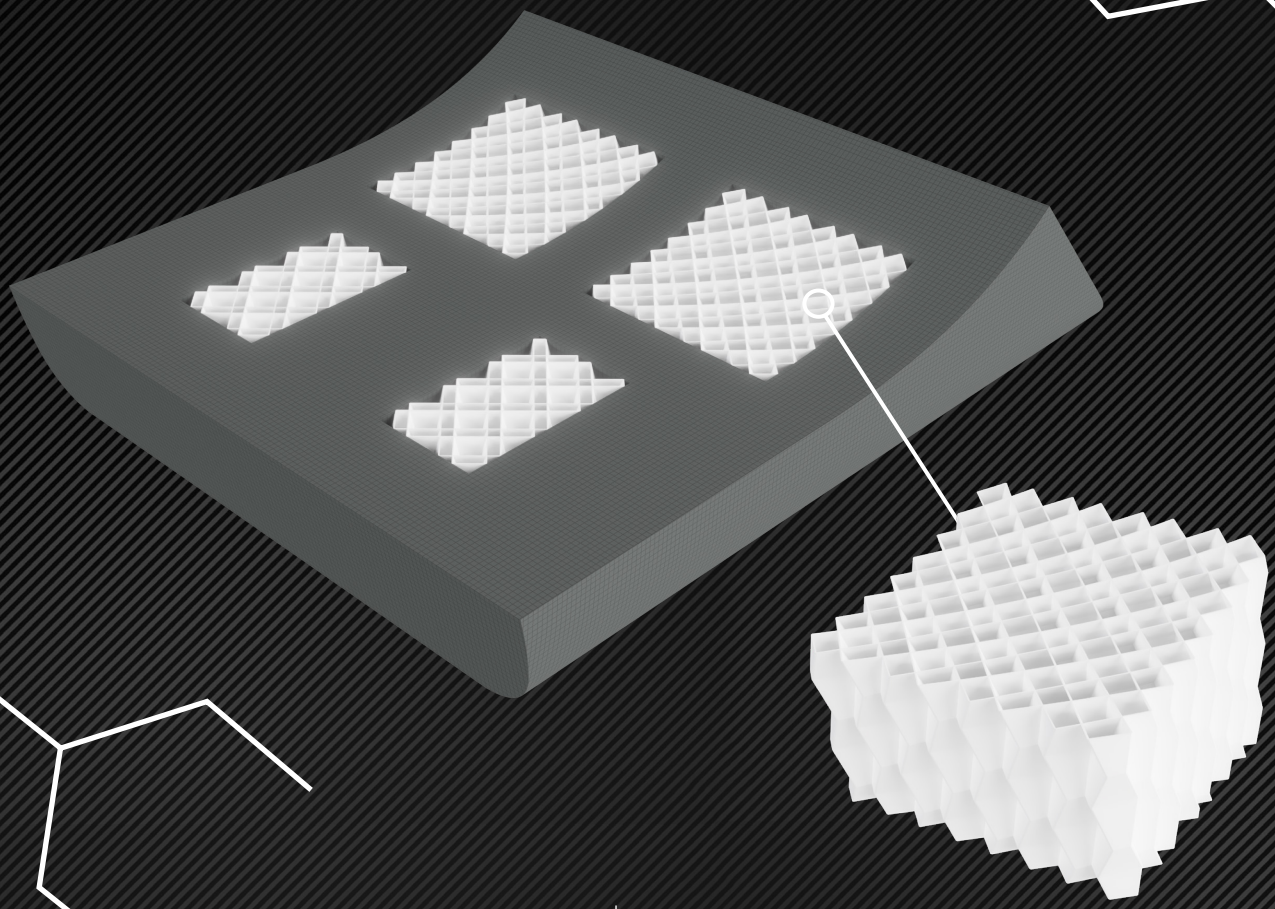
NEW

ORIKAMI

High-efficiency *protector technology*



Unparalleled *safety!*

You will find it in the new **Drifter 2!**

AIVIUK BEYOND THE GLIDE

ORIKAMI

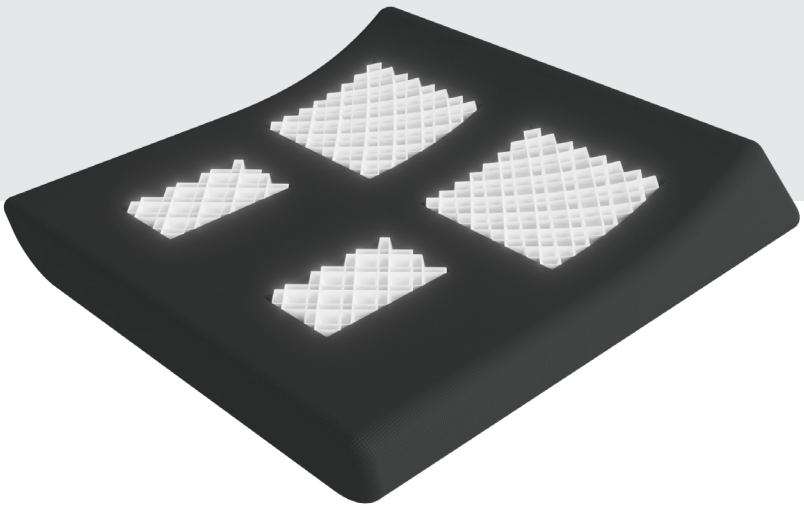
High-efficiency *protector technology*

Orikami is the revolutionary new protector technology developed by Niviuk's R&D team. It has been incorporated into to the back protector of our new Drifter 2 harness, and it is the thinnest and most efficient on the market. At only 5.5 cm thick (for the Drifter 2), it is EN and LTF approved.

