Sailplane Design and Record Flights

Jean-Marie Clément
JMC Consulting Group
Via delle Forze Armate 26, Milano 20147 Italy
vv1000@fastwebnet.it

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Abstract

On 23 November 2003, the author flew the first declared out-and-return flight of 2.000 km in the history of motorless aviation. He reflects here on the design of sailplanes for gliding record flights. He describes equipment for this purpose to improve safety and comfort during high altitude and long flights above hostile terrain.

Introduction

The gliding records are of three types: altitude, speed, distance (and, once, duration). The altitude records shall not be considered in this paper. They are totally without interest for the whole population of glider pilots; they do not represent the skill of the pilot and airspace limitation make attempts impossible in most parts of the planet. Therefore, I will focus on speed and distance records.

Speed records

The speed records are the favorite of most pilots since they look like the FAI competitions, using known techniques without great risk and flying above known terrain. The speed is the ratio between the actual distance flown and the total flying time. Therefore, the less you stop the faster you go. In simple terms, reducing the flying time can be achieved by any of these actions:

- Improving the L/D at high speed, so you do not need stopping for climbing. This can be done by manufacturers only working on aerodynamics and higher wing loading (trivial…).
- Improve the flying technique, especially with strong head wind (not trivial). Few pilots know about the speed to fly with strong wind, and no flight computer will tell them the right speed to fly. Figure 1 shows the change of the speed for best L/D for the Discus (at 50 kg/m^2) versus the head wind component. Few pilots know that their lovely ship flying with a 80 km/h headwind (very common in wave flight) has a best L/D of only 18 at ... 165 km/h! A very fast hang glider! The manufacturers of computers should incorporate this aspect in their software.
- The higher you fly the faster you go, but the velocity to never exceed (Vne) is the last limit, and theoretically decreases approximately 5% every 1,000 m. But, depending on the dynamic behavior of the structure, this decrease does not start from the same point for all gliders, some of them show an "altitude bonus" (Fig. 2): 0 for 1st generation fiberglass ships (ASW19, 20, etc..), 3,000 m for the Ventus 2, Duo Discus and Nimbus 4D, 4,000 m for the Discus 2 and 6,000 m for the Ventus 1. The pilot should carefully read the flight manual and make full use of this advantage, when it exists! The manufacturers should improve this bonus, rather than improving the Vne itself at sea level.
- Often, the pilot cannot maintain the Vne because of turbulence because of the velocity-rough-air (Vra) limitation. Surprisingly, for our Discus, that speed (206 km/h) is identical to the Vne at 8,000 m (Fig. 3). This speed makes the pilot uncomfortable in gusty air (common at high altitude), but how many of us know that? By chance, the manufacturer has included another safety factor, unknown to the pilot!
- Reducing the drag also improves the L/D at high speed. Balancing the glider for having the minimum drag from the stabilizer is also important during a 15 hour flight. The manufacturer should specify in the flight manual the position of the Center of Gravity corresponding to that position for a given flying weight. Since this is usually not specified, a phone call is necessary!
- Flying fast does not mean that you need to fly the best and most expensive glider. Large and expensive giant ships like the ETA appear to be of no interest. Figure 4 shows the distribution of the speed versus the elapsed time during an out and return 500 km speed record at 250 km/h using a Nimbus 4DM at 47 kg/m^2 made in wave in Patagonia in 2003[1]. It can be seen that the pilot stayed less than 2 minutes below 150 km/h and that the highest speed is flown during the longest time. This flight was made without stopping, only slowing down for climbing when necessary. More than 50% of the time has been spent above 240 km/h. Figure 5 (drawn using polars from the flight manuals) shows that the 10 points L/D advantage of the ETA respect to the Nimbus 4D and the ASH26 totally disappear above 130 km/h and is, therefore, of no use for this type of flight, even though you would pay one million US dollars more for the ETA! Also, the difference between the Nimbus 4D and the old Discus 1 (all at max.

[1] IGC file can be downloaded from the web site www.topfly.aero

wing loading) is only 4 points L/D above 160 km/h, at an additional cost of 200.000 US dollars! A lot of money per point! Is it really worth? Yes if you consider that two pilots are in the cockpit, essentially from a safety and human efficiency point of view. Record flights at high altitude near the Vne is extreme flying, two more eyes and one more mind is always good.

