A COMPARATIVE EVALUATION OF GLIDER PARACHUTE RESCUE SYSTEM DESIGN ASPECTS

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ABSTRACT

Emergency escape from gliders has traditionally involved personal parachutes which rely on the pilot effecting a timely exit from the cockpit, and manually releasing his chute when clear of the aircraft. Problems with canopy jettisoning, pilot egress from the cockpit and pilot incapacitation warrants the consideration of alternate parachute recovery solutions.

Irvin's experience with emergency escape parachutes and recovery systems for unmanned aircraft has been used to present a comparative evaluation of alternative recovery systems and a trade-off analysis of benefits and disadvantages.

Concepts for recovering the whole aircraft, complete with pilot, overcome many problems but introduce others. These include extra weight, the need for reliable and safe deployment systems and the requirement for a crash worthy cockpit and shock attenuation devices to protect the pilot at ground impact.

In contrast to personal parachutes, such an integral recovery system needs an airframe specifically designed to provide suitable anchor points, load paths and resistance to opening shocks. In consequence it becomes subject to scrutiny against airworthiness standards by the relevant governing body so that retrofitting such a system to an existing airframe is likely to be problematic. These factors, together with their likely impact on cost and safety considerations, are discussed.

A preferred system concept uses a drogue parachute to stabilize the stricken glider and auto-extract the pilot who then returns to earth via a conventional personal parachute.

GLOSSARY

AAD	Automatic Activation Device
C_D	Non-dimensional Drag Coefficient
C of A	Certificate of Airworthiness
FMECA	Failure Mode Effect and Criticality Analysis
GRS	Glider Recovery System
PPS	Personal Parachute System
PRS	Pilot Recovery System
RPV	Remotely Piloted Vehicle
Specific Wt.	Parachute system weight/payload weight
UMA	Unmanned Aircraft

1. INTRODUCTION

The personal parachute system (PPS) utilizing a round canopy for maximum reliability has for many years been the mainstay method of emergency escape from gliders involved in airborne accidents, providing a light and cost effective solution. However a recent review of emergency escape situations (1) (3) indicates a likely survivability of only 50% attributable to the PPS, encouraging consideration of the alternative idea of recovering the whole airframe complete with pilot.

Total aircraft recovery applied to gliders - the Glider Recovery System (GRS) - when characterized in comparison to the conventional PRS, is found to provide distinct advantages in terms of response time, namely the time taken to achieve a safe rate of descent under a fully inflated parachute. However significant disadvantages of weight, cost and ground impact problems also materialize prompting consideration of a further concept - the Pilot Recovery System (PRS) in which the pilot is "auto-extracted" from the cockpit by parachute to descend thereafter in a conventional manner. This revised system is shown to combine the advantages of the PPS and the GRS whilst avoiding the attendant major disadvantages in each.

2. CONVENTIONAL PERSONAL PARACHUTE SYSTEMS

In order to achieve the fastest possible opening characteristics the PPS uses a small non-porous round canopy, deployed in a *canopy first configuration* - one in which the canopy is allowed to begin inflating before the lines are fully paid out of the parachute container. Such canopies will usually open within 1.5 seconds and less than 300 feet distance from a dead drop, with improvement on this if significant initial velocity exists at ripcord pull. The penalty for such fast opening is high shock loads which, at extremes of height and speed, may exceed 10 g as the canopy opens. Opening shocks can be attenuated to some extent by the use of porous fabric in limited areas of the canopy typically at the crown. Nylon rip stop broadloom fabrics of 35 grams per sq.m are commonly used for this purpose.

Whilst the smallest possible canopy is desirable for good specific weight and speed of opening, such a design is not conducive to a good rate of descent performance when acting as a pure drag retarder. Equally, the use of non-porous fabrics results in a canopy with appreciable oscillatory characteristics during the descent. Both these problems are overcome by shaping the canopy into a bi-conical or multi-conical profile (see Figure l) and providing drive slots to cause the parachute to fly with some horizontal motion, in order to develop a lift force to add to the drag. In this way, lift to drag ratios approaching 1 can be achieved to good effect, providing an enhanced resultant force which enables an acceptable low rate of descent (typically 5 to 6 m/s) to be achieved by the smallest possible canopy. The horizontal motion and drive slots have the added benefit of stabilizing the canopy, preventing any undesirable pendulum like oscillation during the descent.

Canopy deployment is most commonly achieved via a ripcord which releases pins from the restraining pack closure loops, allowing a spring assisted auxiliary canopy to eject clear of the back pack, inflate and thereby deploy the main canopy. This simple and effective release method generally proves to be ideal for the purpose but can be compromised by a mentally or physically incapacitated pilot having problems in locating and actuating the ripcord.

