

WHAT PRICE FOR SAFETY?

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INTRODUCTION

During the past decade remarkable and permanently increased effort has been promoted inside the "technical soaring community" to enhance "passive safety" in gliding. A special subcommittee was established by the OSTIV Sailplane Development Panel to study the subject and prepare appropriate amendments to OSTIV Airworthiness Standards and also for preparing recommendations to the JAR-22 Study Group. The author attempts to summarize the work already being done and wants to point out some problems arising, which are more of commercial and "philosophical" nature, than a technical one.

BRIEF HISTORY

At first the author wants to apologize for possible deleting of some details or persons involved. But this review should not be considered as a complete historical survey. It should only roughly demonstrate, what is already done and what were the reasons for doing so.

The appearance of modern composite materials dramatically changed the sailplane design. The new technology enabled to create an "absolutely pure" aerodynamic shape with excellent surface qualities and it resulted in relatively easy crossing the magic "L/D = 40" margin and to push the distance and speed records to figures which were unbelievable a few years ago.

On the other hand it presented new problems, as any new technology. The fatigue and safe life substantiation were extremely complex because of the unknown influence of "aging," especially from sun radiation and moisture effects. They have been finally resolved thanks to immense effort of - mainly - German manufacturers and research institutions. A further appreciable support came from Australian sailplane researchers. The continuing effort to increase the current limit of 12,000 flight hours is the best demonstration, that a great job has been done!

Another serious problem, which appeared with composites, especially with the most advanced ones (like carbon-fibre reinforced plastics), was the relatively high "brittleness" compared to the excellent static and fatigue strength. This fact, together with permanently increasing all-up mass, wing-loading and resulting higher stalling speed, resulted in a growing number of fatal accidents at outfield landings with nose impact on an obstacle or the ground during stall/spin accidents. The brittle front part of the cockpit dispersed without providing the occupant with an adequate protection by absorption of kinetic energy. This became very critical especially in case of composite tandem two-seaters.

This fact was recognized by the OSTIV -SDP and started the strong energy engagement in the matter in the late 80ties. At the same time the other institutions like German DOT (Bundesministerium für Verkehr) encouraged and supported the research in their domains.

It is out of the scope of this paper to summarize and describe completely all effort devoted to the matter till now. The attempt to describe the most important actions of OSTIV, SDP and research institutions involved, co-operating or acting parallel is presented in Figure 1.

To get an idea of the immense work that has been done (and still continues!) the reader must read through the referenced literature marked in Figure 1 and other text by figures in square brackets.

WHAT IS THE IMPROVEMENT IN CRASHWORTHINESS DURING THE LAST DECADE?

Sailplane structure / construction

Again, we cannot answer this question without slight simplification. To provide the pilot of a modern sailplane with the current standard of passive safety, we should design and manufacture sailplanes with:

- A reasonably strong cockpit cage (called "survival cell" in Formula One racing cars) combined with an energy absorbing structure ("soft nose" as we use to say in our slang) in front of the pilot's legs / front control column mounting (the latter is expressed in new OSTIV AS, the former is suggested by JAR 22 Study Group and demonstrates a slight difference in philosophy between both gremia - see following section).

- A properly shaped and fixed seatpan with the backrest and parachute pack, providing adequate support to the spinal column during impact decelerations.

- A safety harness retaining the occupant under "15 g deceleration" and preventing "submarining" without endangering the male pilot's crotch.

- Properly designed instrument panels with well rounded edges from tough material and

- Front pedals combined in a strong block, enabling controlled backward displacement of feet and lower legs during the energy absorbing crumpling of the forward fuselage structure.

- Seat cushions and adequately strong headrest made of energy absorbing foams / materials.

GLIDER / PILOT PARACHUTE RECOVERY SYSTEM (GPRS,PPRS).

Although originally not readily accepted by the gliding community, the development of automatic recovery systems gets growing support during last two years. The increasing numbers of mid-air collisions with more victims, together with the better understanding of associated technical problems convinced more and more people, that "automation" of the rescue process is the most promising way how to bail - out in the few seconds remaining for survival after a mid-air collision. The initiative of German Aero Club and some competition pilots was very appreciated! (see the web pages <http://www.soaring.net/Actuelles/> for recent news!)

