# GLIDER RECOVERY AND PILOT RESCUE SYSTEMS

**by W. Röger and P. Stabenau, Fachhochschule Aachen, Germany**

Presented at the XXIII OSTIV Congress, Borlänge, Sweden (1993)

## 1. INTRODUCTION

Looking at mid-air accidents of German-registered gliders over the past 15 years, the chances of surviving turned out to be less than 50%. The well-established conventional emergency parachute obviously seemed to be unable to provide reliable safety at low flight heights. The results of [1] show that after the accident a minimum of at least seven seconds is necessary for a successful bail out. Any earlier impact on the ground leads to the loss of life. It is quite clear that a glider recovery system can only improve this situation. It will successfully save lives by slowing down the diving aircraft and improving the chance of the pilot's rescue.

On the authority of the German Federal Ministry of Transport, the FH Aachen is researching the fundamentals of an effective recovery system design for gliders and its powered derivatives. The research work is still in progress. Final results will be presented in late 1993.

## 2. THE DAMAGED GLIDER

The majority of mid-air glider fatalities arise from collisions. Figure 1 shows the statistical results of damages from the accidents mentioned above. Roughly half of the gliders involved suffered damage to their wings, one third lost their elevators and the rest their tail cones. Since the cockpit and the wing roots mostly stay intact and the kind of accident is unpredictable, it is obvious that any part of the recovery system must be installed inside this area.

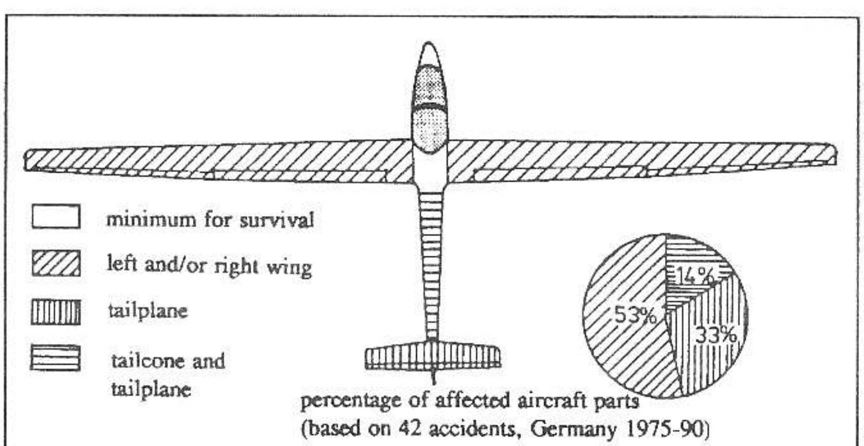


FIGURE 1. Statistical distribution of damages on gliders.

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. The actual three-dimensional motion of the dive will be demonstrated by a $^1/_3$ scale radio-controlled glider. Flight path parameters are stored by a 12-channel digital flight recorder installed inside the fuselage. This glider can be selectively damaged on purpose and will be recovered by a small parachute.

In the first run the longitudinal motion of a damaged glider was calculated by a computer [2]. Figure 2 shows the different flight paths of a standard class plane 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. At the bottom of the loop the speed of ≈90 m/s (≈295 ft/sec) is quite close to the $V_{ne}$ and may lead to structural disintegration. The z-acceleration acting on the pilot is described by Figure 4. All three cases sooner or later endure a peak of ≈ $-30\ m/s^2$ (≈ $-98\ ft/sec^2$).

**3. RECOVERY TECHNIQUES**

Though several recovery systems are currently available, none of them have ever been used in a glider. To date, only the tailless glider SB 13 was tested and certified for use with a cross-cluster-system.

