Glider Rescue Systems

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Abstract

Looking at mid-air accidents of gliders the chance of surviving by bailing out and using the conventional emergency parachute turned out to be less than 50%. A glider parachute rescue system can improve this situation. A parachute decelerates the whole glider with the pilot remaining inside the cockpit and lowers glider and pilot to the ground. Most of the mid-air accidents are collisions. Losing parts of the glider structure results in a diving motion and the speed of the glider increases dramatically. Due to the T-shaped tail unit the parachute must be deployed by an active device such as a rocket or a mortar. To obtain longitudinal static stability during the descent, a pitch down attitude angle of about -30 degrees should be kept. The most critical situations appear during the deployment of the parachute and the impact on the ground. In the high speed range the parachute or the riser may collide with the tail unit and this may damage the tail and produces a nose down pitch rotation with a high negative z-acceleration and a negative angle of attack. For avoiding severe injuries during the ground impact a descent rate of not more than 6m/s is necessary. In case of energy-absorbing parts the descent rate may come up to 8m/s. Flight tests for certifying a glider rescue system are only performable in the low speed range. The parachute, the lines, the rocket or the mortar should be tested without a glider.

Introduction

The German Federal Ministry of Transport (BMV) has commissioned the Fachhochschule Aachen (Aachen University of Applied Sciences) to investigate the design requirements for a glider parachute rescue system [1,2,3,4,5,6]. Looking at mid-air accidents of German-registered gliders over the past 15 years the chance of surviving by using the conventional emergency parachute turned out to be less than 50%. After the accident a minimum of at least seven seconds is necessary for a successful bail-out. It is quite clear that a glider rescue system can improve this situation. Shortly after initiation the parachute is deployed. The parachute inflates while the whole sailplane decelerates with the pilot remaining inside the cockpit. Neither unstrapping nor bailing out is necessary. Such a parachute rescue system probably is a most widely known system. Microlight aircraft, supersonic drones and returning spacecraft make use of its principle. Though several rescue systems are currently available none of them have ever been used in gliders.

The majority of mid-air glider fatalities arise from collisions. The height above ground is mostly below 1000 m. Fig. 1 shows the statistical results of damages from the accidents. Roughly half of the gliders involved in collisions suffered damage to their wings, one third lost their stabilizer and the rest their tail cones. Since, on the one side, the cockpit and the wing roots mostly stay intact and, on the other side, the kind of accident is unpredictable, it is obvious that any part of the rescue system must be installed inside this area.

Motion of the glider

Losing parts of the structure always results in a diving motion due to the shifted center of gravity and the unbalanced pitching moment of the wing.

In the first run the longitudinal motion of a damaged glider was numerically calculated [7]. Figure 2 shows the different flight paths of a standard class glider depending on the kind of damage. The negative loop, or part of it, is typical in all cases. Figure 3 gives an impression of the speed-time history. During the diving the speed of the glider or glider increases. At the bottom of the loop the speed of about 90 m/s (296 ft/s) is quite close to the Vne (never exceed) and may lead to structural disintegration. The centrifugal force must be counteracted by a part of the lift. This results in a negative value of the angle of attack. The parachute may be required to be deployed in a dive at high speed and negative angle of attack.

Parachute

Although many different types of parachutes exist, the calculation of the nominal diameter were only performed for flat circular and cross main canopies as well as clusters of three chutes. Figure 4 shows the calculated nominal diameter depending on the descent rate for a load of 400 kg. With a flat circular parachute and a descent rate of 6 m/s a diameter of about 18 m is necessary. This parachute guarantees a vertical descent rate without any horizontal speed.

The parachute must be reefed, to avoid a large filling shock, which could result in disintegration of the glider. Stepwise disreefing by pyrotechnic cutters or continuously by sliders are known and proven technologies. The slider is more advantageous because the filling time is optimized throughout the whole speed range.

Most of the modern gliders have a T-shaped tail unit. For that reason 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.