Alternative approaches to release can include a static line which is provided in addition to the ripcord. This is attached to the host airplane in order to automatically pull out the canopy when the pilot and airplane separate one from the other. Problems of entanglement are possible as

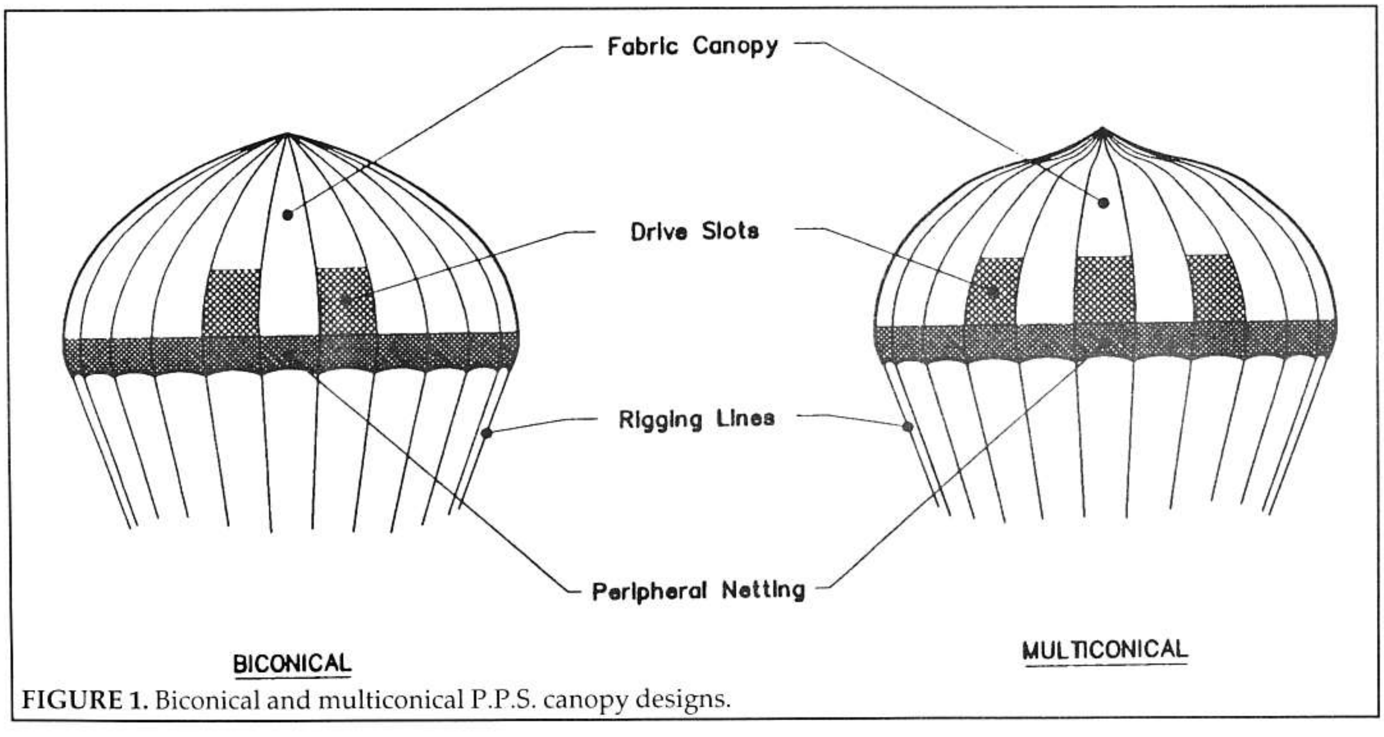


FIGURE 1. Biconical and multiconical P.P.S. canopy designs.

the canopy will inevitably be pulled out in closer proximity to the stricken air vehicle, but the benefits to a disabled pilot are self evident.

An additional safety feature available to aid canopy release is the provision of an Automatic Activation Device (AAD) which uses a barometric sensing/timing device to actuate the ripcord and release the canopy at a given altitude thereby safeguarding an incapacitated pilot once adequate separation from the aircraft is achieved. It also ensures that the canopy is opened at a safe height (not too high or too low). Such AAD's can be provided in addition to the manual ripcord and are armed via a lanyard connected to the aircraft to prevent inadvertent operation during normal glider height and speed excursions.

These sensible and beneficial additional activation features tend to be overlooked by recreational pilots in favor of the simple ripcord pull release, primarily because of the added cost involved. Equally, the possibility of an unplanned canopy deployment as the pilot walks away from his parked glider, caused simply because he forgot to disconnect his static line or activation lanyard, does little to encourage the adoption of such a valuable additional safety feature. This problem can in itself be overcome by making the PPS an integral part of the seat and seat restraint system such that when strapping into the glider the pilot is also fastening his emergency parachute. In a bale out situation the pilot pulls a toggle to disconnect the parachute from the seat rather than unbuckling straps.

Once inflated, the horizontal (forward) motion of the PPS provides the additional beneficial feature of steerage, providing the pilot an opportunity to avoid undesirable ground obstacles and also to arrange, if possible, a landing into wind to negate drift effects. Finally, as a ground impact shock absorber, the legs of a *compus mentis* pilot provide a spring damper system which is of unsurpassed performance in safeguarding him or her on landing.

3. TOTAL AIRCRAFT RECOVERY SYSTEMS

An idea which gets regularly aired is that of recovering not only the pilot but the whole aircraft and pilot, when faced with a flight failure situation. System concepts range from the more improbable notion of recovering whole airliners to those of recovering light airplanes, gliders (5) and microlights, the latter two categories achieving functional reality in one or two notable examples often referred to as *ballistic* parachute systems. The field of total aircraft recovery is well developed in its application to pilotless aircraft (6) also known as Remotely Piloted Vehicles (RPVs) or Unmanned Aircraft (UMAs). Such aircraft are commonly used by Armed Forces world-wide for surveillance work, target practice and even munitions delivery. Their attendant recovery systems typically feature either a single or a cluster of parachutes depending upon the payload weight involved (see Figure 4), and a shock absorbing airbag (see Figure 5) to attenuate landing shocks and thereby protect sensitive and usually very expensive onboard equipment.