Its development and technological inspiration is based on the Japanese art of origami, as its structure folds in on itself to absorb and disperse energy during an impact. After the impact, the protector returns to its original shape. It is certified according to the EN and LTF standards, which means that it can withstand several impacts, without having to replace it.

In contrast to other protectors, the incorporated Orikami does not rotate nor displace from the foam matrix when an oblique or lateral impact occurs. This advantage is achieved thanks to its higher out-of-plane stiffness, which prevents the out-of-plane deformation of the Orikami pieces, always keeping them perfectly located in their slots.

Unparalleled *safety!*



The ultimate paragliding *harness protector technology*

- **Safety throughout a wide speed range**
  Highly effective protector technology that safeguards the pilot from damaging impact exposure in a broad range of flight situations, from low-intensity crashes to high-intensity ones.

- **Absorbs and disperses energy during an impact**
  The energy of the impact is absorbed thanks to the elastic buckling deformation of its structure, rather than by a complete plastic deformation.

- **The rebound after the impact is lower**
  Compared to that of other, similar existing solutions that are already on the market.

- **More than single-use**
  Designed for multiple impacts, by recovering its shape and characteristics after each.

- **Orikami stays securely in place within the foam matrix**
  Resisting rotation even when impacted from off-center directions.

- **EN and LTF certified**

- **Material**
  High-efficiency polymeric matrix.

- **The protection is effective during the whole flight**
  From take off, through flying, to landing.

- **The thinnest**
  Only 5.5 cm, in the Drifter 2. EN1651 & LTF09 certified protector technology that allows the high aerodynamic performance of the harness.

- **Lowers the packing volume**
  Compared to conventional foams.

01 Safety in the *paragliding industry*

OUR PHILOSOPHY

From the beginning, at Niviuk we have invested our resources in innovation and the development of our own technologies that we apply to all our products. Our priority is providing the highest quality, accessibility and offering the best performance with the maximum commitment to safety and comfort.

Our R&D team has developed this protector material with the aim of providing a more efficient solution than the other options already available on the market.

SAFETY STANDARDS IN THE SECTOR

Today, the paragliding industry aims to maximise glide performance while increasing pilots' safety and comfort. The complete paraglider set-up includes both the paraglider (with its canopy, lines and risers) and the harness (with its parachute compartment, protector and other safety features), which is attached to the risers of the paraglider. Therefore, research is applied to both, not only to the paraglider. For this reason, revolutionary high-performance harnesses aimed at paragliding competitions, such as our Drifter 2, are designed to increase the overall glide performance, keeping it easy to use.

New harness designs aim to minimise the aerodynamic drag to allow the maximisation of the glide performance. Therefore, the main aims that drive the current research are the reduction of the drag coefficient and the minimisation of the frontal area. The first one can be achieved by investigating and adapting new aerodynamic shapes, while the second one mainly depends on the thickness of the protector. Consequently, the current objective of the development of innovative protectors for paragliding is to minimise their thickness, while maintaining or even improving the same level of safety for the pilot.

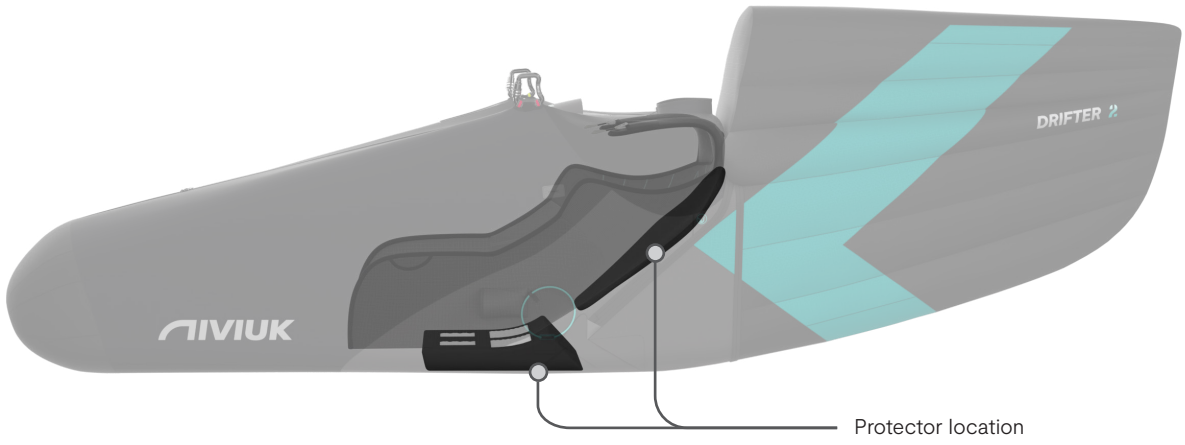


Figure 1: Protector location on a Drifter 2 harness from Niviuk Paragliders.

Traditional paragliding back protectors are always based on the dissipation of the impact energy to effectively safeguard the pilot from being injured. In fact, according to the EN1651:2018+A1:2020 and LTF09 standard (the test scheme is shown in Figure 2), no protector is approved if the maximum peak of impact acceleration recorded during the test is equal to or greater than 50 g. In addition, as defined by EN1651, no impact during the test can be equal to or greater than 38 g for more than 7 milliseconds, nor can any impact be equal to or greater than 20 g for more than 25 milliseconds. The standard also defines the following requirements regarding the methodology of the test:

- ✓ The impact pad must not be dependent on manual activation.

- ✓ Stiff or rigid parts on the impact pad are only allowed if they are not likely to cause injury to the back or neck.

- ✓ The impact pad shall be operated at an ambient temperature between 15oC and 25oC. It shall be at ambient temperature prior to the test.