Distance records

They are a sophisticated combination of speed and duration, where the high speed can usually not be maintained during the whole flight because of changing meteorological conditions, ranging from "just survival" (Fig. 6) to "extremely strong"[2]. The distribution of speed versus time is totally different from the previous example (see footnote 1). Figure 7 shows this curve for the first ever out and return of 2,000 km, that I flew on November 23rd, 2003[3]. It can be seen that 50% of the time has been spent below 150 km/h because the weather conditions during the return leg were very weak, precisely 5 hours 46 min below 140 km/h (which was the task average), and that the distribution is pseudo Gaussian. In this case, the ETA would have given the pilot a small advantage. Generally speaking, on very long distance flights one should optimize the glider for getting the best L/D in the range 140-160 km/h, for which the expensive ETA is again of no interest. You need to fly in Europe under weak conditions to take advantage of the speed range 100-130 km/h.

How can we cope with the two requirements "fly fast when it's good" and "fly slowly when it's poor"? Some thoughts:

- Design a variable geometry wing for getting the best under these two extreme situations.
- Use a variable wing loading. However, dumping the water ballast after many hours at temperatures in the range of minus 30°C is not possible because of the gelatinous (viscous) aspect of the mixture of water and glycol. And even if you fly with 50% antifreeze and dump it, the penalty will be too high during headwind legs (if any), so this maneuver can be done only during the last downwind leg.
- Every improvement of the flying speed is good for the distance but the pilot has to keep in mind that when things start to go wrong, everything will be harder and the whole flight can be jeopardized.

But, remember that distance = speed x time. So, increasing the flying time is by far the fastest payback factor!

The FAI Sporting code authorizes night flight. This means that the glider must be Night-VFR certified (navigation lights, instruments lighting, strobe, map reading light). In Europe, only motorized gliders can be Night-VFR certified because of Civil Aviation Rules. The pilot has to hold a Night-VFR rating, i.e. has to hold a power plane license since TMG and glider pilot licenses do not mention any Night-VFR rating.

However, because of the present limitations of availability of energy in the gliders, the high cost and the limited availability of night vision equipment (3rd generation with several km visibility), the low reliability of the glider moving map navigation systems based on the PDA platform and Windows CE, the impossibility to make any outlanding by night, the extremely high risk to make an engine start by night, *there is no question about traveling by night*. Only “parking” flight is feasible.

The characteristics of a “parking’ flight are as follows. At low altitude in order to avoid internal condensation of the canopy. At low altitude in order to reduce the need for heating the pilots. Always in sight of an illuminated runway. Far below the clouds in order to avoid the risk of leading edge icing and IMC flight (clouds cannot be seen by night!). *As a consequence, increasing the flying time means a new form of duration record!*

Duration records

The duration records were cancelled by the FAI in 1954. The final duration world records were: single seater, 35h03 Marcelle CHOISNET and 56h15 Charles ATGER in 1952; two seater: 38h45 Jacqueline MATHE and Marinette GARBARINO, 57h10 Bertrand DAUVIN and Henri COUSTON, 1954. It is interesting to observe that the flying time in single-seater and two-seater was the same. The duration was mainly limited by meteorological conditions.

The gliders were specially prepared and pilots were specifically trained for this type of flight in a "National Center" in Saint Rémy de Provence, that was dedicated to that kind of flight and sponsored by the government in the post-war period, with appointed personal, runway and ridge illumination. Nothing like this can be repeated today.

Conclusions: since pilots were able to fly over 56 hours in both single-seater and two-seaters 50 years ago, there is no doubt that such performances can be significantly improved and converted into distances in excess of 4.000 km.

Problems to solve

But we need to solve the following problems to enable significant distance (duration) flights.

Maintain pilot's efficiency

Sleeping is possible in a two-seater. Micro-sleeps (15 seconds) every 15 minutes can keep the pilot efficient for at least 2 days. Mini-sleeps of 15 minutes every 4 hours can keep the pilot efficient for several weeks. The manufacturers will have to improve the seating ergonomics to allow for sleeping and living during at least two days and one night!

Solve basic physiological body requirements

Bring sufficient drinking water: minimum 5 litres per pilot per day is simply impossible because of inadequate design of

[2] French 1st Out & Return 1.000 km, August 12, 2002. IGC File available at www.topfly.aero

[3] See Footnote 1

the luggage compartment and freezing. The manufacturers will have to redesign the fuselage (and/or the wings) to allow for storage and insulation of the necessary drinking water.