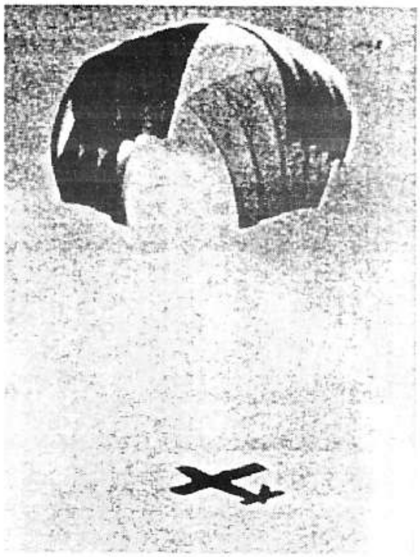


FIGURE 4. RPV recovery under a cruciform parachute.

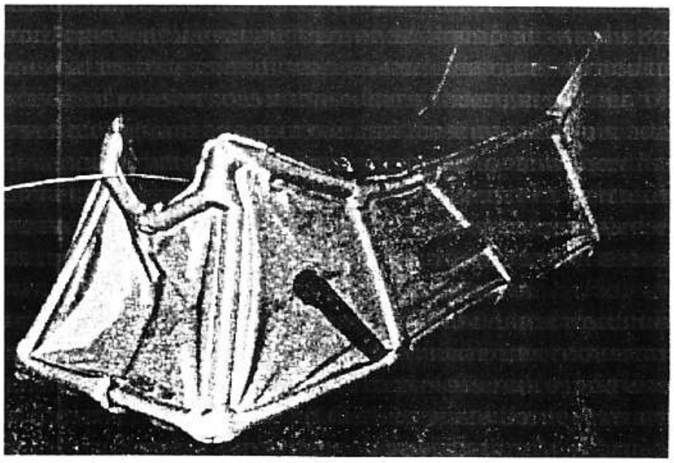


FIGURE 5. RPV ground impact shock absorbing airbag.

Parachute systems for RPVs/UMAs are technically representative of the requirements for the emergency recovery of sailplanes and light airplanes in most respects. All up weights to be recovered are in many cases surprisingly heavy, as can be seen from the examples shown in Table 1. They can often approach the weight of standard class gliders and small light aircraft; a 350 kgm RPV is not uncommon. However, in RPVs/UMAs the attitude of the airframe at parachute deployment is not a random event but a carefully pre-established situation, which ensures that a reliable parachute deployment is achieved. In such a Glider Recovery System (GRS), the orientation of the airframe at system initiation is unpredictable, which experience in the development of RPV systems shows to be highly undesirable.

Adequate deployment reliability may be achieved by resorting to high energy ejection of the recovery parachutes at initiation, in preference to using a simpler spring actuated auxiliary system. Pyrotechnically or pneumatically energized *mortars* as illustrated in Figure 7, or high energy *bullets* can be used to deploy an auxiliary or the main canopy(ies) as required, but with undesirable consequences to cost, weight, system complexity and safety and arming requirements. Such high energy deployment de-

Table 1 Specific Weights of Various Recovery Systems.

System	System Type	Mass Recovery System Kg	A.U.M. Kg	Specific Weight %	RoD m/s
T10R	Paratroop Reserve	5.5	136	4.0	7.4
Ariane 5	Space Recovery	1300.0	32000	4.1	25.0
Ariane1	Space Recovery	670.0	16000	4.2	12.5
Re-entry demonstrator	Space Recovery	435.0	9000	4.8	6.0
PR7	Paratroop Reserve	8.0	160	5.0	7.2
IRVIN EB80	Emergency Escape	6.3	115	5.4	5.4
PARA-CUSHION	Emergency Escape	6.5	115	5.7	5.7
HSP	Aerial Delivery	800.0	13300	6.0	10.0
GQ SHADOW	Emergency Escape	7.0	115	6.1	5.5
Banshee	RPV	3.6	59	6.1	4.7
FLEXPACK	Emergency Escape	7.6	115	6.6	5.3
I Ton Loads	Aerial Delivery	67.0	1000	6.7	10.0
MSP	Aerial Delivery	540.0	8000	6.8	10.0
Raven	RPV	5.0	65	7.8	4.0
Vector	RPV	3.2	38.6	8.2	4.1
PX4	U.K.Troop 'Chute	15.5	160	9.6	7.1
Pheonix	RPV	14.9	150	9.9	5.1
T10	U.S.Troop 'Chute	14.1	136	10.4	7.0
51mm Flare	Flare	0.1	0.45	11.1	8.0
Low Level Parachute	U.K.Troop 'Chute	18.5	160	11.6	5.9
Crecerelle	RPV	18.0	145	12.4	6.0
Dragon	RPV	18.0	130	13.8	5.3