- ✓ The test shall be carried out with a 50 kg dummy installed in a device to ensure a vertical guided fall. The dummy shall be installed in a rearward position at a specific angle α (illustrated in Figure 2), in the range between 20° to 25°. The dummy shall be constructed with specific dimensions and materials, following EN1651:2018.

- ✓ The harness shall be fitted and anatomically adjusted to fit the test dummy and all components shall be tightened as far as practicable.

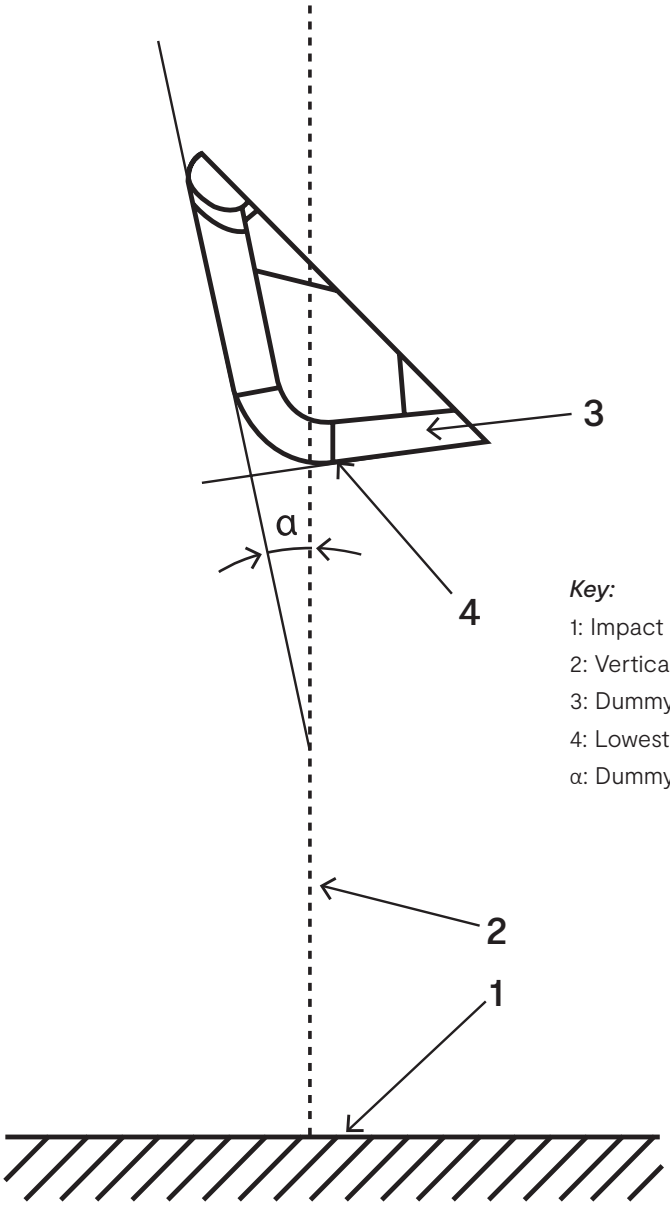
- ✓ The fall height shall be measured from the impact surface to the lowest point of the dummy and shall not be less than 165 cm. (Note that the thickness of the foam under the dummy reduces this distance, causing a reduction of the impact velocity and the impact energy).

- ✓ The test should be performed twice and the maximum peak value of the second test should not differ by more than 20% from the first test. There are some differences between the EN and LTF standards which are explained in Figures 8 and 9.

It is therefore essential that the protector absorbs and dissipates the energy of the impact to effectively safeguard the pilot. The protectors should exhibit low gradient of g/sec during the impact. Orikami is engineered with a pre-folding shape that ensures the elastic buckling deformation of its walls during an impact as the energy absorption mechanism. Therefore, it obtains a lower gradient of acceleration (g/sec) compared to other options.

There are several approaches to back protector systems for paragliding, each of which with its own advantages and disadvantages.

Section 3 of this document summarises the main protector technologies currently in use in the paragliding industry and the differences between them.



Key:
1: Impact surface
2: Vertical drop axis
3: Dummy
4: Lowest point of the Dummy
α: Dummy rearwards leaning angle

Figure 2: Diagram of the impact test standard regulated by EN1651.
Taken from EN1651:2018+A1:2020.

The simplified physics behind energy dissipation, assuming a constant velocity deformation and a constant impact area over the impact time, are explained below.

The idealised behaviour of an impact attenuator is such that it transmits a constant force throughout its deformation before reaching the densification stage, thus maximising the absorption of impact energy, as shown in Figure 3A. Conventional foams, on the other hand, increase their transmitted force during compression because the volume of their internal pores is reduced, initiating the mechanism of material hardening. As a result, a traditional foam has a region where no energy is dissipated, so its efficiency is lower than the idealised behaviour, as shown in Figure 3B.

