Paperang

The Paperang Paper Airplane System

Designed and published by Edmond Hui PhD

The Paperang Paper Airplane System is shareware, priced $10. Try before you fly! If you enjoy making and flying Paperangs, please register. Registration entitles you to receive the latest 'print enabled' version of this document, full e-mail support, and makes you feel much better. To register, please visit www.paperang.com

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About This Document

Thank you for installing this Adobe Acrobat pdf document, which is designed for on-screen use. It has been downloaded from the Paperang Website, **www.paperang.com**

The latest version of this document is available from the website.

This revision of the document was created 27 January 2001. I have resisted the temptation to overcomplicate it with further instructions, designs, and diagrams; nor have I taken the advantage of new technology which would allow me to include animations and video. This is because I believe that it's important that the document should be as simple as possible to download and use.

I'll be delighted to receive comments on the Paperang. You can e-mail me at the address given on the website; I will do my best to reply, although if response is overwhelming I will post a 'frequently asked questions' section on the website, or improve this document as appropriate.

If you register this document, you will be able to download and access any subsequent version without further payment.

Conditions of use

1. The contract between Edmond Hui ('the publisher') and the purchaser shall be under the jurisdiction of the laws of England.

2. The product provided is an electronic document and the publisher is not responsible for any loss or injury resulting from its misuse or use other than in accordance with the directions or without proper precautions.

3. A paper airplane is a projectile and with all projectiles there is a chance of injury by impact with a person. Never launch the airplane towards another person.

4. A paper airplane must always be launched from a safe and stable position. Do not launch while standing on furniture, ladders, stairways or while leaning out of windows.

6. All paper airplanes should be considered experimental, and thus have an unpredictable flight path. Make sure the flying area is clear of delicate breakables.

6. The instructions require the use of scissors. Children should only build the Paperang under adult supervsion.

Contents

Introduction

This Adobe Acrobat pdf document describes the Paperang, a high performance, easy to make, precision-engineered paper airplane system. The Paperang itself was invented in 1977. Since then, it has been the subject of a book and much media attention, the story of which is described in the next chapter, *A Paperang History*.

I believe that paper airplane design and flight forms a unique part of the world of aviation. It's the cheapest way to make an aircraft, it's probably the most common form of aviation, there are probably more manufacturers of paper airplanes than any other type, it involves the least danger… the list of superlatives go on. The essence of paper aviation is that anyone can be involved, the airplane can be built quickly, the materials are always to hand, and the results give much enjoyment at little risk.

What's interesting is that paper airplanes fly in the same air as the most sophisticated jet aircraft, and obey the same laws of aerodynamics. A well designed and made paper airplane will fly better than one that has been poorly designed.

My contribution is the realisation that folded paper is best thought of as a flexible membrane. Designs which take this property into account, with shapes like hang gliders, have distinct advantages over traditional paper 'darts'. The innovative breakthrough was the discovery of how a strong, near-perfect hang glider shape, complete with airfoil section, swept back wings, and controlled washout, can be produced from a single piece of paper. The design features of the Paperang are discussed in the chapter, *The Best Paper Airplane System in the World*.

Having explained the background to the Paperang, the rest of the document is devoted to fully illustrated instructions on making and flying the Paperang.

Should you have any problems building or flying the Paperang, please send me an E-mail. My E-mail address is available from the website (see URL below).

Edmond Hui, London, 3 September 1998

A Paperang History

1977 The Invention

I had just qualified as a hang glider instructor, and was keen to create some form of flying model which would demonstrate indoors how the real gliders would soon carry my students into the sky outdoors. A paper airplane seemed a natural choice. If I could design and make a paper airplane based on hang gliders, the trainees could each form a really personal understanding of the aerodynamics that their lives would soon depend on, and have alot of fun at the same time.

I discovered how to create a near-perfect hang glider shape, with efficient, tapered spars supporting perfectly straight leading edges; this structure in turn supporting clean, airfoil sectioned wings. I tried to launch it in my small room, but it stalled heavily and hit the floor. There seemed no particular merit in the way it failed to fly. At that moment, a friend came in, saw that the shape was right, and suggested we went to the indoor badminton court to try it. When we launched it there, the effect was electrifying. The natural flying speed of what would later be named the Paperang turned out to be about twice that of ordinary dart shaped paper airplanes.

1984 The Name

My wife Sandra coined the name Paperang, because it looked like a boomerang, and was made of paper.

1987 First Publication

My book Fold it -Fly it was published, closely followed by the American edition, Amazing Paper Planes. It sold well, and Amazing Paper Planes is still in print today. You can buy it at www.amazon.com.