NB: The above recovery systems are listed in order of increasing Specific Weight

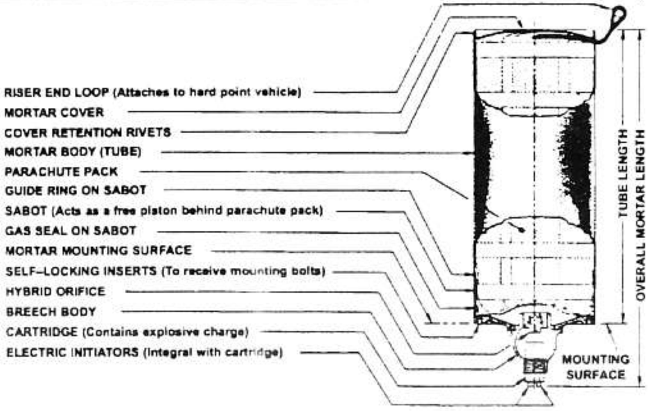
vices clearly represent a significant hazard on the ground requiring a foolproof approach to inhibition when not required. Equally a suitably rigid reaction point must be found in the airframe to adequately react deployment loads.

Although there are a variety of different round parachute designs which can be used for such applications, the Cruciform or Cross design (see Figure 4) is most commonly chosen for its high drag performance (typical C_D approaching 0.85, (2)) and simplicity of construction which is conducive to lower manufacturing costs. In contrast with most other round parachute designs, Cruciform parachutes also perform well in clusters with minimal mutual interference thereby enabling a number of small fast opening canopies to be efficiently used in preference to a larger single chute with much slower inflation characteristics and therefore greater height loss to safe rate of descent.

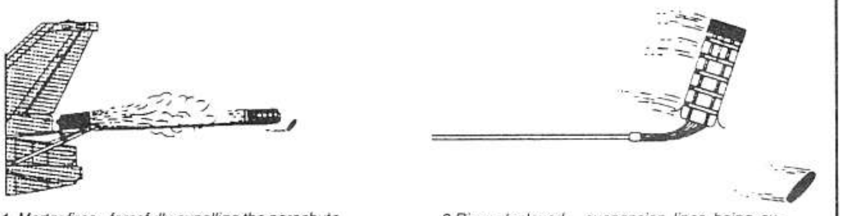
However, in practice the GRS is less able to benefit from rapid chute(s) inflation to quite the same extent as the PPS on account of the greater shock loads associated with faster openings. A glider is vulnerable to high parachute opening forces reacted along the longitudinal axis of the airframe. In this respect the human body is much more resilient. A shock load of 10g reacted along the fuselage is likely to cause the wing spar to fail in the forward direction with the risk of crushing the pilot in the process. Although it is theoretically possible to get the parachutes for the total recovery solution to inflate in the same filling distance as the smaller personal parachute solution, in practice this cannot be realized unless a specially strengthened airframe is provided which is able to react the forces generated by rapid parachute inflation. For this reason the GRS requires shock attenuation devices such as *canopy reefing* and / or a *lines first* deployment method, which adversely effects filling distance.

Whilst aircraft recovery parachutes could be arranged to have horizontal drive to enhance stability and minimize oscillatory, motion, produce lift and thereby minimize canopy size, this generally proves to be impractical, especially when clusters of small fast opening parachutes are used. Clusters are a naturally stable non-oscillating configuration but are not conducive to exploiting the benefits of horizontal motion. Indeed, a cluster of gliding parachutes would be prone to unstable operation and a single gliding canopy could be adversely effected by the destabilising aerodynamics of the glider payload. Equally it is undesirable to have horizontal motion if the parachutes cannot themselves be steered into wind or away from obstacles.

It is therefore inevitable that the GRS will use parachutes which are pure drag retarders of proportionally larger canopy area than is the case for the smaller personal parachute solution which can exploit the benefits of lift generating horizontal motion. In consequence, the specific weight will be greater in the case of the larger system, i.e. there is no weight economy of scale, indeed rather the reverse. Typically, a PPS will have a specific weight of some 5-

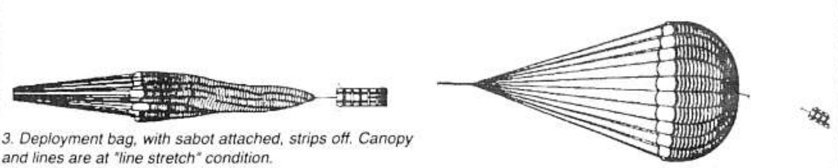


A typical sequence of events during mortar deployment of a spin recovery parachute.



1. Mortar fires...forcefully expelling the parachute pack. Cover separates and falls away.

2.Riser deployed ...suspension lines being extracted as the pack rotates 180°.



3. Deployment bag, with sabot attached, strips off. Canopy and lines are at "line stretch" condition.

4. Fully effective chute working in approximately 1 second.

FIGURE 7. Anatomy of a mortar system.

6%, as compared to the GRS which the field of RPV's/UMA's indicates will be closer to 8 - 10%, as illustrated in Table 1.

The specific weight may be improved if the parachute system can be designed to a lower maximum design speed, thereby enabling the use of lighter weight materials. Such an argument may be relevant to microlight applications where the inherent drag of even a failed microlight wing will provide sufficient drag to limit terminal velocity of the microlight and pilot combination. However, the clean designs of modern gliders make potentially high terminal velocities possible driving the maximum design speed to even greater values than the normal 150 knots figure used for the PPS. This will require the parachute to be stronger and inevitably heavier, to cope with the extra operating loads which are possible.