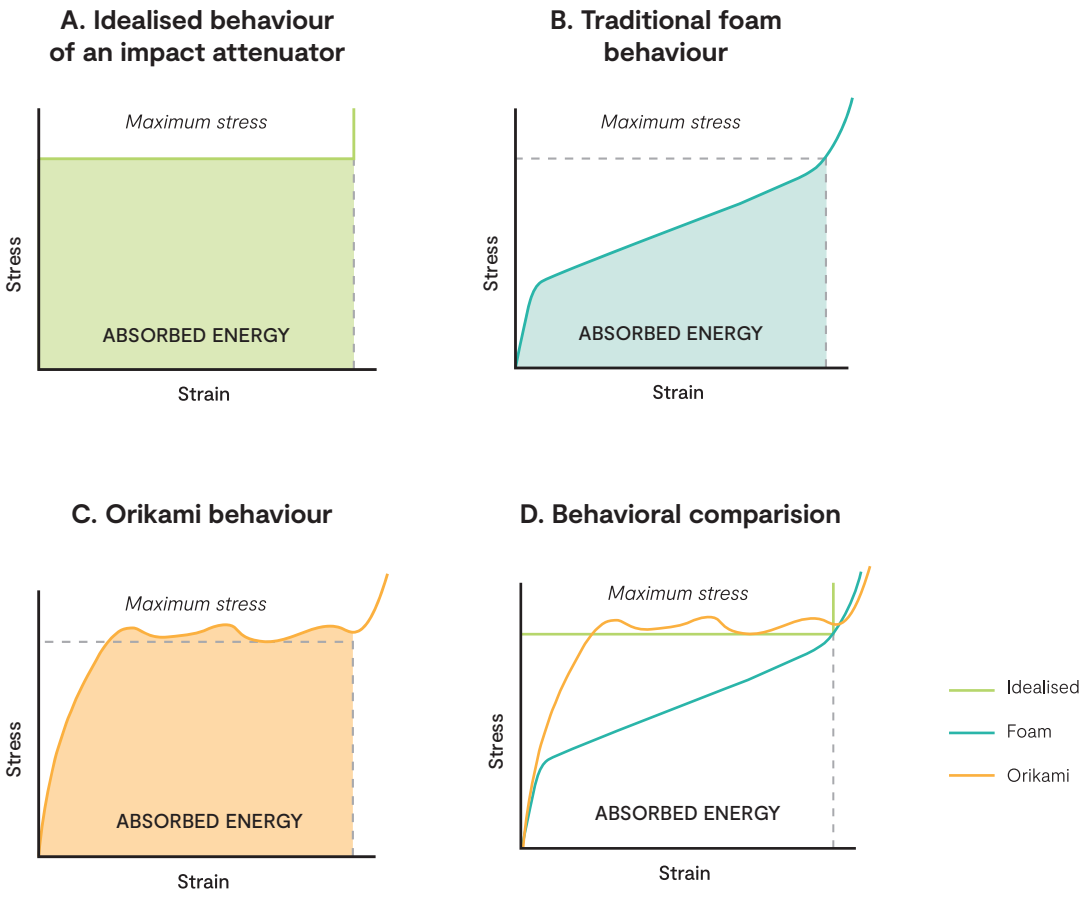


Figure 3: Stress-Strain curves for different impact attenuators.

The well-known energy-absorbing capability of foams is related to the special deformation mechanisms of the cell structure, i.e. cell wall buckling and collapse of the cell. The result of the combination of these capabilities with engineered cellular-architected lattice structures is a metamaterial with outstanding energy-absorbing capacity that provides pilots with innovative cutting-edge impact protection. Orikami is a promising example of this technology. As Figure 3C illustrates, its capacity for energy dissipation is maximised compared to foams for the whole deformation range before reaching the densification stage, thus offering top-level protection performance to the pilot.

Within foam-based protectors, a distinction is drawn between materials for single-impact applications, whereby non-recoverable deformation is allowed, and multi-impact applications, whereby the impact attenuator material must automatically recover to efficiently attenuate multiple successive impacts. For the first ones, its high volumetric energy absorption is achieved via a combination of non-recoverable deformations (i.e. plasticity or fracture[1]). On the other hand, common multi-impact absorbing materials have lower volumetric energy absorption in contrast to single-use impact attenuators because they exclusively utilise non-permanent deformation mechanisms (e.g., viscoelastic dissipation, elastic buckling). Some examples of these materials include expanded polystyrene foam (EPS) rigid polyurethane (PU) as single-impact solutions, and expanded polypropylene foam (EPP), polyurethane (PU) foam and vinyl-nitrile (VN) foam as multi-impact applications[2]. Orikami is aimed at multi-impact applications to ensure extensive and effective protection of the pilot and an extended lifespan of the equipment, thus eliminating the need for the replacement of the protector once utilised.