At the time this paper was written the research still continues, at FH Aachen, individual system manufacturers and authorities. We cannot tell at this moment, which solution will be the best one, whether GPRS or PPRS (abbreviations GRS / PRS are used in some literature instead). Both systems have their advantages or disadvantages. The opponents to GRS argue about the higher mass (a bigger parachute is necessary) and problems with dynamic opening shocks compared to PRS [17]. Also the fact that the descent inside the fuselage torso does not provide any possibility to control the impact point is discussed.

It is out of the scope of this article to discuss "pros and contras" of both systems; let us wait for first practical figures!

1983 - 1989 Sailplane Accidents in Germany analyzed by TÜV Rheinland [1, 8]

1988 Dr Segal accomplishes the full scale glider Impact test [4]. The maiden flight of ASW 24 - first "crashworthy cockpit" design.

1989 First published call for GPRS [13]

E. Crawley et al. publish results of composite scaled models dynamic/static tests [5] OSTIV SDP Wiener Neustadt meeting discussion on the energy absorption at crash impact. Medical aspects of crash cases, spinal protection by proper design of seatpan backrest, parachute pack shape. Revision of 'Icose items' restraint crashloads. [6] TÜV starts Restraint System investigation [8]

1990 OSTIV SDP Stuttgart meeting-Proposal on accepting "Crawley's 15g' crashload and partial fuselage nose crumpling for OSTIV AS crash cases. Crashworthiness Subcom. establ. Investigation of energy absorbing seat-cushion foams. Canopy jettisoning, bail-out problems investigations in FH Aachen. Seatpan and restraint system design aspects. [1, 7, 8]

1991, 1992 OSTIV SDP Uvalde, Orlinghausen meetings- continuing elaboration of revised OSTIV AS Crash cases. Anthropometry and Cockpit design, canopy jettisoning research in FHA continued [9, 10]. Suggestion to establish a GPRS subcommittee.

1993 OSTIV SDP Borl~nge meeting development of detailed design requirements (H-point, angle of shoulder harness, discussion on 'trushable seatpan attachment'. 1~ draft of Amended" ground loads cases' standard. [1,2]. Further progress in GPRS investigation in Germany (FHA). 1994 OSTIV SDP meeting in Budapest definition of the "Energy Absorbing Structure (crushable nose) / Strong cage' fuselage design. Rationalisation of pilot seating position, spine supporting elements, energy absorbing headrest and seat cushions. [11] The Symposium on GPRS investigation results (FHA) in Bonn, Germany. [12, 13]

1995 OSTIV SDP meetings Omarama, Zlin continuing work on OSTIV AS Amendment / Advisory Materials. Draft of the OSTIV AS for GPRS. LBA Preliminary Suppl. Requirements, FAA Spec. Conditions 23-ACE-76 for GPRS.