To urinate regularly and easily, the manufacturers will have to install permanent and safe devices, the present ones are potentially dangerous! (Figs. 8 and 9). Defecation is totally unsolved, and will be a big problem. In the future, astronaut's technology will have to be used.

Pilots have to follow a special low-residue diet days before the flight. To eat sufficiently and regularly during a flight, the manufacturers will have to redesign the fuselage to allow for storage and easy recovery of the necessary food. In 1950, world duration record pilot Guy Marchand was flying without parachute in order to increase the space for the food!

To avoid ankylose, a specific gymnastic must be practiced at regular intervals. To accomplish this task, the manufacturers will have to redesign fuselage in order to allow for movements of the legs and feet in the front seat.

To avoid skin and gluteal pain, use anti bedsore gel cushions and lumbar support belt which are all available on the market. The manufacturers should offer these devices at least as options.

Modern medicines against headache, pain, anti-spasmodic. must be onboard. The manufacturers will have to install as many pockets as possible (my 250.000 $ ship had none! My wife had to make them herself).

Increase the cockpit comfort

Increasing cockpit comfort will increase the pilot's efficiency. Here are important improvements.

Avoid the internal condensation of the canopy. A double canopy skin with neutral gas in the middle was used in 1954 by Dauvin!. Also possible is an acrylic multi-layer with integrated electrical de-icing as currently used in some power planes.

Reduce the cooling of the cabin by adding an insulating layer during the manufacturing of each half front part of the fuselage. Today, the feet of the front seat pilot touch the fibres that are at outside temperatures! (Fig. 10). Paint the nose of the fuselage with a heat retaining colour. White paint is the worse in daylight! Gliders of the 50's were painted black. Completely close the nose hook compartment, or do not install a nose hook. Install a sealing gasket between the canopy and the fuselage. This technology is conventional on power planes, are of low cost and efficient for noise reduction.

Improve the space in the cockpit. Long flights at high altitude mean heavy and thick dressing and reduced living space (Fig. 11).

All these improvements depend only on manufacturers!

Provide for sufficient energy

Distance flights mean duration in excess of 15 hours, with energy requirement for a double GPS navigation system, a frequent use of the radio (flight in controlled airspace), a transponder, electrical heating of the pilot's feet and possible use of gyroscopes when the meteorological situation deteriorates. Ampere requirement starts from 2,6 Amp (31 W) with one heater, up to 12 Amp (144 W) with continuous heating by night. "Gel" electrolyte (e.g. Dryfit) batteries are unusable at temperature below –20°C. Pb+pure Sn give better result with 30% maxi 50% usable capacity. The weight cannot stay in the fuselage, this means that batteries must be located in the wings (new design by manufacturer). Li-Ion batteries are very promising but expensive and delicate. Solar cells are mandatory at present, but they work mainly when you do not need them, i.e. in the middle of the day, when the sun is heating the canopy. Also, they cannot recharge the lead batteries because the temperature is below 0°C. Fuel cells are the solution of the future: 1 litre of methanol gives 1,6 Amp during 50 hours for a weight of only 1,5 kg. However, an altitude-pressure limitation at 3.000 m has yet to be solved. (Fig. 12). *Again, all these improvements depend on the manufacturer*!

Safety

Safety is too often neglected by both the record hunters and also by the FAI, who only requires the survival of the pilot for 24 hours after the flight! It can be significantly improved by using the following means.

One 406 MHz EPIRB (ex ELT) should be embedded in the fuselage in a non-carbon fibre area. Do not use the luggage compartment. There is no need for access by the pilot during the flight; with no cable between ELT and antenna (extremely unsafe).

One personal 406 MHz EPIRB per crew member is recommended. What about bailing out at 6.000 m with 100 km/h wind? The glider's ELT will be of no help since the pilot shall land 40 km away from the wreck! (Fig.13).

One personal life jacket per crew member is recommended. In Patagonia, the lakes are immense and cold, and are often the safest landable area. (Fig. 14).