Two recovery techniques have been thoroughly investigated: the glider recovery system (GRS) and the pilot rescue system (PRS). Although the two systems vary considerably in the mass and volume of their parachutes, they have three things in common:

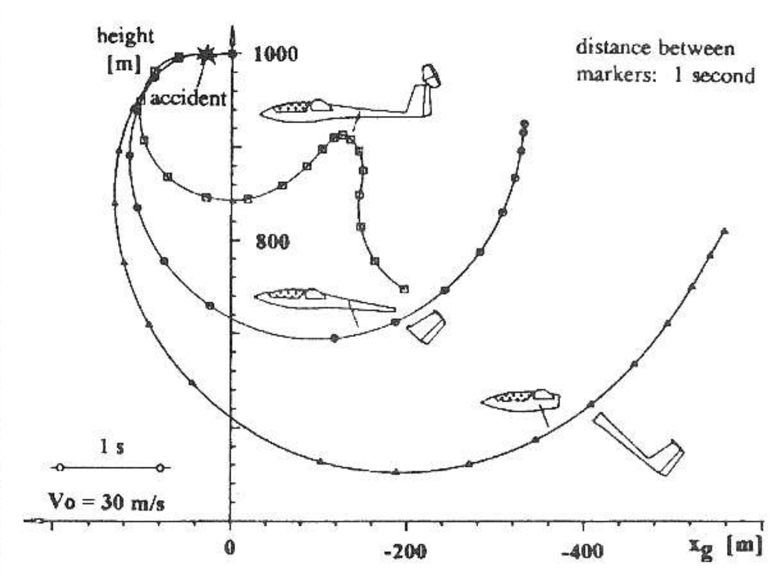

FIGURE 2. Flight path of gliders with different damages.

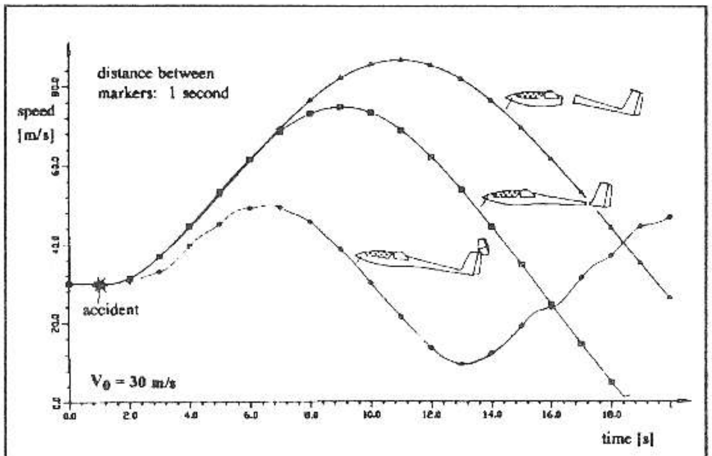

FIGURE 3. Speed-time history of gliders with different damages.

1) Both can be stored behind the pilot's headrest and connected to the main spar;

2) Since the parachute only opens along the glider's aerodynamic x-axis it has to be moved around the tail unit, otherwise it may collide with it. This can be achieved by any lifting device such as small rockets, guns or mortars;

3) Since it is deployed by the pilot immediately after the accident, the parachute decelerates and stabilizes the tumbling glider to a steady state descent. From this point onwards the two systems differ.

Figure 5 describes the operational sequence of the GRS. After activation, the parachute system opens and the final sinking phase at ≈ 6 m/s (≈ 20 ft/s) is reached shortly after the first full opening.

The PRS shown in Figure 6 is much more complex in its function. As its inflated parachute area is only $^1/_5$th of the GRS the glider descends at a higher speed of ≈ 15 m/s (≈ 49 ft/s). This is much too high for a smooth landing. Shortly after stabilization the connection between the parachute and glider is released, the seatbelts are automatically released and the parachute is linked up to the pilot's harness. From this moment on there is no longer a rigid connection between the glider and pilot. Due to the decreased payload, the parachute tightens the remaining connection between pilot and parachute and decelerates to a descent rate of ≈ 6 m/s (≈ 20 ft/s). This acceleration pulls the pilot out of the cockpit. The damaged glider falls down to earth and is lost. The pilot sinks safely to the ground suspended beneath his parachute.

**4. BEHAVIOR OF THE PARACHUTE SYSTEM**

Manufacturing a light parachute capable of bearing high opening loads no longer poses a technological problem. However, physical laws are not subject to changes.