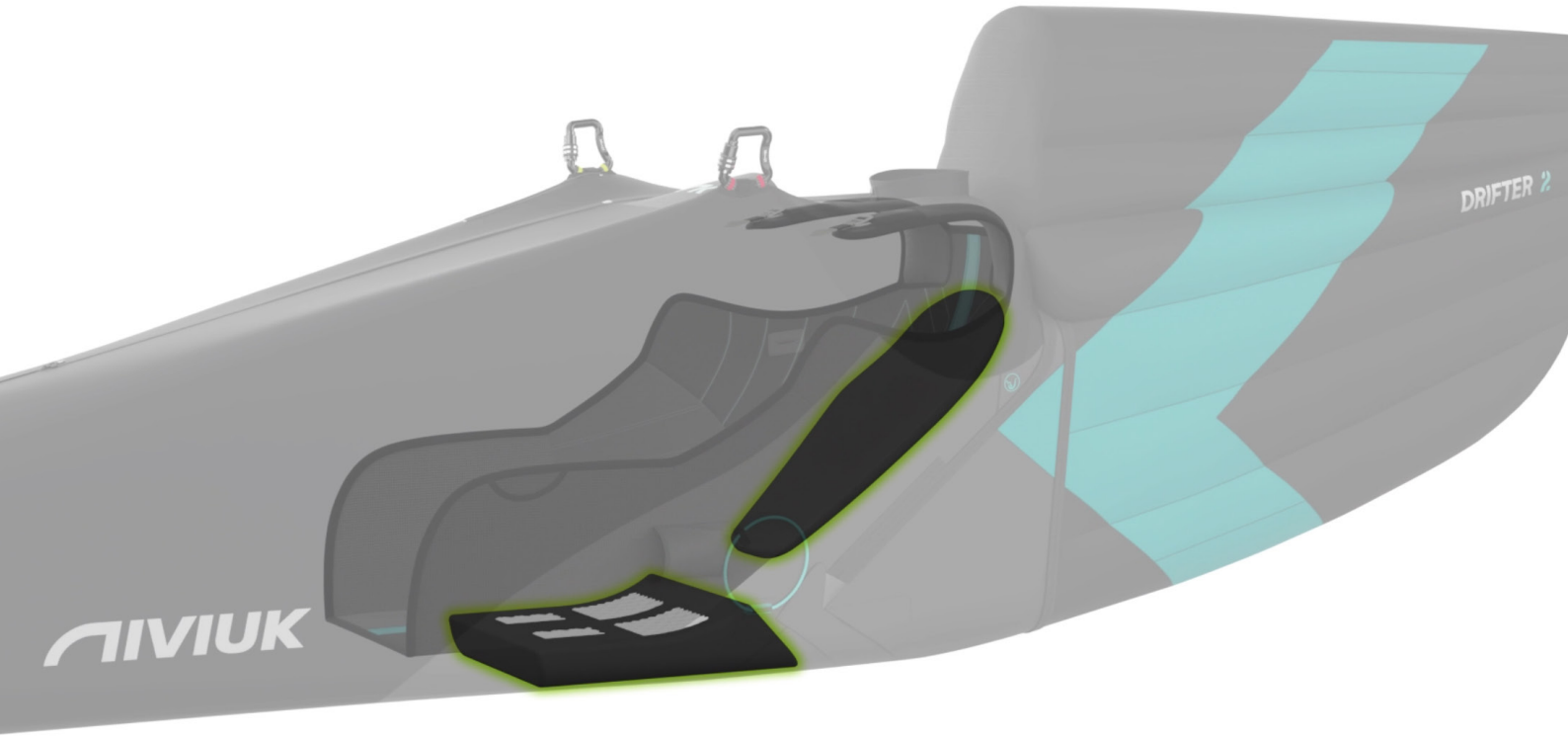


Figure 4: Protector location on a Drifter 2 harness from Niviuk Paragliders.

1. Ashby, M. F., & Gibson, L. J. (1997). Cellular solids: structure and properties. Press Syndicate of the University of Cambridge, Cambridge, UK, 175-231.
2. Clough, E. C., Plaisted, T. A., Eckel, Z. C., Cante, K., Hundley, J. M., & Schaedler, T. A. (2019). Elastomeric microlattice impact attenuators. Matter, 1(6), 1519-1531.

02 Why *ORIKAMI?*

Orikami is a state-of-the-art impact-absorbing metamaterial developed by Niviuk's R&D team for multi-impact energy absorption applications. The protector technology is based on the traditional Japanese art of paper folding. In fact, in Japanese, ***ori*** means 'folding' while ***kami*** is the word for 'paper'. A true engineering folding process, which underlies the art and techniques of origami paper folding, can be applied to the design of sophisticated metamaterials with unique mechanical properties. In this case, Orikami offers outstanding shock absorption capacity in the event of an impact, ranging from low to high-energy impacts.

Orikami's remarkable protective performance is based on the physical phenomenon of elastic buckling that occurs on its walls to absorb impact energy. For this reason, Orikami has been designed using rigorous scientific research methods. A variety of solutions were comprehensively tested and validated before the optimum solution was found. Unlike other cellular lattice energy absorbers already on the market, Orikami is designed to avoid the conventional high-stress peak of the linear elastic region of honeycomb or tubular cellular solutions when compressed. As depicted in Figure 5, similar options experience a high-stress peak when starting the compression. Conversely, the Orikami structure has a pre-defined folding point that is engineered to avoid the high stress peak. As a result, Orikami prevents the pilot from receiving a dangerous instantaneous energy shock at the beginning of the impact.

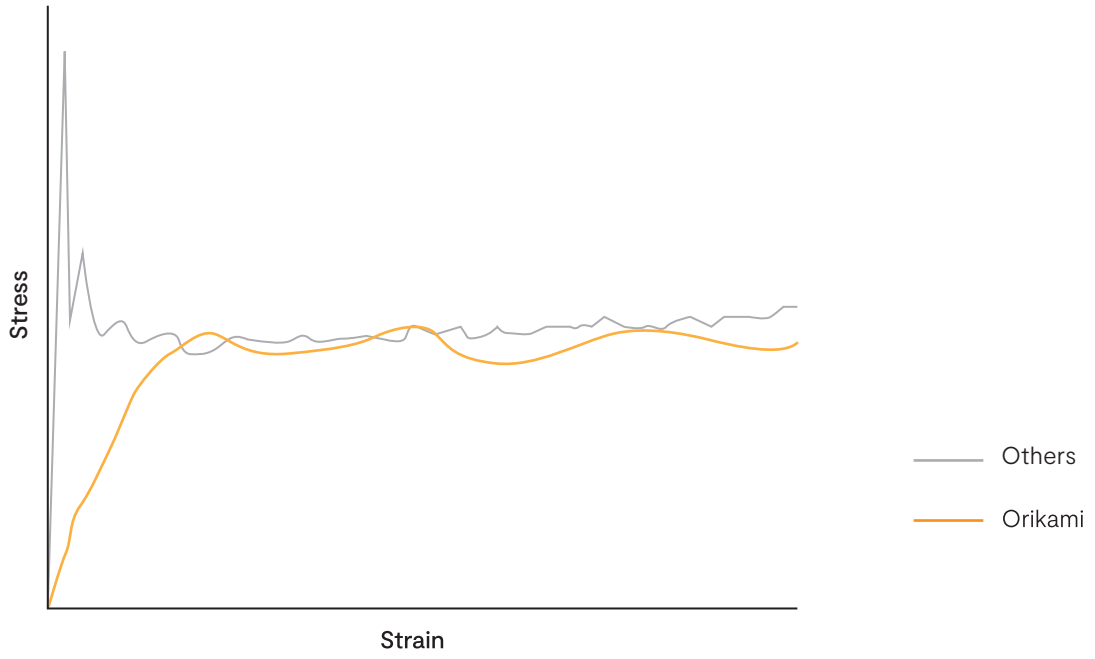


Figure 5: Stress-Strain curve for Orikami under a compressive load.