Communications

Maintaining contact with the crew is of paramount importance, both for the performance and the safety. This can be achieved today with satellite phones. The gliding performance can be improved by getting from the ground crew a continuous meteorological update (Internet and satellite images), Metar and TAF from airports along the route. The safety will also be greatly improved, not only because of the continuous contact with the crew, but also in case of bail out or outlanding.

In a near future, the satellite phone shall transmit satellite images directly onto the screen of the navigation computer, and any other information that can be obtained either via the Internet of from the ground assistance. This can already be done today in populated areas where the GPRS system works well, but these are not the areas where world records can be flown; at least today.

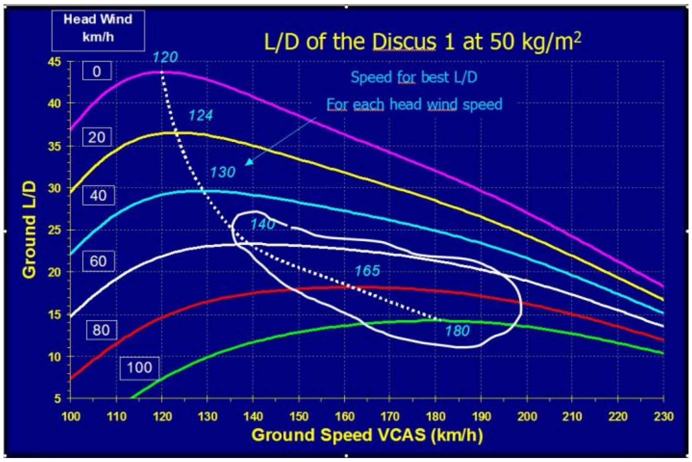

Figure 1 Influence of the headwind component on L/D and related speed with McCready = 0 (just to arrive as high as possible).

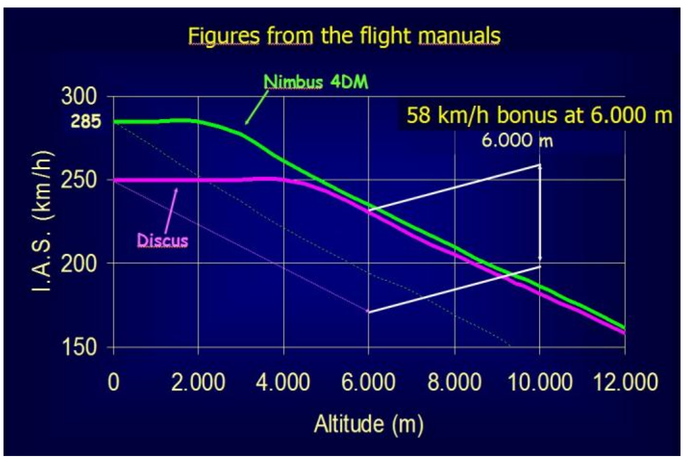

Figure 2 Vne (CAS) vs altitude: the altitude "bonus" depends on the type of glider.

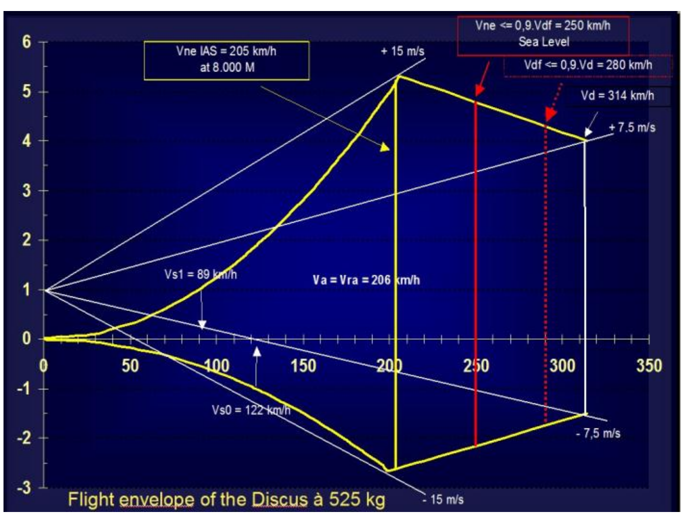

Figure 3 Flight envelope of the Discus at 525 kg.