Motion of the parachute and the glider

During the steady state descent the angle of attack of the glider or glider is out of the normal flight range. To avoid an 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 (AOA), the stabilizer always produces dynamic stability during a pitch rotation. Longitudinal static stability is only available if an increasing AOA will lead to a nose-down pitching moment. Figure 5 shows the resultant aerodynamic force coefficient C_R, resulting from drag and lift, of an undamaged glider versus angle of attack. The values are related to the aerodynamic center (a.c.) which is situated behind the center of gravity. The pitching moment coefficient Cm 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 (Fig. 5), 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 angle of attack. To obtain longitudinal static stability during the steady state descent, a pitch down attitude angle of about -30 degrees should be kept at any position of the center of gravity. This may be realized by two attachment points in the fuselage x-axis and a v-riser.

Vortices detaching from the wings at post stall angles of attack hitting the canopy reduce the drag of the canopy. Wind-tunnel tests with a scaled glider model and a parachute show a considerable loss of drag in relation to total drag, the sum of the individual drag of glider and parachute. Figure 6 shows to what extend the forebody wake reduces drag depending on the value of the angle of attack.

Ground impact

The most critical situation during the rescue process is the ground impact. A series of twenty full scale dynamic drop tests were performed in cooperation with the German Federal Highway Research Institute. All tests were filmed by video and a high speed camera [1,2,5].

The cockpit was manned by a Hybrid II Dummy whereby the fuselage was equipped with accelerome-ters, wing dummies and a stabilizer. The glider was loaded up to a mass of about 350 kg and 527 kg. The test plane was lifted up to a height from which the selected vertical impact velocity of 6 or 8 m/s could be reached during free fall. The pitch down attitude angle was varied from 0 to 80 degrees.

During the ground impact the deceleration occurring in the x- and z-axis of the head, the chest and the pelvis of the Dummy were recorded. Additional the load on the spinal column was measured. The most critical points are the load on the spinal column and the pelvis acceleration. A value of 5 kN may be acceptable for humans up to an age of approximately 60 years. The load limit of the pelvis acceleration known from crash tests is 60 g.

The tests were performed with different types of gliders whereby the stiffness of the cockpit structure has been changed by using different composites and reinforcements. The original wings were replaced by a framework acting as wing dummies with a span of 2.5 m producing the same pitch inertia moment as an original wing. The mass of the glider could be increased to 527 kg by using additional weights fixed at the wing dummies.

It was found that a pitch down attitude between -20 and -45 degrees produces the lowest load on the spinal column and the lowest pelvis acceleration.

To demonstrate the influence of the influence of the ground, one glider fitted with an energy absorbing nose was crashed on a meadow and on asphalt with a pitch down attitude angle of -45 degrees and a vertical impact velocity of 6 m/s. Immediately after the first ground impact the glider started to rotate nose up, the tail wheel hit the ground and the bottom of the cockpit crashed on the ground. Figure 7 represents the time histories. In relation to soft ground (meadow) on hard ground the deceleration of the pelvis was nearly doubled and the load on the spinal column increased by a third. The second peak occurred when the strong cockpit structure stopped the vertical velocity. The biggest increase happened during the third peak (380 ms), when the bottom of the cockpit crashed on the ground. The acceleration value was nearly four times that of the soft ground. In Figure 8 the situation with the totally destroyed nose (80 ms) and the situation shortly before the second ground contact is shown. On hard ground the impulse from the ground was higher and this resulted in a faster pitch rotation producing higher impacts during the following motion. All values are below the limits.

As mentioned before a pitch down attitude angle of about -30 degrees should be kept to obtain longitudinal static and dynamic stability during the steady state descent. At the same time this pitch down attitude reduces the load on the pilot during the ground impact.

Tests

The working of all components like parachute, rocket, riser and bridle as well as the effects of a collision between parachute and the tail-unit or the pitch rotation after the opening shock cannot be demonstrated by numerical calculation. For this reason tests and flight tests are necessary. However flight tests are very dangerous, especially in critical situations and in the high speed range.

The first tests looking at the danger of a collision between parachute and tail-unit were performed with an original fuselage mounted on the roof of a car (Fig. 9). The car was driven up to a speed of 130 km/h on the airfield of the NATO Airbase in Geilenkirchen (Germany). The parachute and the riser were pulled backwards by the air stream and the riser touched the stabilizer. For this reason there is a great risk a collision or the opening shock of the parachute may destroy the stabilizer, the vertical tail or may twist the fuselage cone.