This is why the descent speed of the inflated parachute and the mass of the payload have a considerable influence over the nominal diameter $D_0$ and hence the mass and volume of the packed chute. Figure 7 shows the nonlinear function of the nominal diameter $D_0$ depending on the sinking speed for flat circular and cross parachutes. The GRS requires a parachute about five times larger than the PRS because it has to land a high mass at a low speed. Consequently, the mass of the GRS parachute is also high (Figure 8). The dia-

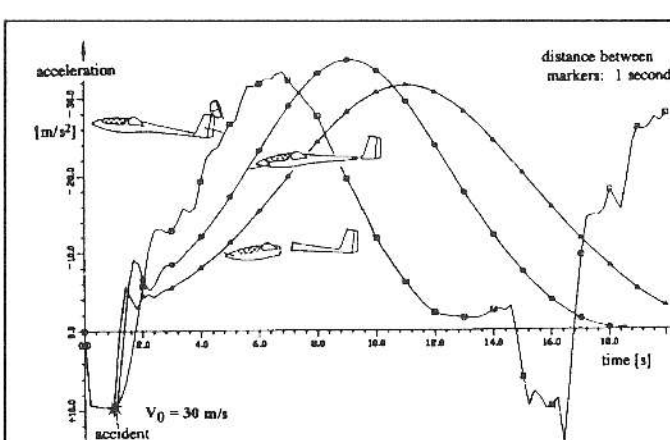

FIGURE 4. Z-acceleration-time history, gliders w/different damages.