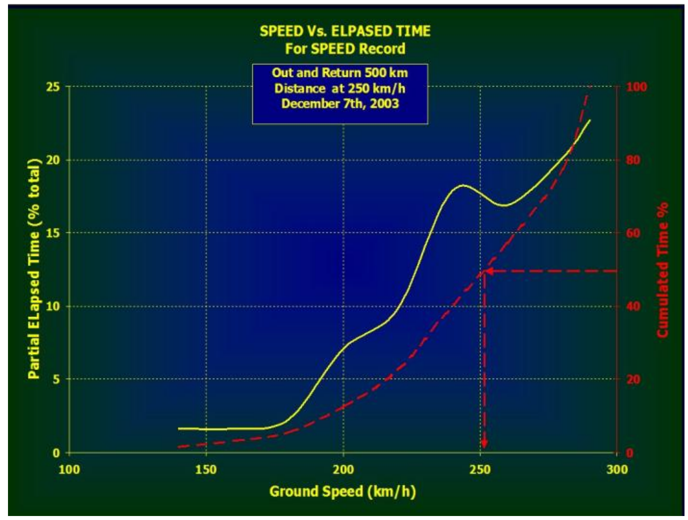

Figure 4 Speed vs elapsed time for a speed record.

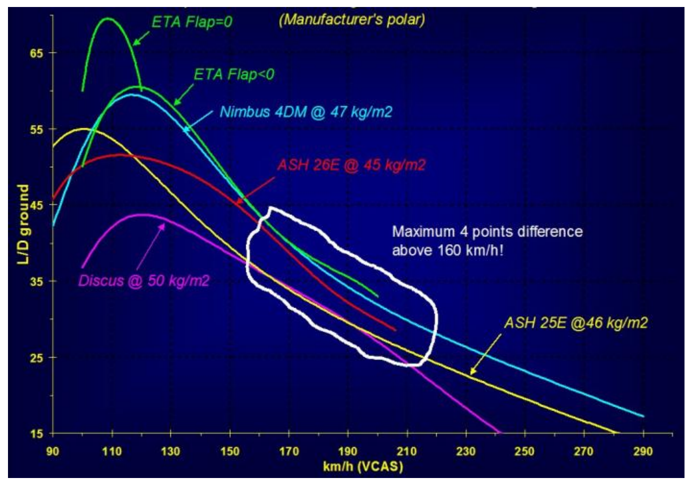

Figure 5 Compared L/D of various gliders at maximum weight.

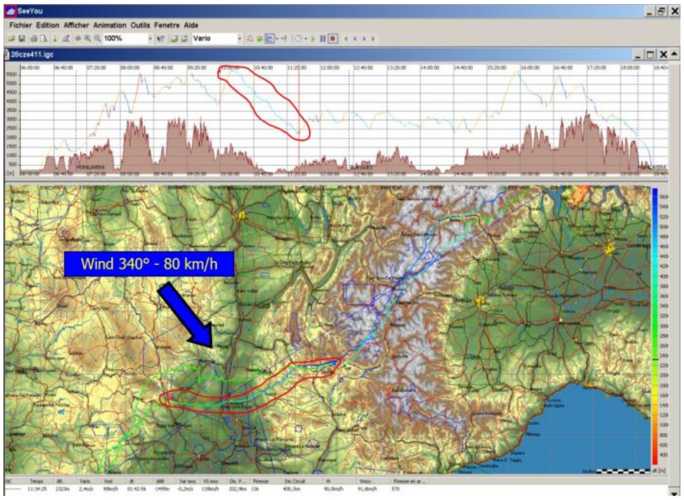

Figure 6 Record distance flight with “a just to survive” period: crossing the Rhone valley, starting at 6,000m and recovering at 2,300 m in the rotor.

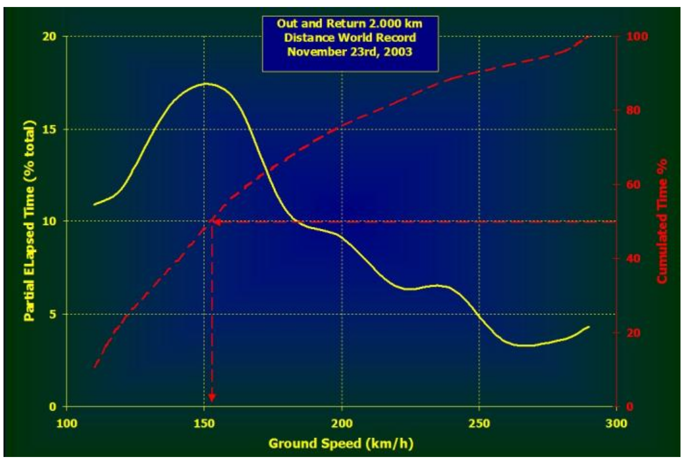

Figure 7 Speed vs elapsed time for the author’s distance record.

