procedure, t=15s pilot pull-out).

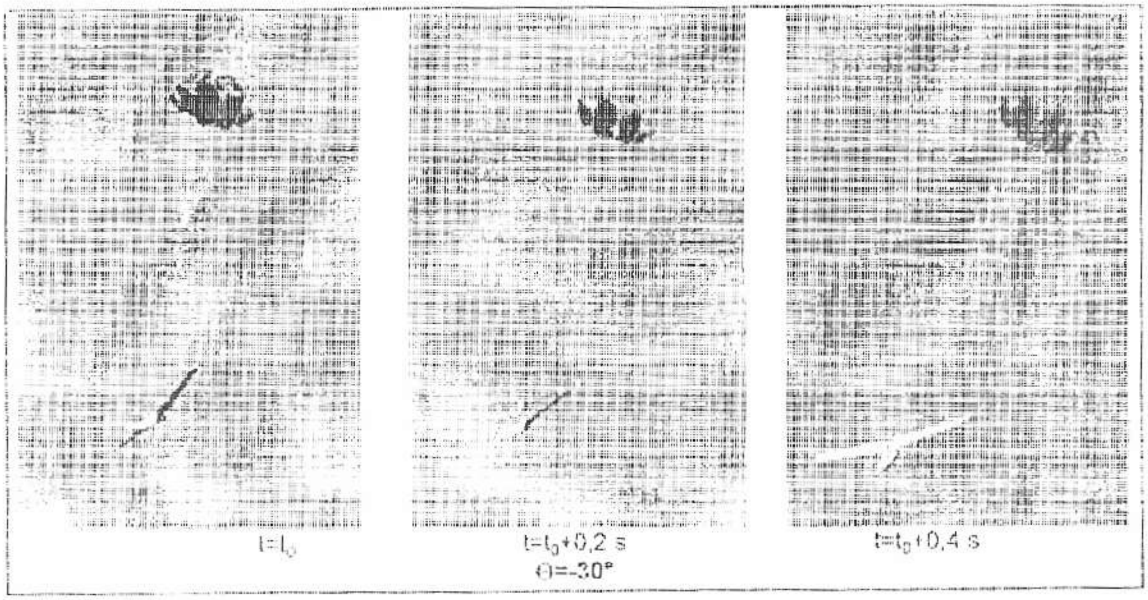

FIGURE 6. Pitching rotation of glider missing tail cone after pilot pull-out.

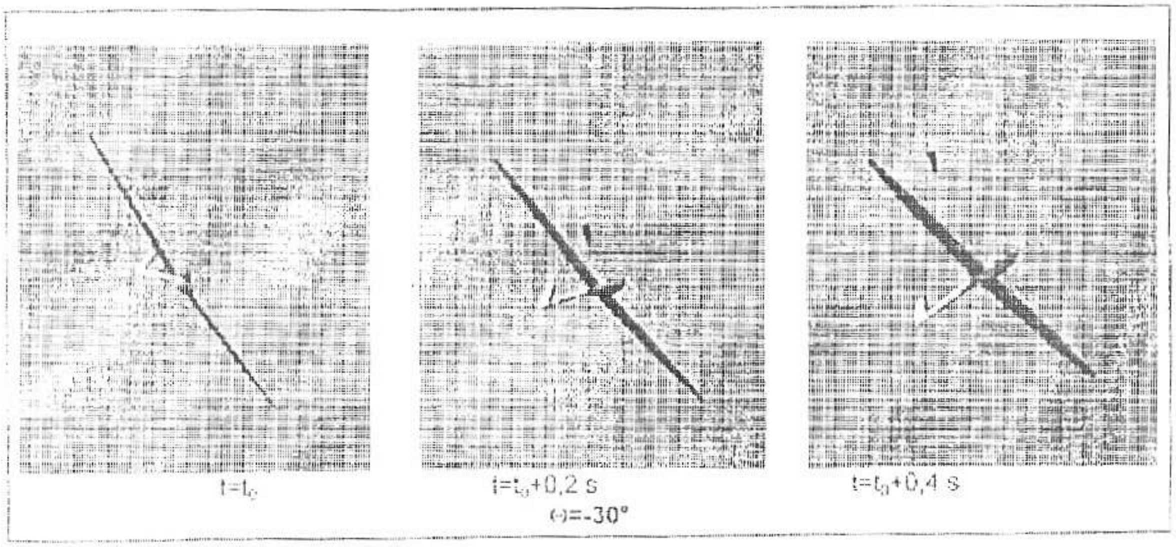

FIGURE 7. Pitching rotation of glider missing stabalizer after pilot pull-out.