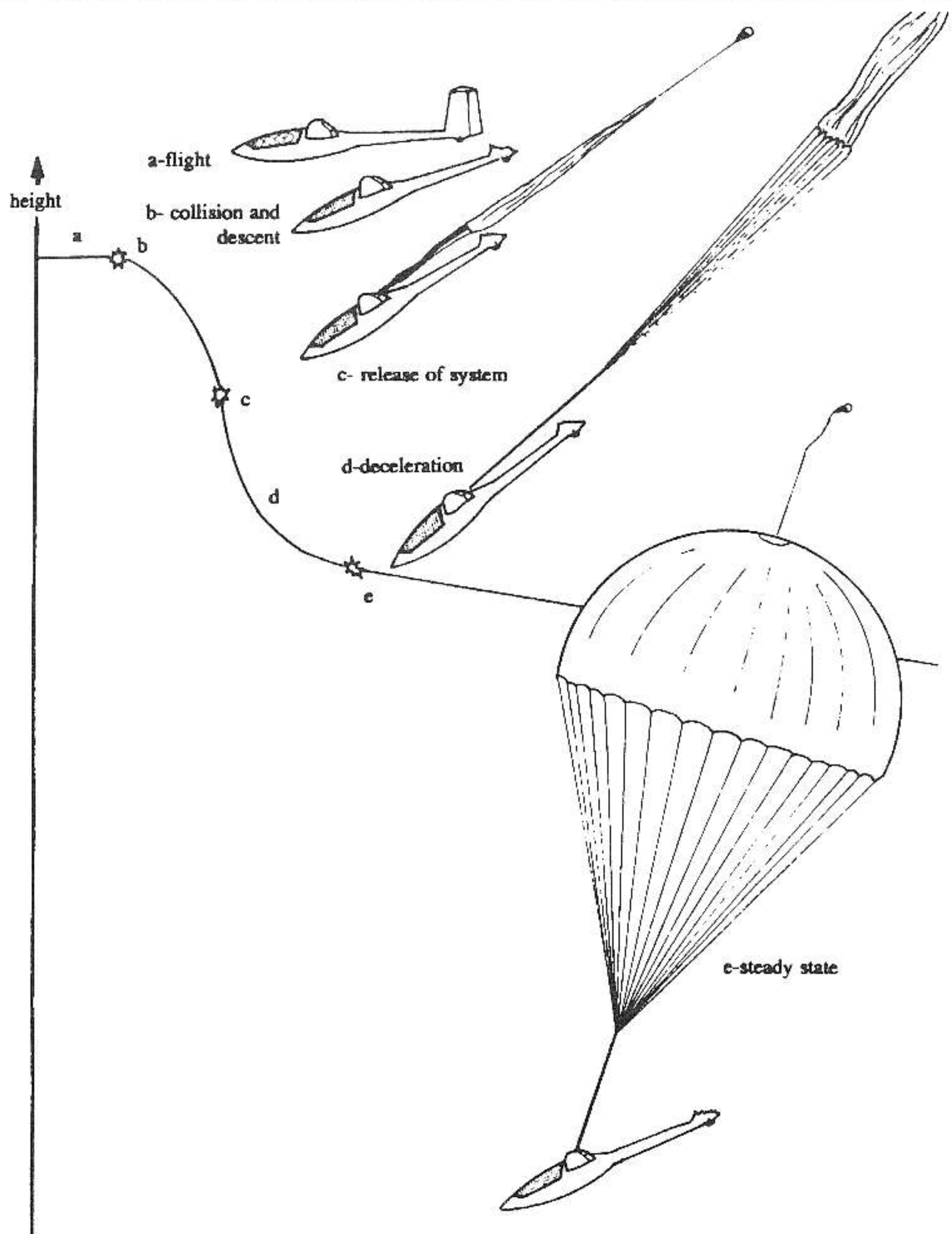

**FIGURE 5.** Operational sequence of the Glider Recovery System (GRS).

grams were calculated by a weight-optimizing algorithm which automatically used the corresponding US-Mil-Spec data sheets [3]. Therefore, jumping between the sheets results in a steeped curve.

Working on a recovery system only makes sense if the performance of existing systems is increased. The minimum deployment height including reaction and inflation times was calculated with a modified computer program from K. -F. Doherr [4,5]. Both systems will work down to a height of ≈ 150 m (≈ 500 ft), with the PRS having a slight advantage. The GRS decelerates the plane immediately but the large parachute system takes time filling. The PRS loses time during the more complicated mechanical release sequence but wins the race because the small parachute opens much faster.

After the deceleration phase the number and location of the connecting risers between glider and parachute as well as the shift in the glider's center of gravity, play a vital role for the attitude and the motion of the glider. It was discovered that a nosedown pitch angle (45° or more) and an attachment point slightly behind the main spar is advantageous. At this angle the plane is dynamically stable and no extensive swinging was noticed during the tests. The nose-down position also makes it easier for the PRS to pull the pilot out uninjured. At this angle, the initial ground impact of GRS can be partly compensated by the ability of modern fuselages to absorb energy. The effect of the forces acting on the spine and neck during the rebound phase are currently being investigated. It is expected that energy-absorbing seatpans or additional airbags near the landing gear will be necessary.

**5. PULLING OUT THE PILOT**

The PRS has no touchdown difficulties for it makes use of the human legs as the most flexible landing gear of all. Even in the air, no unsolvable problems arise during the pull-out phase.

The deceleration during this phase depends on the mass ratio pilot/glider and on the apparent airmass affected by the parachute canopy. The values vary between 1.5 to 5 g and it takes only 0.3 s time to pull out the pilot. Tests have shown that there are no serious problems during the pull-out procedure. Figure 9 shows the typical behavior of a dummy during a pull-out at an initial acceleration of 5 g and ± 40 degree pitching angle. The centers of gravity of each individual part of the body tend to move away from the rear cockpit frame and the instrument panel with less chance of getting hurt.