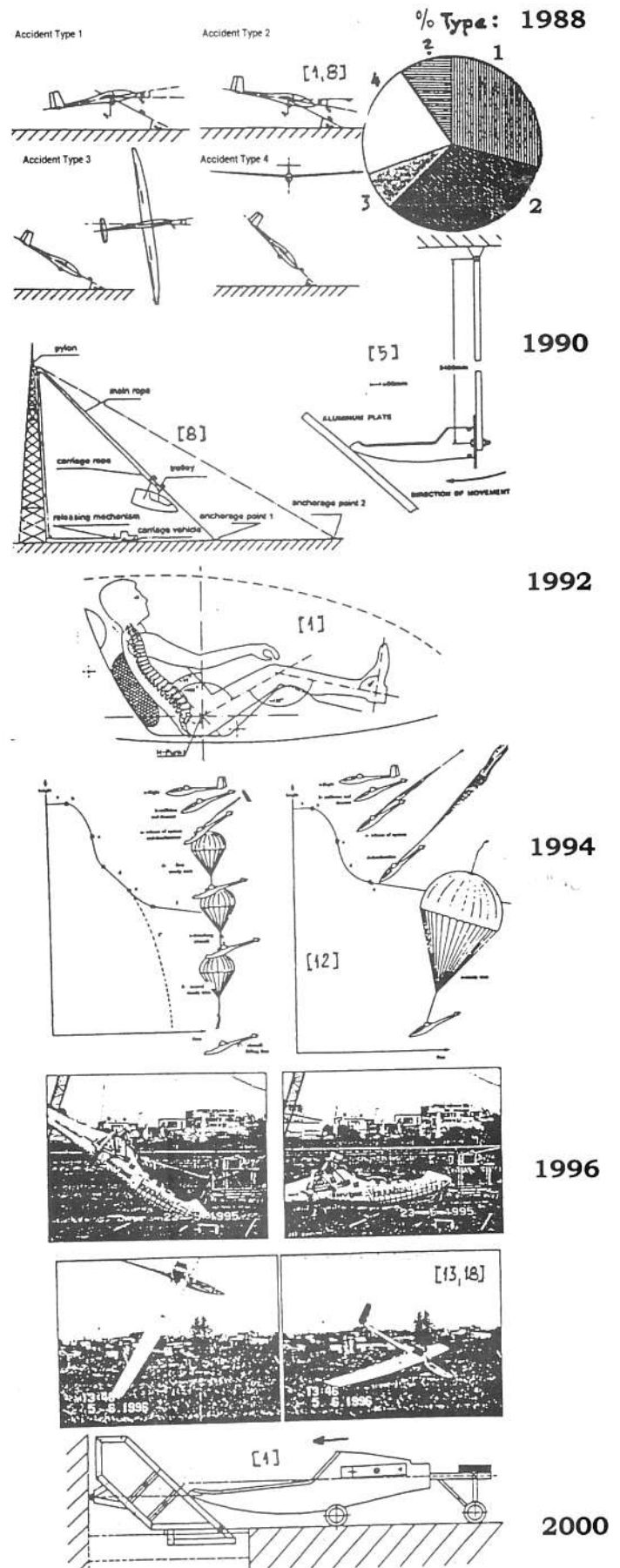
1996 OSTIV SDP meeting Helsinki-Am. 4 to OSTIVAS issued (embodied to 1997 Edit.) [14] TÜV Rheinland accomplished impact tests [1].

1997, 1998 SDP meetings St. Auban, Elmira finalization of A.M. to appropriate OSTIV AS paragraphs on Crashworthiness. Co-ordination of SDP activities with JAR 22 SG and FAA

1999 OSTIV SDP meeting Bayreuth
The updated OSTIV AS Crashworthiness requirements embodied into Amendment I to 1997 Edition. Continuing research on safety harness, e.a. foams, GPRS in FHA. The first World Championship sailplane equipped with GPRS. [15, 16, 17, 18, 19]

ABBREVIATIONS:

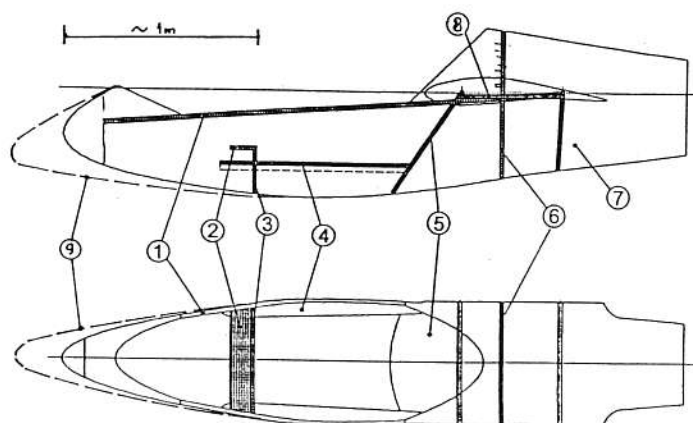
TÜV - Technische Überwachung Verein
GPRS (GRS) - Glider (parachute) Recovery System
PPRS [PRS] - Pilot [parachute] Recovery System
OSTIV-SDP - Sailplane Development Panel of the „Organisation Scientifique et Technique du Vol á Voile"
OSTIV-AS - OSTIV Airworthiness Standards
FHA (Aachen) - Technische Fachhochschule Aachen
LBA - Luftfahrt Bundesamt (Germany)
FAA - Federal Aviation Authority (USA)
A.M. - Advisory Material