Figure 8 This urine bag followed us for 1,800 km!

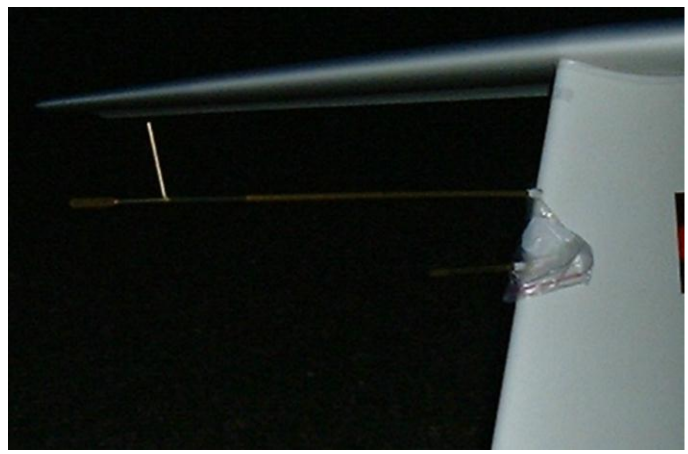

Figure 9 This urine bag could have plugged to pitot probe!

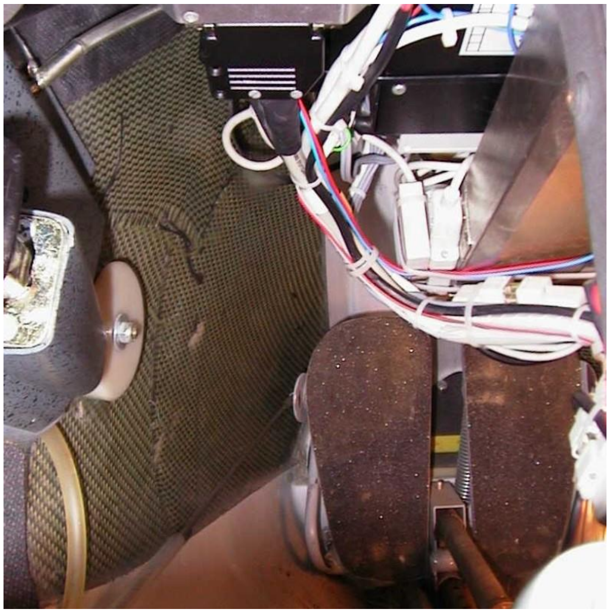

Figure 10 The pilot's feet are directly in contact with the fabric and, therefore, of the outside temperature.

Figure 11 Terry Delore and Steve Fossett (13 Dec 03) taking off for a world record of distance and speed over a 1,500 km triangle.

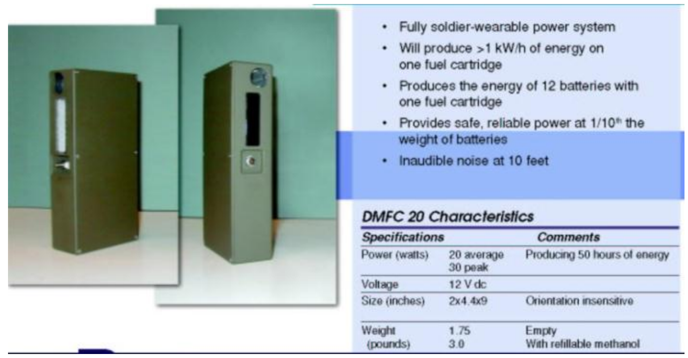

Figure 12 The final solution for tomorrow: 20 Watt (1.6 Amp) during 50 hours for 1.5 kg.

Figure 13 The personal EPIRB 406 MHZ with GPS incorporated should be integrated within the parachute and every pilot trained to use it.

Figure 14 Life jackets: a dedicated space for life jacket should be provided for each seat. Mandatory in power planes. In Patagonia, the lakes are immense and cold and often the only landable area.

Figure 15 What does the ideal record glider look like?