**6. CONCLUSIONS**

Mid-air accidents involving gliders result in damage to their structure and often in a loss of maneuverability. The aircraft starts to spin or goes into a negative loop. The stress on the aircraft and pilot increases by every

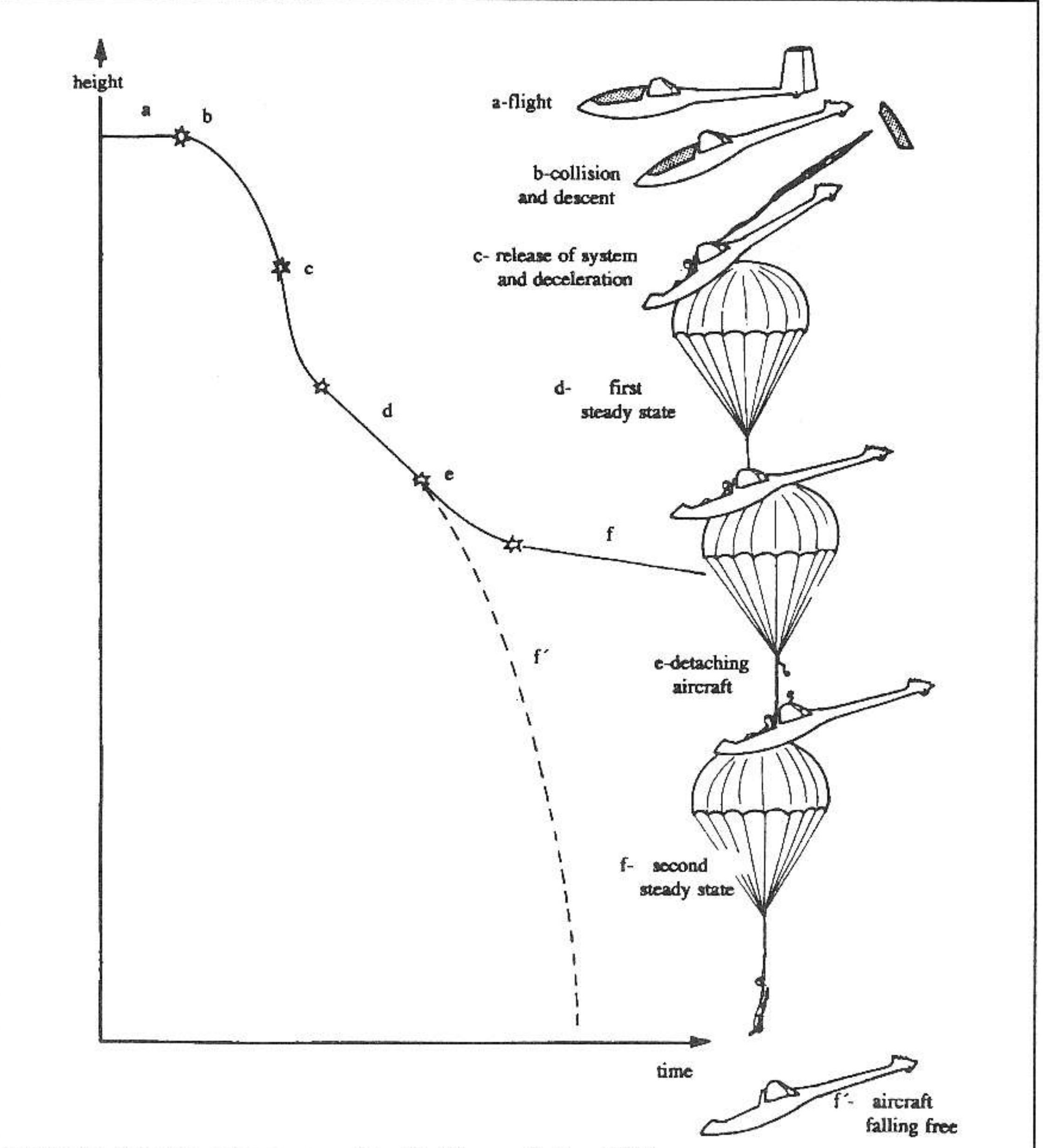


FIGURE 6. Operational sequence of the Pilot Rescue System (PRS).