SOME INTERESTING DESIGN FEATURES:

Despite that, we have promised to avoid discussion on technical details in this paper, the author nevertheless would like to show some proposed effective design features, to improve crashworthiness. It must be emphasized that the examples shown below are "acceptable, but not the only means" to show compliance with new OSTIV AS requirements. In other words, it depends on the individual designer, how to resolve the problem.

"SOFT NOSE - STRONG CAGE" CONCEPT



- ① reinforced canopy frame
- ② crossbeam
- ③ bulkhead
- ④ reinforced seatpan connecting surface
- ⑤ bulkhead + 1: crosstube
- ⑥ ring bulkhead
- ⑦ bulkhead + 2: crosstube
- ⑧ upper landing gear box
- ⑨ prolonged Energy Absorbing Structure

Fig. 2 Structural reinforcements – "strong cage / soft nose concept [1]. Item 9 added by the author of this essay.

Figure 2, reprinted from [1] with slight modification by the author shows the proposal developed by TUV Rheinland how to ensure the "strong cage" appropriate strength (Items 1-8). Item 9 is the author's proposal and that of some involved colleagues for extending the "Frontal Absorbing Structure" ("soft nose") by, say, 30 centimeters to increase the crush-length. By doing so the decelerations at impact can be reduced and better protection of the extreme parts of legs is given. Prof. L.M.M Boermans from Delft TU and associated researchers have confirmed by calculations, that the resulting drag increase (performance drop) would be almost nil or negligible. Some colleagues have noted that the increase of bending moments from side load components of such a long nose at non-symmetric impact would increase the risk, that the long nose may break away sideways instead of crumpling and absorbing

energy. At this point we have to emphasize, that the above described concept is necessary for both crash scenarios, for the "free" nose-impact and the ground impact of the fuselage torso, descending on the GPRS parachute.

"FLAT - IMPACT" PROBLEM

The flat-impact is the "nightmare" of researchers and designers. Although we are not fully satisfied with the current "crushlength" in frontal fuselage part (see proposal above) we are quite unsatisfied with the one between the pilot's pelvis ("ischial tuberoses" as our flying doctors call these two things on our skeleton) and the lower fuselage shell. In modern glider the pilot practically "sits on the fuselage floor" when the landing gear is retracted. This means, that practically no "Energy Absorbing Structure" exists for the almost vertical impact direction at "zero pitch". This case is practically not probable for the first impact of the sailplane on the ground, because in any case the forward speed vector exists and the resulting deceleration is inclined forwards. But it was shown during the drop tests, and confirmed by crash analysis, that after the first impact the sailplane rebounds rearwards and the second impact follows in the "flat" or almost flat attitude. Figure 3 is a sketch of the trajectory of L13 BLANIK after the "nearly precise" OSTIV AS / JAR 22 "45 degrees Head-On-Impact" (two guys survived with minor spinal problems) [20].

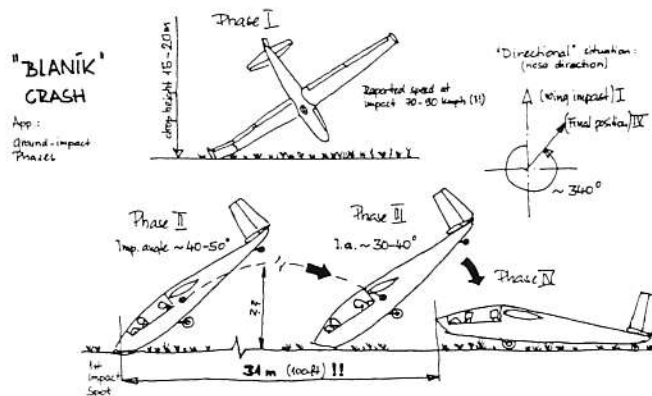
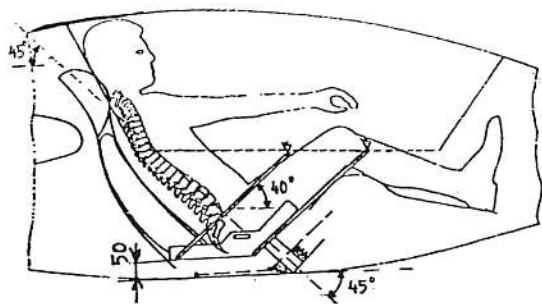