1992 Rediscovery

I telephoned the Independent newspaper in England on a Friday, and hit what must have been a slow news day. I described this ‘revolutionary paper airplane’ over the phone, and faxed instructions on how to make one to the science reporter. A cheer came over the phone– the reaction of the news room when the Paperang flew. They were so impressed, they published a story about it on the front page, October 19 1992- ‘Stealth bomber moves into the realm of

paper darts'. It's probably the only time I'll ever make the front page of a national newspaper.

There followed a full page article in the Daily Mail, and an interview on the BBC world service. Amazingly, my publisher refused to reprint the British edition of Fold it-Fly it, which was by now out of print. The Independent was besieged by requests for instructions on how to make the Paperang, and together we produced a poster with instructions on how to make one variant of the Paperang. The royalties from the sale of that poster almost equaled those of the earlier book.

1998 Flying in Cyberspace

New technology now allows me to create a Paperang website with downloadable pdf files. The Paperang has waited 21 years for the right medium for publication- it has literally come of age. The internet allows me to reach an audience of millions, with a better product than the original book, and at a much lower price to the customer.

The Best Paper Airplane System in the World

Aerodynamic advantages of the Paperang:

- Keeps its design shape through a great speed range– stable in pitch, roll and yaw.
- Accurate and efficient airfoil shape created naturally from its construction.
- Glide ratios of up to 15 achievable.
- Versatile design: variables allow you to experiment with weight, wing area, sweepback, and airfoil section.
- Paperangs can be optimised for speed, glide angle, sink rate, or aerobatics.

I believe the Paperang has the best combination of glide angle, minimum sink rate, stability, and performance whether flown at high or low airspeeds of any paper airplane. Its construction method bars it from most competitions, and its very efficiency makes it unsuited to competition tasks- throw it hard and it will loop! Throw it very hard and it will do double and even triple consecutive loops- this is proof of strong and efficient design, but not useful in competitions for distance and time in the air. But if competitions measured ability to fly in a straight line (a test of accuracy and stability), or glide angle or sink rate during a steady glide (measures of aerodynamic efficiency), then I am confident that the Paperang would be found to be better than any other existing design in the world.

The Paperang is not designed for competition or for record breaking. Competitions and records normally depend on the strength and skill of the human competitor, as well as the ability of the paper airplane to cope with a powerful launch at high speed, followed by a transition into a steady glide. Any competition design is a compromise between performance during the launch, transition and glide phases. Successful competition airplanes are great designs, but may not necessarily be best for day to day flying.

Designing the Paperang

The paperang was designed without compe-

tition compromises. The only assumptions were that a great paper airplane should have these properties:

- It can be built quickly from paper and normal office stationery materials
- Its performance should be measured in terms of gliding efficiency, stability, and reliability; irrespective of pilot skill.
- It must be easy and fun to fly

The major problem in paper airplane design is not aerodynamic efficiency- it's stability. Without stability, efficient aircraft just fly efficiently into the ground. To be stable, an aircraft has to have flying surfaces shaped to return it to a steady glide after it has been disturbed by turbulence. It has to be strong enough to keep that shape during launch and throughout the flight, and over many flights.

Paper is flexible. When folded, it's strong along the direction of the fold, but weak at right angles to the fold. This is a crucial weakness for most paper airplanes, which have a useless V-shaped centre section or 'fuselage'. The center longitudinal fold actually weakens the wings, making them likely to flap when launched and distort during flight. It's impossible for such airplanes to be reliably stable. With higher performance, accurate flying surfaces become much more important and creating a better paper airplane is as much about creating structural strength to support the surfaces as it is about the aerodynamics of those surfaces.

The Paperang solves these problems by borrowing from hang glider design. It's a 'flying wing' and has no fuselage. The swept- back wings are very strong, especially in the centre section.

Flying wings made of flexible surfaces are not new- hang gliders evolved from Rogallo's designs for NASA re-entry vehicles, and Malayan kites have been using the same basic configuration for hundreds of years.

In aerodynamic terms, a flexible membrane can be made into a stable flying wing if it is aproximately delta- shaped, and stiffened by spars along the centreline and leading edges.

This three-sparred support forms the wing surface into a double cone shape, which happens to have the three basic requirements for efficient, stable, flying wings: sweep back, washout, and a curved airfoil section.

My contribution to paper airplane design is to realise that hang glider 'Rogallo' shapes can be achieved easily with a single sheet of paper. It's called the Paperang, and is based on these innovations:

1. A centreline cut. I know of no other paper plane design which has a cut along the centerline starting from the front edge of the paper. This cut makes possible the production of strong, swept back, tapered spars overlapping in the centre.

2. The wing is strengthened by a staple through the centre of the airplane. This locks the spars into position, and grips the flying surface to the spars while allowing minimal movement for trim adjustments. The wing upper surface is attached to the spars naturally at the leading edge fold, and to the centreline by the staple. This arrangement defines an accurate double conical shape, automatically generating an airfoil section, sweepback, and washout.