Ground impact shock loads are most effectively attenuated by facilitating a significant deceleration distance as illustrated in Table 3. In this respect a 'crumpling' body achieves this much better than a rigid glider when impacting with the ground at 5 to 7 m/sec. Lower descent speeds than this are in practice not possible due to the debilitating effect such a reduction invariably has on oscillatory motion leading to even greater problems. So for the cockpit seated pilot to survive ground impact as well as he would if landing on his own two feet, his supporting airframe requires energy absorbing features such as a crash worthy cockpit or an airbag or indeed, both! This further adds to system cost and complexity of the GRS approach.

Once incorporated as part of the airframe the GRS will inevitably become subject to the rigors of airworthiness standards which are currently somewhat undefined for such a new system concept. Regulatory consideration will focus on reliability to ensure that the system will indeed function when required, and perhaps more importantly, will not function inadvertently. The full rigors of a Failure Mode Effect and Criticality Analysis (FMECA)(7) needs to be applied to demonstrate the safe and reliable functionality of the design. Equally the implications of ground impact stresses on the airframe during recovery will need to be properly understood and defined by the airframe designer who becomes responsible for safeguarding the pilot in this recovery mode.

Table 3 Shock Loads (G) at Various Deceleration Distances

Stopping Distance (m)	Rate of Descent prior to ground impact (m/s)						
	4.5	5	5.5	6	6.5	7	7.5
0.1	10.3	12.7	**15.4**	18.3	21.5	25.0	28.7
0.2	5.2	6.4	**7.7**	9.2	10.8	12.5	14.3
0.3	3.4	4.2	**5.1**	6.1	7.2	8.3	9.6
0.4	2.6	3.2	**3.9**	4.6	5.4	6.2	7.2
0.5	**2.1**	**2.5**	**3.1**	**3.7**	**4.3**	**5.0**	**5.7**
0.6	1.7	2.1	**2.6**	3.1	3.6	4.2	4.8
0.7	1.5	1.8	**2.2**	2.6	3.1	3.6	4.1
0.8	1.3	1.6	**1.9**	2.3	2.7	3.1	3.6
0.9	1.1	1.4	**1.7**	2.0	2.4	2.8	3.2
1	1.0	1.3	**1.5**	1.8	2.2	2.5	2.9

☐ Typical situation for Personal Parachute System

Table 2 Recovery System Response Times
Conventional Personal Parachutes vs. Glider Recovery System

ACTION	Conventional Personal Parachute	Glider Recovery System
Decision to abandon Flight	1 to 1.5	1 to 1.5
Undo Straps	1	N/A
Jettison Canopy	1.5 to 20	N/A
Exit Glider	3 to 4	N/A
Pull Rip cord	1	1
Parachute Canopy open	1.5	2.5
Time to Safe Rate of Descent	1	1
TOTAL TIME (sec)	10 to 30	5.5 to 6

4. COMPARING PERSONAL PARACHUTES WITH GLIDER RECOVERY SYSTEMS

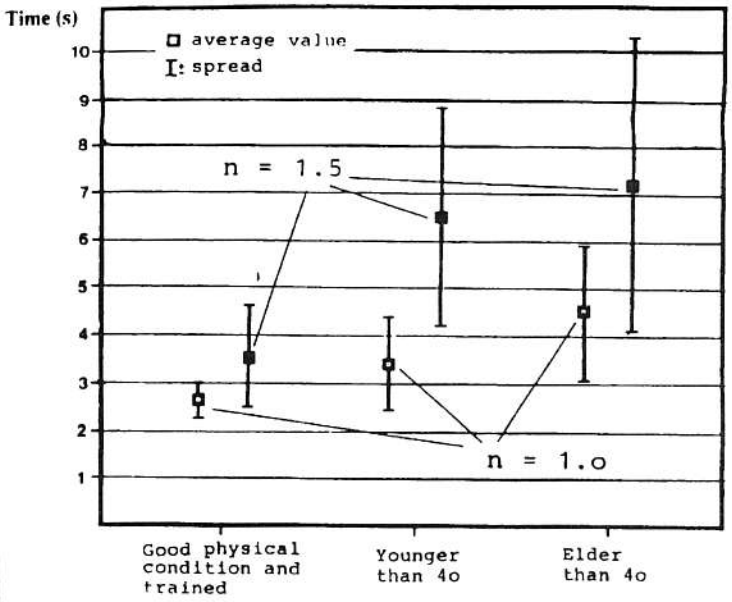
Given the evident advantages of low cost, low weight and performance of the PPS, one might be forgiven for wondering why the idea of the GRS has ever emerged even to the extent of being realized in a couple of notable cases. Table 2 goes some way to providing an answer by analyzing the cumulative actions and associated response times involved, from the emergency instigating event, to the achievement of a safe rate of descent under canopy.

These figures seek to suggest likely pilot response times in an emergency and are necessarily based on a common sense assessment of time scales considered likely in the case of each action required. Actual experiments undertaken by Prof.Dr.W. Roger et al suggest that the time taken by the pilot to exit the cockpit can be well in excess of 3 to 4 seconds, depending upon the cockpit shape & size, age of pilot and the flight loading at the time, see Figure 2.