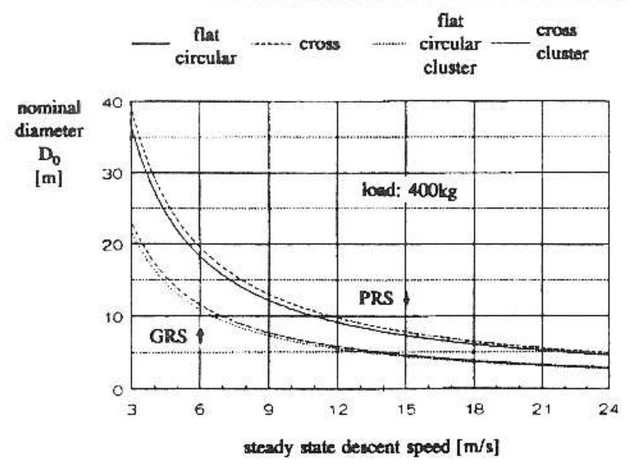


FIGURE 7. Comparison of nominal diameters of GRS and PRS.

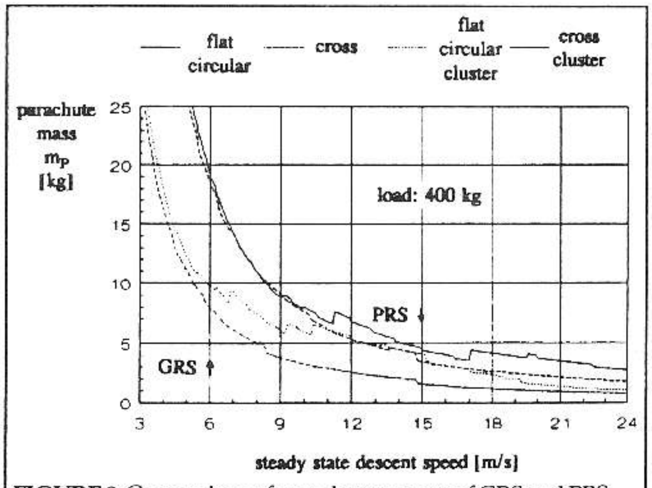


FIGURE 8. Comparison of parachute masses of GRS and PRS.