Fig. 3 Blanik crash - post impact trajectory

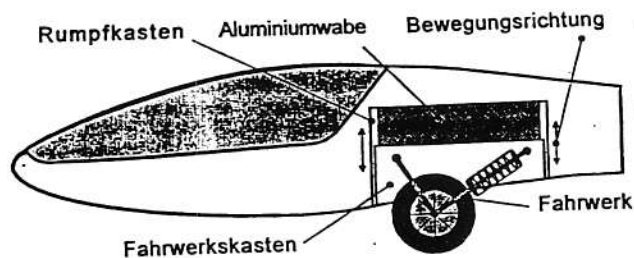
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DESIGN IDEAS FOR IMPROVING THE ENERGY ABSORPTION CAPABILITY

How can we resolve this issue? In this case the requirement to increase the crush-length is not acceptable. This would mean to increase the front area of the fuselage which results in an unacceptable increase of drag and therefore a reduction of performance. But the vertical impact is much less critical, when the landing gear is down! OSTIV increased (not only from the "crashworthiness point of view") the energy absorption capability required for landing gear in the last Amendment to OSTIV AS. The JAR 22 Study Group prepares almost the same for JAR 22.



a) Energy absorbing seatpan arrangement [1]



b) Landing gear attachment in "energy absorbing box" [13]

Fig. 4 Energy absorbing – design proposals

Figure 4 shows some (still rough) ideas on how to improve the energy absorption by a movable seatpan, supported by the energy absorption crushable "damper" [1] and the landing gear attachment in special "box", fixed to the airframe by an energy absorbing honeycomb plate [13]. Both elements should yield after the critical crash loads exceed the limit values.

The extension of the landing gear in an emergency is a matter of "understanding why", "Emergency procedures" sections in Flight Manuals and proper training. It may be automatically operated in case of a good GPRS installation as a part of the GPRS activation.

Seat cushions and headrests made of the energy absorbing foams are an additional means, that help to protect the spine. Frankly said, the limited thickness of seat cushions in modern gliders can only absorb a very limited amount of energy. But in case of refitting older model sailplanes or preparing additional seat cushions for small pilots a significant improvement may be reached, using the proper material! Such an attempt is shown in Figure 5.

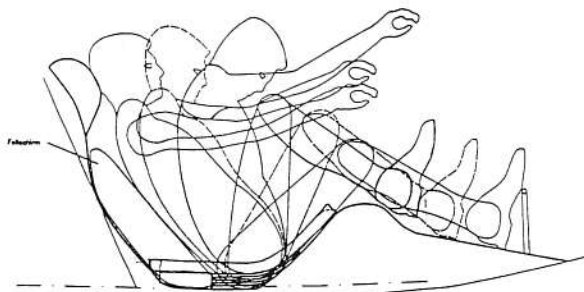


Fig. 5 Movement of the occupant by accident type 4 with the deformation of the front of the cockpit [1]. Schematic sketch of the additional seat cushion (energy absorption layers) added by the author of this essay.

This figure, published in [1] at first shows the sequence of motion of the pilots body in a 45 degree impact. One can see, how important the installed system of safety harness is and how important the proper tightening of the belts must be (see [19] too!). Second, the author "misused" this dimensionally correct sketch for drawing his scheme of layers for an additional front seat cushion for the smaller pilot of a DUO -DISCUS. The lower thin layers are from the most energy absorbing material, the thicker upper one from the material being a compromise between energy absorption capability and seating comfort. The cushion is now in practical operation and passes its "endurance tests."