In addition, Orikami is designed to be a reliable solution for multi-impact applications. This capability is achieved by inducing elastic buckling phenomena on the walls of Orikami as a physical energy dissipation mechanism, preventing permanent deformation of Orikami. Figure 6 shows different frames of a compressive load and unload test performed on a 50x50x40 mm Orikami sample. As it can be seen in Figure 6, Orikami is able to recover its original shape when the compressive load is removed, despite being completely elastically deformed during the compression cycle (only 2 – 4% of the initial thickness is lost during the first compression and less than 2% for the remaining cycles).

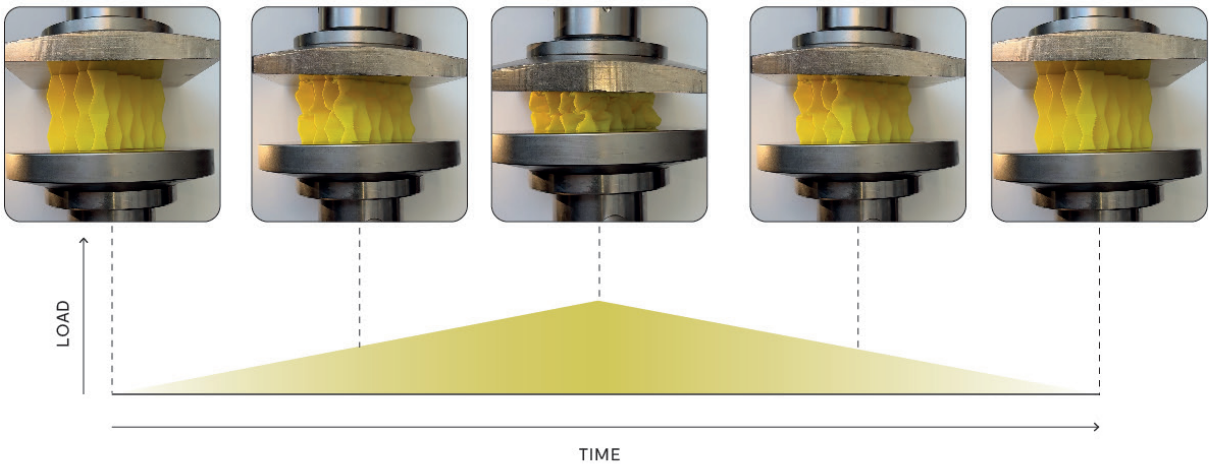


Figure 6: Loading/unloading cycle of an Orikami sample.

Orikami is meticulously moulded to the pilot's body. Combined with a cleverly designed closed cell foam matrix to hold the Orikami pieces in place, Orikami provides its outstanding protection capabilities while maintaining the comfort of a harness that conforms to the pilot's body. What is more, Orikami's out-of-plane stiffness is higher than that of other similar existing options. Therefore, since the out-of-plane deformation is prevented, it is almost impossible to displace the Orikami pieces without breaking the closed foam matrix in which they are placed. Orikami is designed for pilots, engineered for safety and conceived for peace of mind.

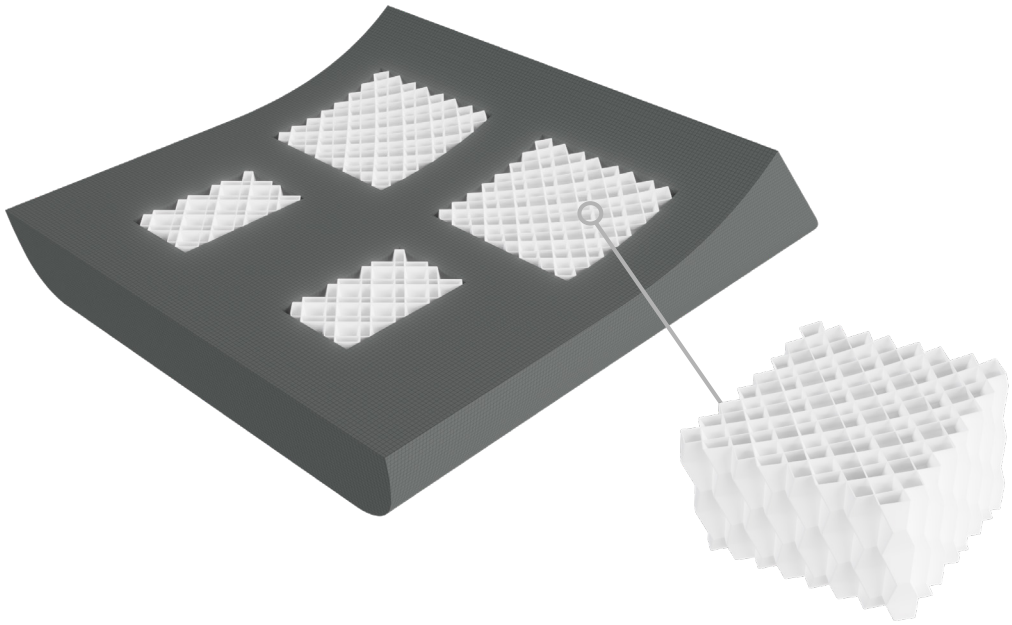


Figure 7: Orikami piece and protector for the Drifter 2 harness.