For real flight tests an old club class glider-a MISTRAL C -with a span of 15m and a mass of 365 kg- was reconstructed as a remote controlled glider and certified by the LBA. This glider is fitted with two independent parachute rescue systems (Magnum High Speed), a data recording system for speed, height, acceleration and angular velocity, a GPS and an airbag to damp the ground impact. Three pilots have a license for flying this remote controlled model. The tests took place on the military trainings area "Lübtheen" south-east of Hamburg (Germany). The glider was lifted upside down by a helicopter (Fig. 10) up to a height of 800 m.

In the first test the rescue system was activated during circling with 2 g at a speed of 110 km/h. The rocket pulled the parachuted out of the container, stretched the lines and the parachute opened within 4 seconds, slowed down by the slider. The opening shock was below 2.5 g. The whole system of glider and parachuted circled to the ground (Fig. 11) at a descent speed of 7.6 m/s. The ground impact was well damped by the airbag and the right wing happily landed between two big stones. There was no damage at the glider. A pilot would have survived this ground impact.

The second test was a high speed test. After the release from the helicopter the glider was controlled in a steep dive. The flight path angle was approximately –80°, the velocity approximately 300 km/h and the height above ground 320m (Fig. 12). In such a condition, with only 4 s to ground impact, there would be no chance to survive by bailing out with the conventional back pack personal parachute.

Due to the low thrust the rocket motor was not able to lift the parachute clear of the stabilizer and due to the high velocity the parachute collided with the stabilizer, and the parachute damaged the stabilizer (Fig. 13). Due to the loss of the stabilizer, the glider lost its static and dynamic stability and immediately pitched nose down. Due to the velocity and the high angle of attack, both wings separated from the fuselage (Fig. 14).

The measured value of the acceleration due to the pitch rotation of the glider is about +12g. Because the attachment points of the seat harness are not designed to this high load a pilot in the cockpit would be pulled out of the cockpit. Hence, stronger harness and attachment points are required.

The parachute inflates and lowered the rest of the glider to the ground. The cockpit remained intact on the ground impact (Fig. 15) and if the pilot had remained in the cockpit he would have had a good chance to survive this rescue procedure.

Conclusion

Glider parachute rescue systems are feasible. The parachute should be deployed actively by a mortar or a rocket to lift the parachute and the lines over the tail unit. The opening shock must be reduced by reefing to prevent the glider from disintegration and turning over.

Using a glider rescue system it has been found that a pitch down attitude angle between -20 and -45 degrees reduces the deceleration in the human body and the load on the spinal column during the ground impact. Additionally this pitch attitude produces static stability during the descent. The impact is additionally reduced by a bulging outwards of the cockpit sills, or by energy absorption of the nose. The ground impact produces several peaks. The first peak occurs with the impact, and the second after the sills are broken or the nose is damaged. A critical third impact may occur when the bottom of the cockpit crashed on the ground whereby the impact impulse struck directly into the spinal column.

The controlled deformation of structural parts, multiple impacts, buckling of the tail cone and collapse of the landing gear helps to absorb energy and reduces the maximum loads considerably. It is very important to design the pilot's cockpit area as strongly as possible, and make provision elsewhere for deformation and energy absorption.

Flight tests for certifying a glider rescue system are only performable in the low speed range. The parachute, the rocket or the mortar should be tested without a glider.

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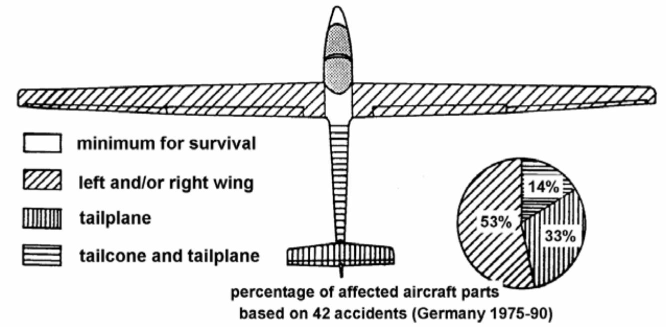