In both system cases the pilot will have a sudden realization that he has a problem which requires him to make the unprecedented decision to abandon normal flight in favor of parachute recovery. In the case of the PPS the pilot then has to undo his straps, jettison his canopy and exit the airframe, combined actions which can take from between 5 to well in excess of 20 seconds to achieve - the most significant and potentially time consuming action being that of removing the canopy (as certified from the recounted experiences of a number of glider pilot escapes).

Pulling the parachute system actuator or ripcord is a common action to both systems but the subsequent parachute canopy inflation is estimated to be slower for the GRS than for the PPS, at 2.5 seconds as compared to 1.5 seconds (assuming similar start conditions) in order to attenuate opening shock loads. Descent time under canopy to a safe rate of descent is assumed to be similar at 1 second.

In totaling these reaction times a clear advantages of at least 4.5 seconds in favor of the GRS can be seen - a time period which can make all the difference be-



(a) Average time period needed to leave the cockpit depending on age and physical condition

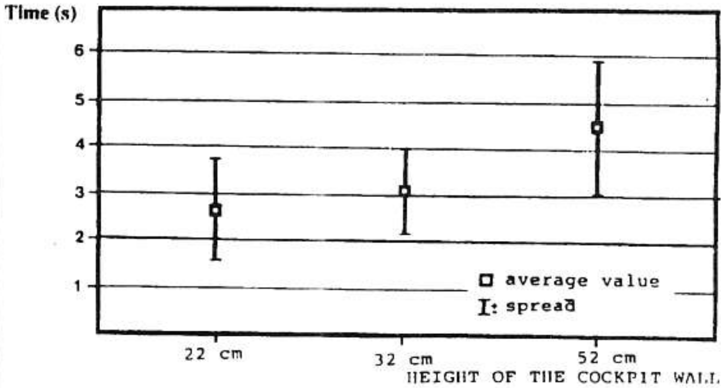


FIGURE 2. Pilot egress time vs. pilot age and cockpit dimensions.

tween life and death. In other words it is the difficulty of the pilot to quickly vacate his airframe to a free fall situation which is the design driver for an alternative system to the PPS. This is well illustrated in the case of microlights where successful abandonment of the aircraft in an emergency may actually be impossible to achieve due to the extreme difficulties involved in getting in and out of the airframe whilst in flight. Since microlights have the further advantages of drag limited terminal velocity, low all up weight and ground impact absorbing undercarriage elements it is perhaps understandable that the application of total aircraft recovery systems has predominantly been in the microlight field.

Table 4 seeks to provide a qualitative analysis of the relevant benefits inherent in both recovery systems. The scores applied are somewhat arbitrary and the reader might prefer to add different values but the table does suggest an advantage in favor of the PPS. However, given the close nature of the scores it is not surprising that the PPS has predominated in the world gliding market mainly driven by the fact that it represents the lowest cost and simplest solution. Equally, with a likely all up weight of some 30 kgms (70 Ib.), the GRS for a standard class glider would clearly be punitive to its performance in weak lift conditions so that the PPS at less than 1/4 the weight is likely to be preferred by the keenest soaring enthusiast.

Whilst the PPS is relatively free of regulatory approvals and constraints, this will not be the case for GRS where the operational consequences are inherently tied in with airframe airworthiness standards. This will inevitably become an additional cost driver to the manufacturer of sailplanes since the recovery system will become a significant aspect of the airframe design, and on going C of A considerations.

5. AN ALTERNATE APPROACH

Although the PPS is a light weight, cost effective solution for emergency escape it is an inescapable fact that the time taken to exit the glider can be life threatening. While the advantages of moving towards a GRS type solution may not be sufficient to overcome the inherent disadvantages of extra cost, weight and system complexity, there is perhaps a middle ground ap-

Table 4 Qualitative Analysis of Recovery Systems

DESIGN ASPECT	PERSONAL PARACHUTE SYSTEM		GLIDER RECOVERY SYSTEM		PILOT RECOVERY SYSTEM	
	PPS	Score	GRS	Score		Score
WEIGHT Parachute System wt. Payload Weight Recovery system AUW for	Typically 5.5% of Payload 113 kg (253 lb) Pilot 6.25 kg. (14 lbs)	4	Typically 8% of Payload wt 350 kg (784 lb) Pilot 28kg (63 lb)	1	Probably 12% of Payload 113 kg (253 lb) Pilot 14 Kg (30 lbs)	4
PERFORMANCE Total Reaction Time	Typically > 9 seconds	0	Typically < 6 secs	6	Typically < 6 secs	6
Deployment time from system initiation	1.5s	5	2.5s	4	2.5s	4
Opening shock load	Wide limits possible	4	Limited by airframe typ 6G	2	Not too limited	4
Accident Survivability	Actually < 50%	0	Estimated > 70%	3	Estimated > 85%	6
Rate of Descent	Typically 5 to 6 m/s	4	Typically 6 to 7 m/s	3	Typically 5.5 m/s	4
Ability to steer clear of obstacles	teering toggles glide ratio 1	5	none	2	Steering toggles glide ratio	5
Ground impact absorber	Pilots legs	4	Crashworthy cockpit or airbag	2	Pilots Legs	4
OWNERSHIP ASPECTS Flight Approvals	Highly variable	2	Well defined	4	Well defined & variable	3
Through Life Costs	Cost of Repacks/Inspection only	4	Stored with glider more maintenance likely	3	Cost of Repacks/Inspection Stored with glider so more maintenance may be req'd	2
Safety/Reliability	Inert system	4	High energy launcher requires ground inhibition	2	Moderate energy launcher requires ground inhibition	3
Storage conditions	User selected storage	4	Same as glider	3	User selected & Glider	3
Cost of System	less than £1000	4	More than £3000	2	More than £2000	3
Airframe situation	Lost & can cause ground impact damage/injury	1	Recovered with pilot	4	Lost & can cause ground impact damage/injury	1
TOTAL SCORES		45		41		52