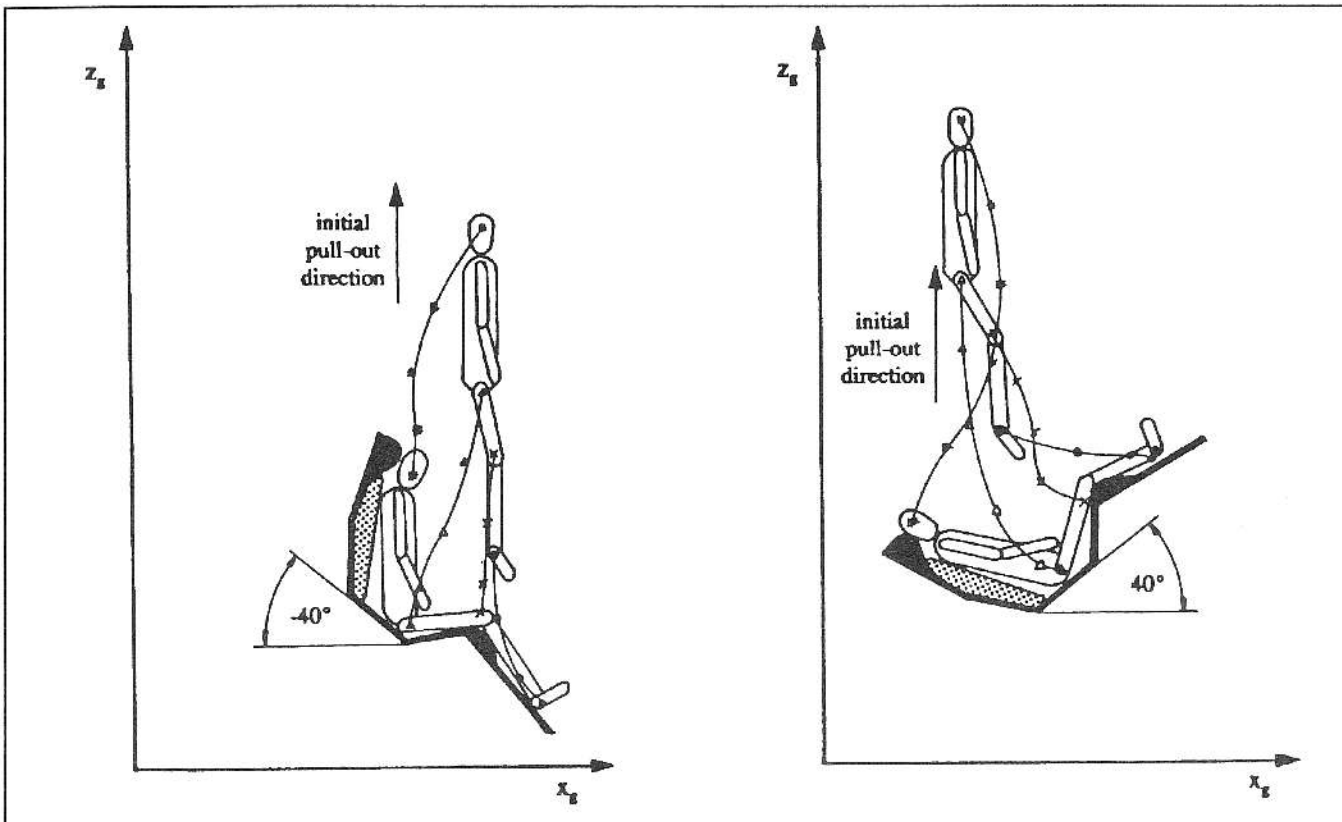

**FIGURE 9.** Pull-out of a dummy from the cockpit (pitch angle: - 40° and + 40°, initial acceleration 5g).

second. A glider recovery system is able to stabilize and decelerate this motion but it should be deployed as fast as possible. Both systems investigated by the FH Aachen, the glider recovery system (GRS) and the pilot rescue system (PRS), require a calculated minimum height of ≈ 150 m (≈ 500 ft) for a successful deceleration.

The dynamic behavior of the glider and parachute depends on the number and location of the attachment points of the connecting risers, the type of damage and, therefore, the shift in the center of gravity. It was discovered that at a nose-down pitch angle no severe swinging occurs, a PRS pull-out from the cockpit is uncritical and the initial ground impact of the GRS seems to be acceptable to the pilot.

The GRS parachute system takes up the most space in the fuselage. It is heavy but mechanically simple. With touchdown on the ground, the pilot's spine and neck is subjected to a high stress during the impact and the rebound phase. The energy must be absorbed by modern energy-absorbing fuselage, a special seat pan or additional airbags.

The PRS needs only one fifth of the GRS parachute area to bring the pilot safely to the ground where he lands on his feet in the classical manner. Though the mid-air release phase of the pilot from the glider is more complex and takes time, the PRS inflates faster because of its small parachute. Being small in volume and mass it is an interesting alternative to the very large GRS. During pull-out tests at nose-down pitch angles there was no risk of injury to the pilot.

Nevertheless, on account of the wealth of experience already gained with ultralight-recovery-systems, we believe that the GRS will be the first one to be marketed in the glider sector.

**7. REFERENCES**

[1] Röger, W., Stabenau, P., Problems and Improvements of Canopy Jettisoning Systems, *Technical Soaring*, Vol. 17, No. 1.

[2] Reinkemeyer, C., *Berechnung der Längsbewegung eines flugunfähigen Segelflugzeugs*, Volumes I and II, Diplomarbeit FH Aachen, 1992.

[3] Kohl, D., *Auslegung und Berechnung von Fallschirmen für Rettungssysteme bei Segelflugzeugen*, Diplomarbeit FH Aachen, 1992.

[4] Baumann, L., *Bestimmung des Mindesthöhenbedarfs für den Einsatz eines Segelflugzeug-Rettungs-systems mit Hilfe von Rechenprogrammen*, Diplomarbeit FH Aachen, 1992.

[5] Pasch, R., *Mindesthöhenbedarf für ein Pilotenrettungssystem*, Diplomarbeit FH Aachen, 1993 (prepared).