Figure 1 Statistical distribution of damages on gliders

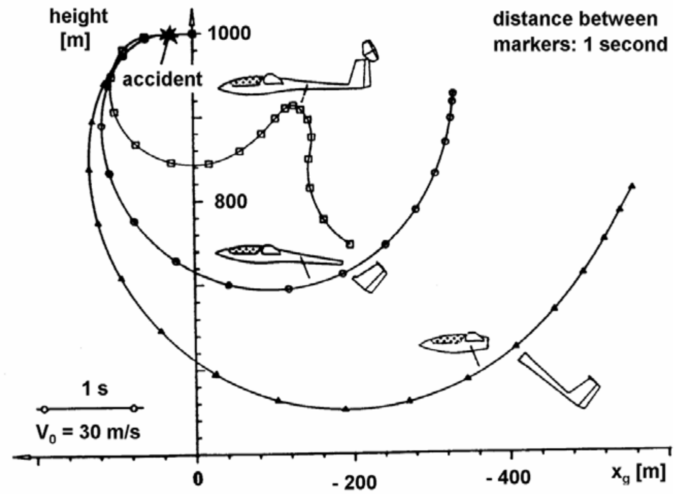

Figure 2 Flight path of gliders with different damages

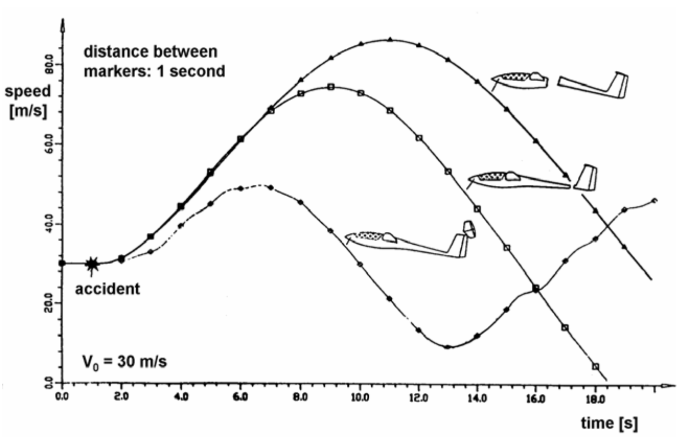

Figure 3 Speed-time history of gliders with different damages

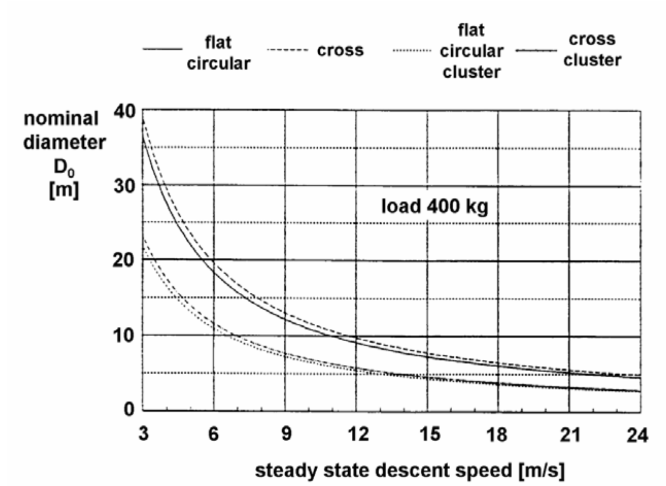

Figure 4 Nominal diameters of the parachute depending on descent rate

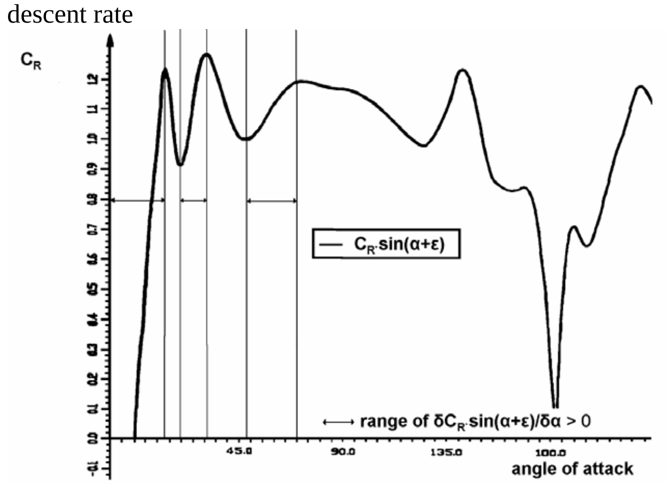

Figure 5 Resultant aerodynamic force coefficient C_R versus angle of attack and ranges of static stability