Scoring System Used		
	Adv	Disadv
Key issue	6	0
Big issue	5	1
Moderate issue	4	2
Minor issue	3	3

proach of providing a parachute assisted method of extracting the pilot from his damaged airframe, which provides a similar performance advantage - the Pilot Recovery System (PRS) - see Figure 6.

Such a system would require merely the operation of a dual action (e.g. twist and pull) instrument panel mounted control knob to actuate a high energy ejected drogue, and simultaneously release locking clamps on the glider canopy and the pilot harness. On inflation the drogue would remove both the cockpit canopy and pilot in turn from the glider, the latter subsequently reverting to a ripcord or static line actuated PPS for the final descent. A barometric sensing device could be incorporated to inhibit system operation below a given safety altitude and the pilot would retain the option of a conventional exit from the glider and use of the PPS if preferred.

The drogue chute would be either a conical ribbon or ring slot circular design featuring significant geometric porosity to enable it to survive and produce drag efficiently at the relatively high speeds of operation likely (typically in region of 50 to 200 knots). Essentially this canopy would be similar in design to anti-spin chutes used for test flying modern jet fighters.

Having postulated the idea of a similar concept Dr.W.Roger et al (4) have highlighted the importance of the drogue chute imparting a stabilizing force upon the glider structure for an instant before releasing the glider and extracting the pilot. Such a sequence of events is shown to be important to provide satisfactory exit conditions for the pilot given all the likely motions of the damaged glider. It is also shown to reduce the glider height loss during the few critical moments of pilot egress from the cockpit.

Although it is further suggested that the same parachute canopy could be used to return the pilot safely to earth, this is only likely to be achievable with substantial, non-optimal compromises being made to the design to favor structural considerations. This would be to the detriment of function and weight; even when the possibilities of reefing control for load attenuation is considered. For this reason the idea of two separate optimized parachutes (i.e. the drogue and the PPS) remains favored for this application.

Dr.Roger and his team have determined (1)&(3) that following the loss of the stabilizer or even the tail assembly and part of the rear fuselage cone, the damaged glider will perform a negative G pitch or "bunt" maneuver to the inverted (see Figure 3 (3)). While such a motion favors pilot egress from the cockpit, it results in a rapid and undesirable loss of height, and less than ideal deployment conditions for the drogue parachute.

Equally they have shown that a glider with a wholly or partially damaged wing will result in a spinning motion with some positive G's on the pilot which will inhibit egress although this motion will be more conducive to satisfactory deployment of the drogue, albeit with the attendant risk of possible entanglement.

These two failure modes and the resulting motion of the damaged glider determine the need for a high energy deployment system for the drogue chute to ensure satisfactory function. A powerful spring, a pneumatic gun or a pyrotechnic mortar are possible options and careful design backed by a Failure Mode and Criticality Analysis (FMECA)(7) to demonstrate adequate reliability will be