PROTECTION ENGINEERED FOR PARAGLIDING

An Orikami sample with a thickness of 7 cm is tested following the EN1651 standard test procedure with a 50 kg dummy. The protector technology is tested with a Drifter 2 harness at 40 cm, 80 cm, 100 cm and the EN Standard height of 165 cm at Air Turquoise Laboratory, Villeneuve, Switzerland. Table 1 analyses the peak of maximum impacts (in multiples of Earth's gravity, g) that occur during the test. On top of that, Orikami is more efficient than the competition when dissipating the energy during the drop impact testing: the maximum impact recorded by the dummy after the first impact and the following is lower than others on the market. Moreover, the time in-between rebounds is shorter when using Orikami, which proves that the mechanism of energy transfer between kinetic to potential elastic energy is more efficient than to other, similar existing protective equipment.

In fact, the results of the tests (Table 1) performed at Air Turquoise with a wide range of impact speeds (i.e. a wide range of impact energies), prove that the scientifically engineered Orikami protector technology provides highly efficient protection performance to the pilot in a broad range of flight situations, from low-intensity impacts to high-intensity ones.

Height (cm)	Impact velocity (m/s)	Maximum impact (g)
40	2.7	13.70
80	3.8	20.33
100	4.3	24.20
165	5.6	35.24

Table 1: Maximum peak of impact at different altitudes following EN1651. The test specimen is an Orikami sample with a thickness of 7 cm.

MULTIPLE IMPACTS

Traditionally, protector material for paragliding has been certified under the EN1651 and LTF 09 standards. In order for the equipment to be successfully certified, it must undergo a series of impact tests. Figure 8 and 9 explain the different tests carried out during the certification process: the equipment is tested by dropping a 50 kg dummy from a height of 165 cm according to EN1651, once with the parachute attached to the harness and once without. For LTF09 certification, the drop test is repeated twice, both with and without the parachute. The certification allows the use of brand-new protective equipment for each different drop test, as the certification of protective equipment only focuses on the protective behaviour of the material as if it had been designed for a single-impact application. Consequently, it is possible to use four different brand-new samples for the entire certification process to pass EN and LTF certifications.

However, Orikami is tested and certified using a single sample. In other words, the same Orikami piece is used for all impact drop tests, as explained in Figure 9. As a result, Orikami is certified to the EN1651 and LTF 09 standards and its multi-impact applicability has been successfully demonstrated.

In summary, Orikami not only offers outstanding protective behaviour in the event of an impact, but also the capacity of protecting the pilot from several impacts, with an innovative concept that represents cutting-edge technology in the paragliding industry. As proof for the multi-impact applicability of Orikami, the same unique sample is successfully tested and certified following the standardised certification procedure that is established by the EN1651 and LTF 09 regulations. In other words, one Orikami piece can withstand the maximum impacts within the standards' allowable range for a minimum of 6 high-energy drop test impacts.

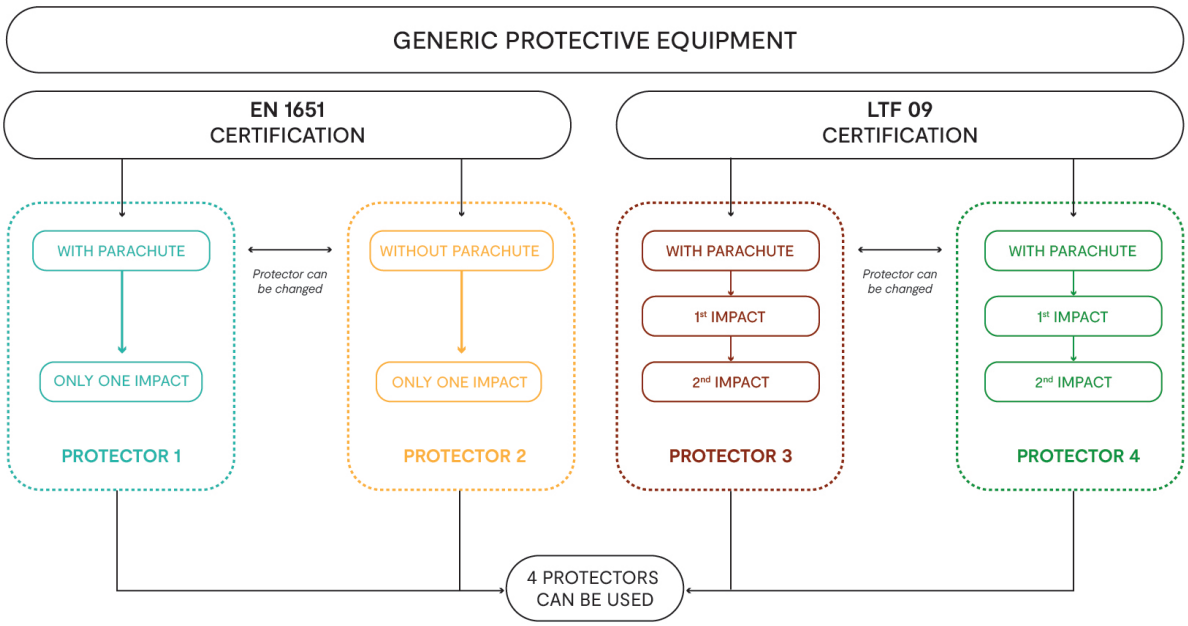


Figure 8: Conventional drop impact testing procedure for the EN1651 and LTF09 standards.