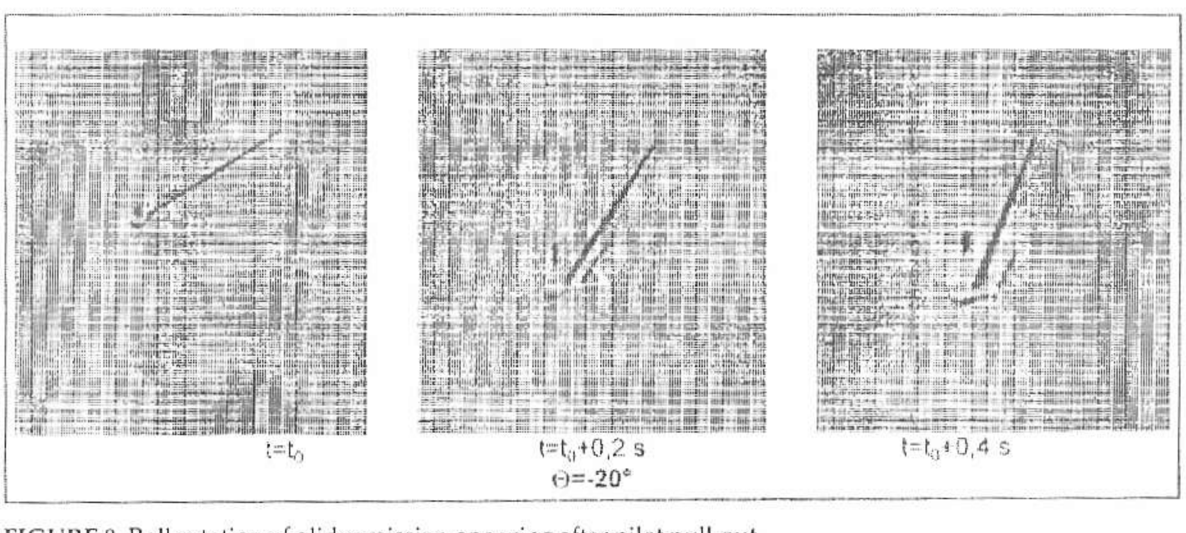

FIGURE 8. Roll rotation of glider missing one wing after pilot pull-out.

reaches a pitch rate of about 25 degrees per second.

Tests with the scaled glider and dummy show the relative motion of glider and pilot. In the case of a fuselage cone loss the glider rotates quickly nose down (Figure 6) and the dummy is pulled backwards slightly above the wing. The undamaged glider hardly rotates during the pull-away phase. The loss of stabilizer (Figure 7) only induces a small nose-up rotation and the model dummy does not collide with the tail unit. The loss of one wing results in a roll rotation and the pilot may hit the uplifting wing (Figure 8).

6. Conclusion

The pilot rescue system only requires a parachute the size of a conventional personal parachute. In the case of a mid-air collision the parachute will be opened during the subsequent dive at high speed and negative angle of attack. The parachute must be deployed by an active device such as a rocket or a mortar to carry the parachute clear of the tail unit. The parachute must be reefed to avoid a large opening shock resulting in disintegration or looping of the glider. The suspension needs a v-riser to adjust the pitch attitude angle to about -30 degrees during the steady state descent at any position of c. of g. The riser should have a length of more than the wingspan to obtain the total drag of the parachute.

The pull-out sequence starts with an initial deceleration of 1.5 to 5 g and is completed within one second. The pilot withstands this deceleration and does not hit the seat or cockpit sill during the pullout procedure. The instrument panel should be raised, or better, jettisoned with the canopy. Due to the large rotation of the free falling glider a collision may occur between the pilot and the glider.

To verify these fundamental points, a full-size test of the pilot rescue system with a dummy should be carried out.

7. References

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