CONCLUSION- WHAT PRICE FOR SAFETY ?

The modern technology, design features and requirements for higher performance of modern gliders have brought some problems in providing the occupants with adequate passive safety. Fig.6 presents the diagram of the kinetic energy (the half of the product of mass and squared

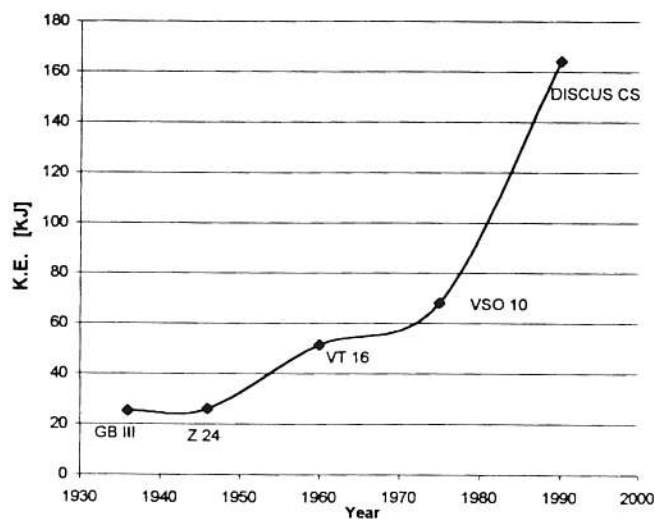


Fig. 6 Kinetic Energy at Stall Speed

stall speed) at stall speed of different single-seater sailplanes, typical for the second half of the century. In opposition to the features of modern cars, where probably nobody would buy his new car without a proven restraint system and airbags, that successfully passed the dynamic barrier tests, the sailplane manufacturers complain about the lack of similar interest among their customers. The author feels, that the matter cannot be better expressed than by using the desperate words of our friend, "big crash-worthiness promoter" and ASWs "father" Gerhard Waibel: "My customer will gladly pay me ten thousand Marks for my promise to increase the glide ratio by one point, but he does not want to pay a Pfennig extra for a more crash-worthy cockpit!"

As we have noticed in previous sections, these opinions start to change.

There is a significant difference between motorcar and sailplane business. Almost anybody would agree, that a Formula One racing car driven by the amateur driver shouldn't be allowed for the operation in normal highway

traffic. The majority of sailplane industry clients are the competition pilots and they insist on performance in first place. But the same gliders are sold to and operated by amateurs, in many cases beginners or moderately experienced people. The last (very useful!) discussion among OSTIV SDP, JAR 22 Study Group and industry on the demands of increasing the limit of the Stall Speed started at Bayreuth and continues by correspondence. It has demonstrated, that also FAI and IGC could help to resolve similar problems, when they establish appropriate "sportive" limitations. In the latter case it would be the specific wing load limit somewhere around 50 kg/m².

Resulting final advise: Potential new sailplane buyers / users! Do not hesitate to pay some extra money for additional safety features! It is the better investment than to spend them for the medical treatment and - in worse case - whole-life after-effects! What has happened to many other people before, may also happen to you!

ACKNOWLEDGEMENTS

Last, but not least: the author, as the last Chairman of the SDP Crashworthiness Subcommittee, that had completed it's current task by issuing the new OSTIV AS edition, would express his thanks for excellent co-operation with many people, who had contributed to our subject. It is not possible to present names without the risk of forgetting somebody, which would be an inexcusable faux pas! However allow me two exceptions: The first is my predecessor Alan C. Patching from the Gliding Federation of Australia who had started the job, and the second is the late Oran W. Nicks, American scientist and gliding enthusiast, who lost his life in an off-field landing. This is a real tragedy as he promoted and summarized the requirements for future GPRS. It is also my duty to remember another late friend, Bill Scull, the former OSTIV Safety and Training Panel Chairman. Although directly not involved in design problems he immensely contributed to our work by providing the operational data and experience.

At the very end of the paper I want to thank Gerhard Waibel for careful reading and removing most of my czechish from the text!

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