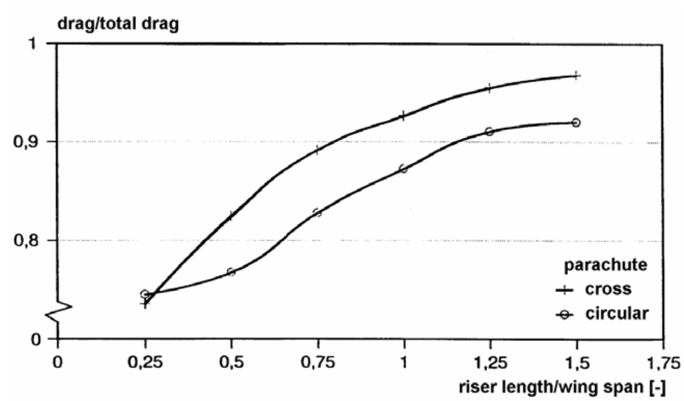

Figure 6 Loss of parachute drag caused by forebody wake of the wings depending on angle of attack

Figure 9 Test rig

Figure 10 Remote controlled glider MISTRAL C

Figure 11 Circling MISTRAL C

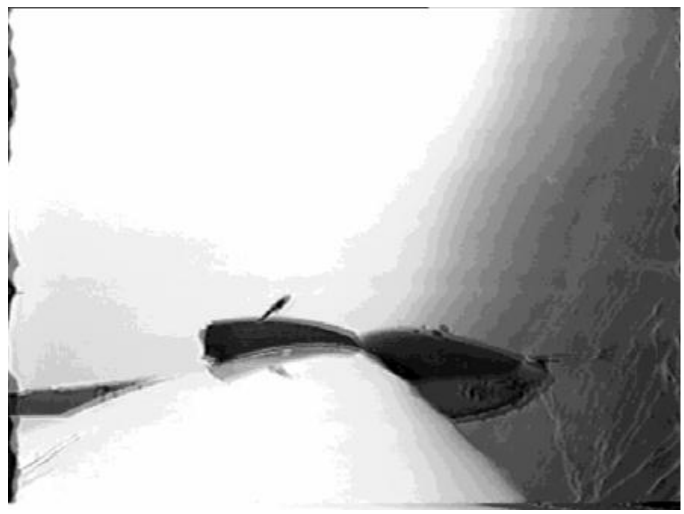

Figure 12 Flight condition at initiation of the rescue system Mistral C, Vne

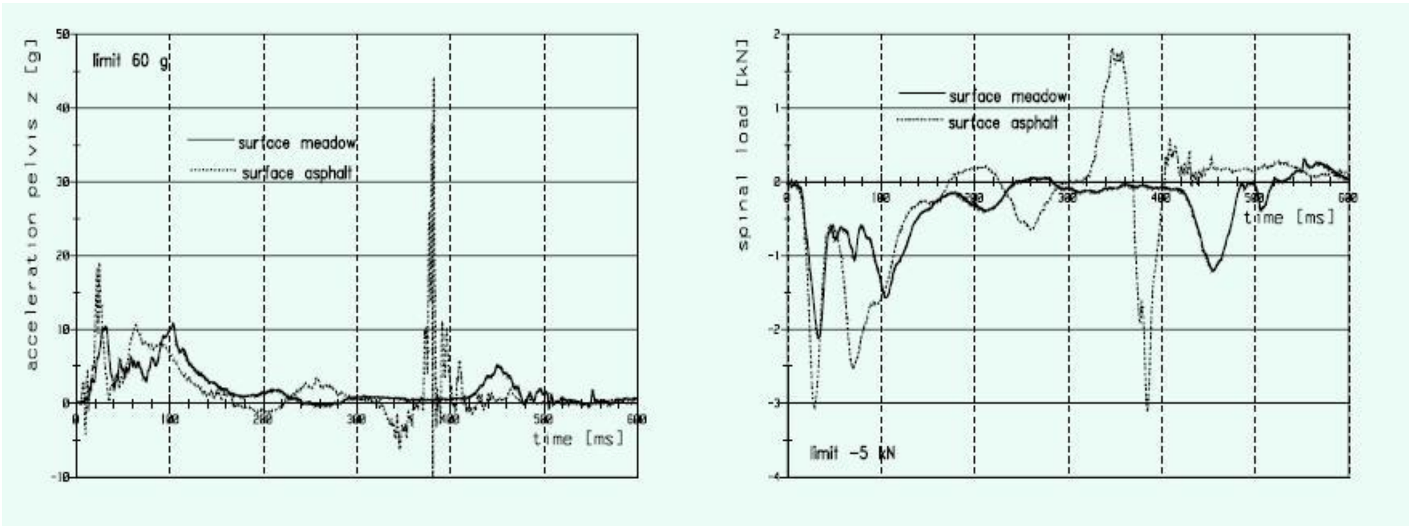

Figure 7 Pelvis acceleration and spinal load depending an hardness of surface mass 356 kg, pitch down attitude angle -45 degrees, vertical impact velocity 6 m/s