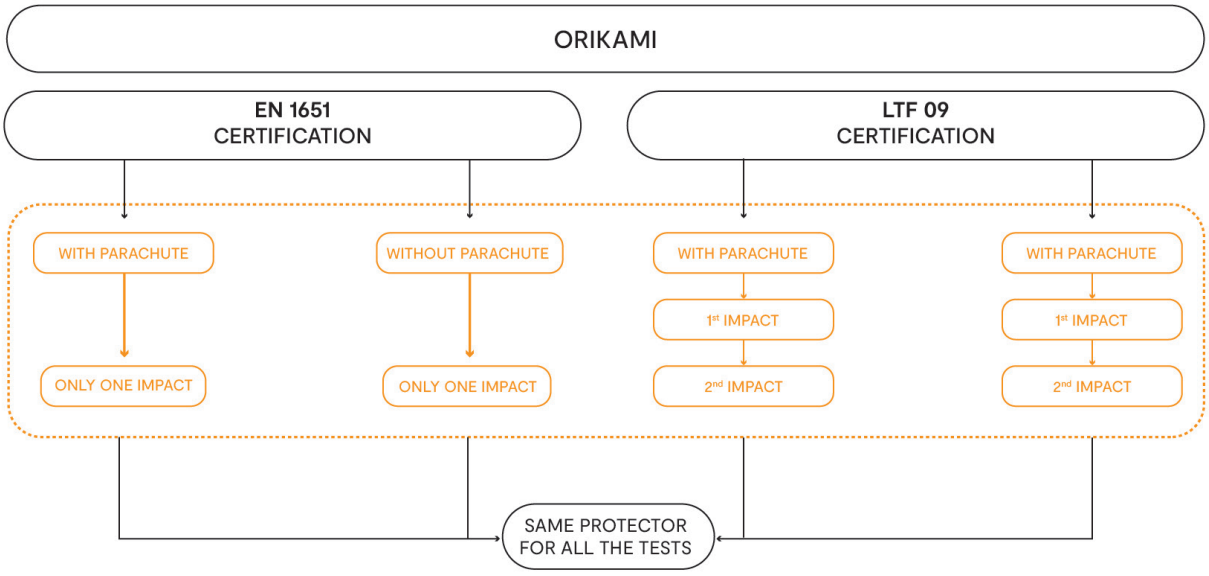


Figure 9: Orikami impact drop testing procedure. A unique Orikami sample is used for all the certification tests.

03
Niviuk impact *attenuation technologies*

The impact attenuation technologies employed in Niviuk's harness range are shown in the accompanying table. Niviuk currently utilises foams, airbags, and inflatable protectors for impact attenuation.

The classification in the table is based on thickness and the maximum peak of impact acceleration [g]. While an airbag protector offers the lowest maximum peak of impact acceleration, it is also the thickest solution.

Pilots who prioritise protective behaviour over thickness may opt for an airbag, whereas those seeking a thin protector for high-performance harnesses traditionally chose foams.

With Orikami, Niviuk now offers the thinnest protector certified in accordance with the EN and LTF standards; providing a similar level of protection as foams but at a mere 5.5 cm thickness. Orikami emerges as the preferred solution for performance-oriented pilots.

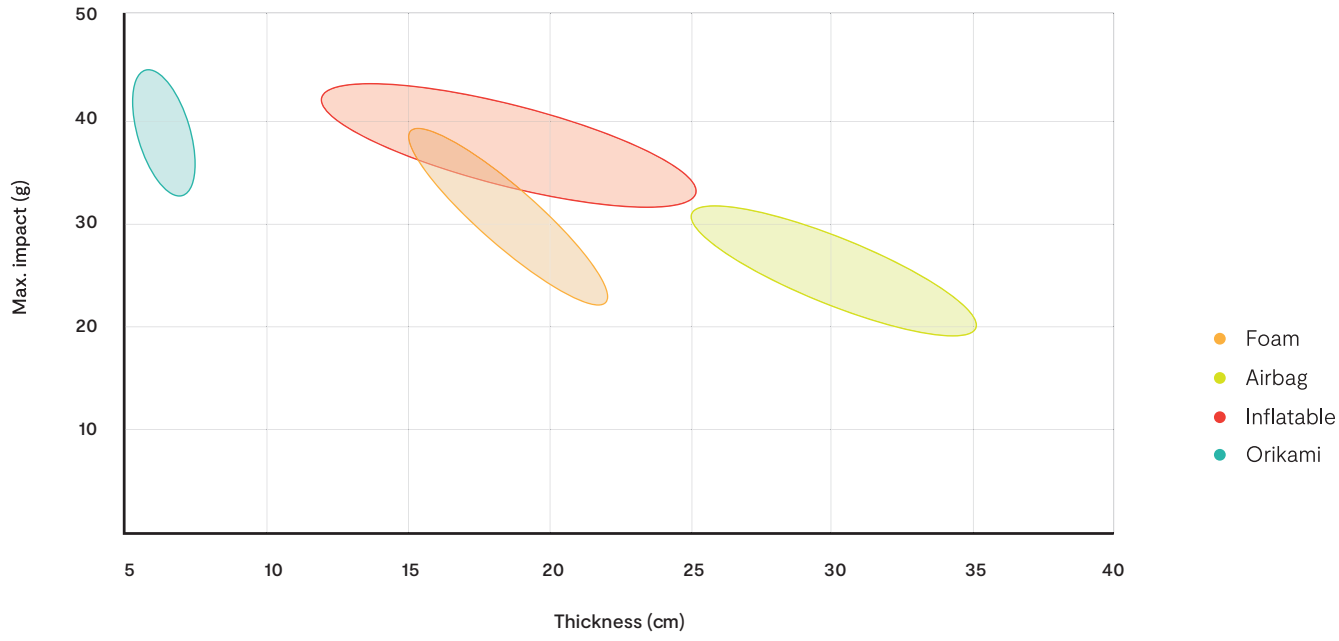


Figure 10: Niviuk impact attenuation technologies.

Orikami has been developed with the aim of offering the market an alternative solution to other existing protector materials, and is specifically designed for high-performance harnesses: more compact, with a high degree of energy absorption for multiple impacts and certified according to the EN and LTF standards.

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