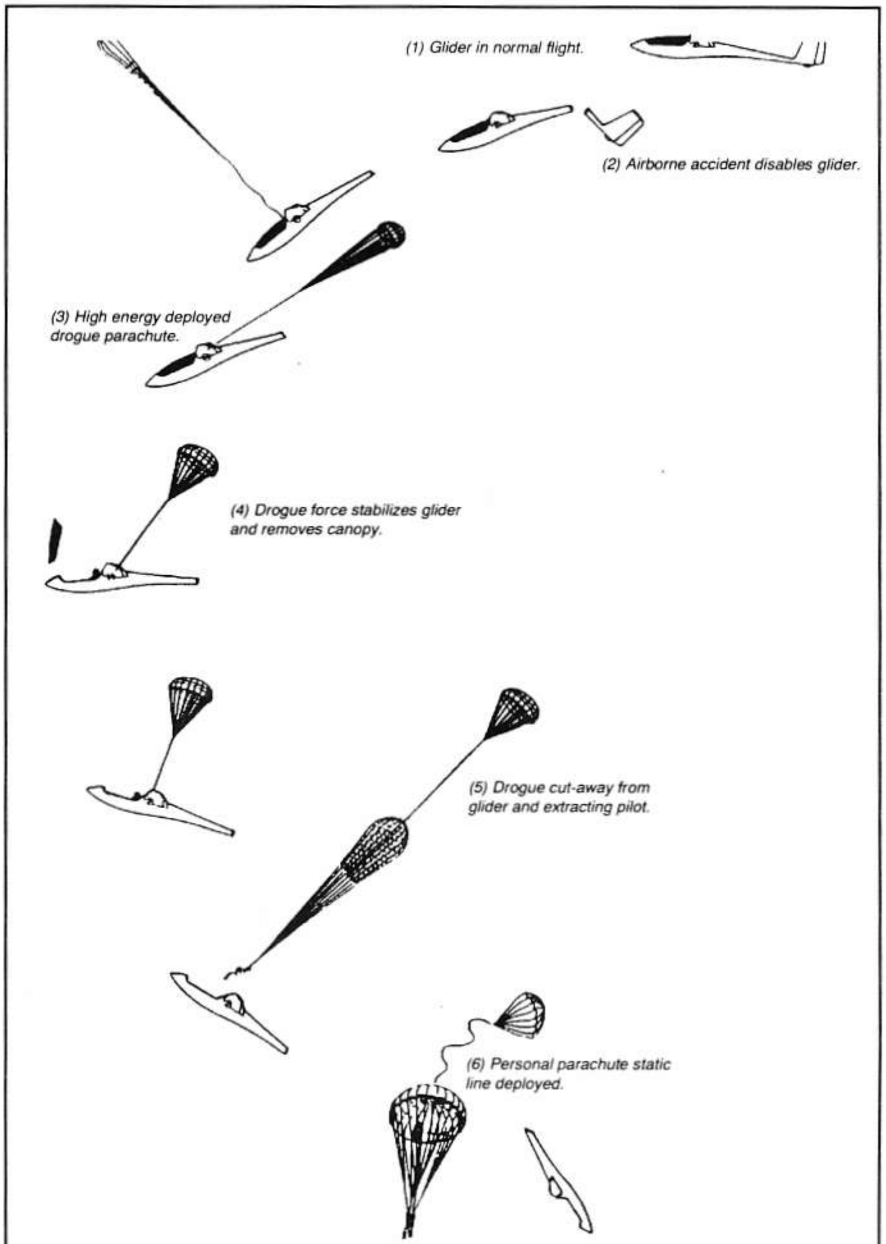


FIGURE 6. Proposed pilot recovery system.

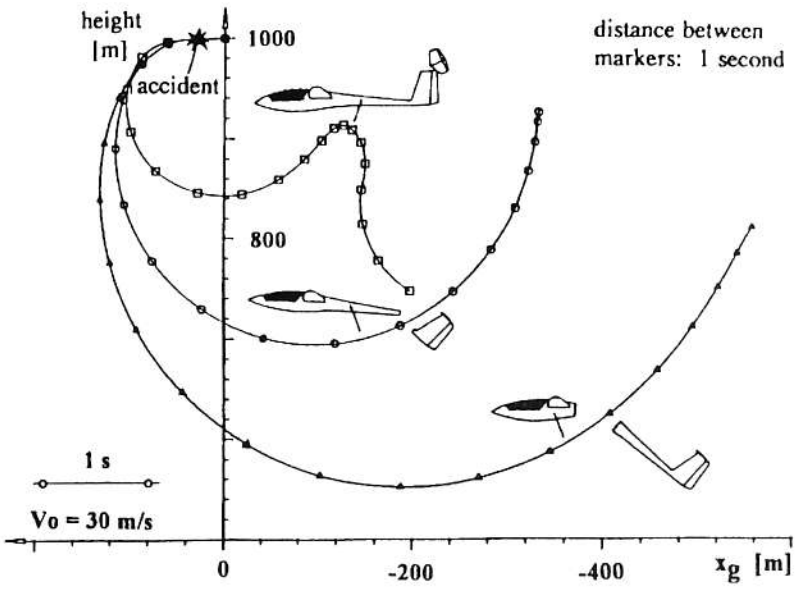


FIGURE 3. Glider flight path following damage to rear fuselage/tail empennage.

required to achieve a safe and cost effective solution to this critical part of the design. With the two canopy approach the size of the stabilizing drogue can be minimized requiring less energy for deployment enabling a simpler and inherently safer initiation system to be adopted perhaps based on a powerful spring or pneumatic gun.

With careful design it should be possible to engineer an extraction system which adds no more than the weight of an additional PPS to achieve the PRS solution. The all up weight should therefore be no more than half the weight of the GRS approach, at typically 30 to 35 lbs. Table 4 goes on to suggest the PRS to have a significant advantage over both the GRS and the PPS.

6. CONCLUSIONS

The GRS is not a practical proposition for gliders due to significant weight and cost increases as well as inherent shock loading problems at parachute opening and ground impact.

The PRS is the ideal solution to emergency escape from gliders utilizing an energetically deployed drogue parachute to remove the cockpit canopy and stabilize the stricken airframe before auto-extracting the pilot who completes his descent using an automatically deployed PPS.

By solving the problems of Pilot egress from the cockpit the PRS offers significant performance benefits over the PPS & the GRS with an acceptable small increase in system weight.

Improvements in emergency escape survivability from gliders will inevitably carry a cost and weight penalty, which in the past has been resisted by glider pilots.

7. RECOMMENDATIONS

The alternate PRS described herein should be subject to an optimizing design study to size and define the various components required and to determine a suitable performance from an appropriate dynamic model. A test program should then be conducted to confirm the validity of the theoretically predicted results.

The design study should incorporate a rigorous FMECA(7) to ensure that the proposed system detail will satisfy airworthiness regulatory requirements for system reliability.

Particular attention should focus on the high energy deployment system required, since this is the key design driver to functionality, reliability and cost. Existing Ballistic Recovery Systems may offer the basis of a suitable low cost and proven ejection system.

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