t = 80 ms t = 330 ms

Figure 8 Drop test on asphalt mass 356 kg, pitch down attitude angle -45 degrees, vertical impact velocity 6 m/s

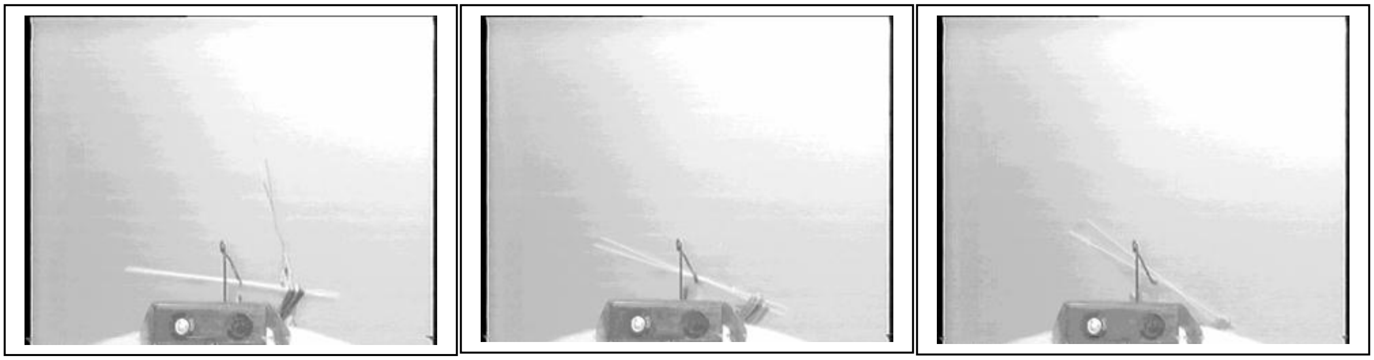

Figure 13 Collision of parachute and stabilizer at Vne, MISTRAL C

Figure 14 Separated wings due to the pitch rotation MISTRAL C, Vne

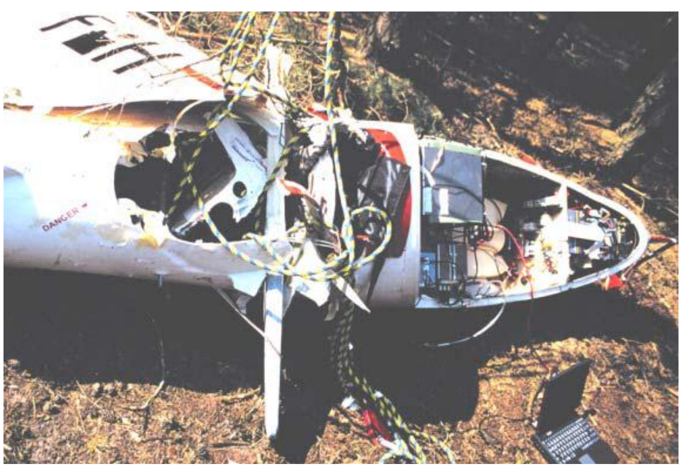

Figure 15 Cockpit of the MISTRAL C after the high speed test