3. A trailing edge cut to an efficient hang glider-like shape.

The Paperang, the result of these innovations, is therefore not a single, set-in-stone design– it is a paper airplane system. The instructions in this document show the making of a 'self-templating' version which is easy to build, since all the folds are made by lining up existing edges of the paper. This method creates an accurate, repeatable, 'middle of the road' Paperang. But the Paperang innovations allow you to make infinitely variable designs that are optimised for different parts of the performance envelope- a shorter centreline cut (with appropriate adjustments in the other folds) decreases the nose angle, increases stability, reduces flying speed and improves sink rate. Increasing the length of the cut improves glide angle to a certain point, after which the reduced sweepback makes the design unstable. The shape of the trailing edge determines wing area and therefore wing loading

and natural flying speed. The combination of leading edge spar and trailing edge shape determine the flying characteristics of any Paperang. The ability to vary all of these characteristics make it the perfect platform for aerodynamic experiments.

Efficiency

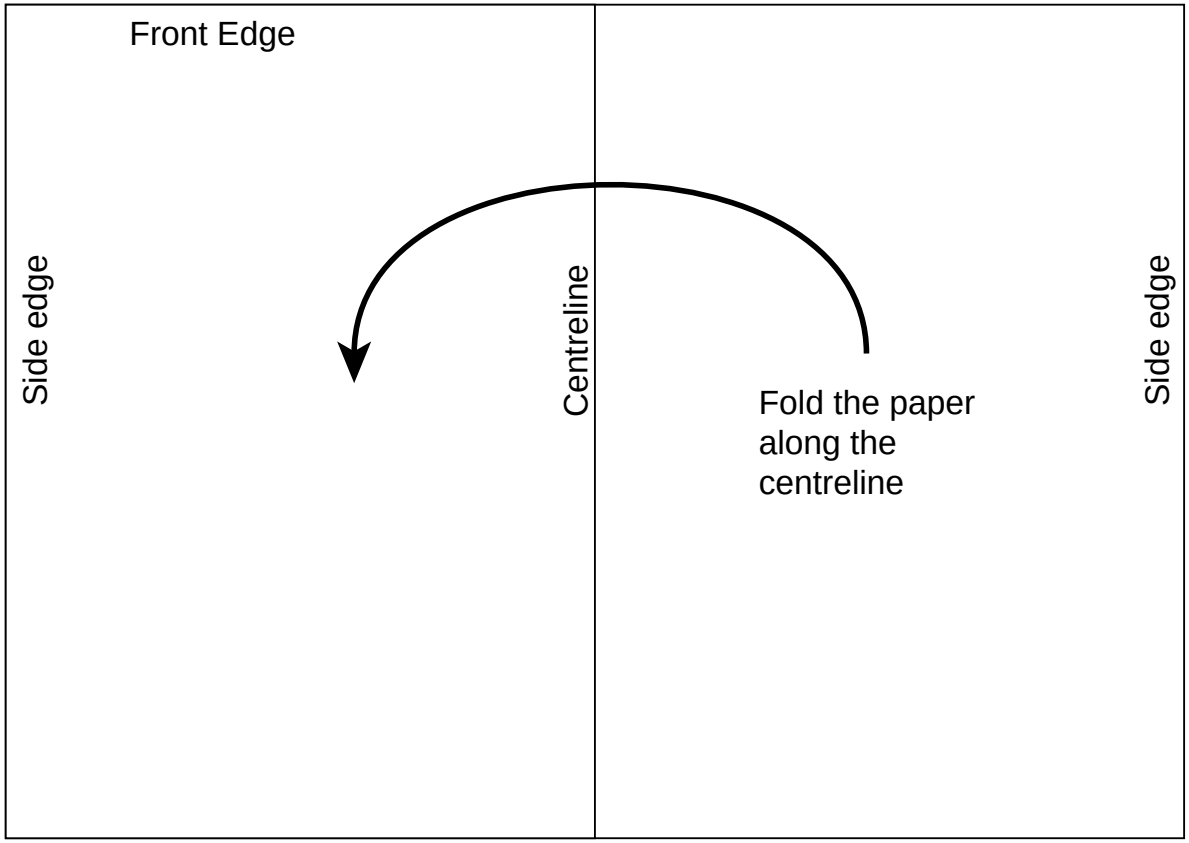
The Paperang achieves its remarkable efficiency both passively (by having no unnecessary drag inducing features such as a fuselage or tail) and actively by having an efficient airfoil section, which is formed naturally by the hang glider shape. Indeed as far as I know, it is the only paper airplane design which has a carefully controlled airfoil section, rather than a ‘flat plate’ section. Wings are more efficient if they have a high ‘aspect ratio’, i.e. are long and thin. The Paperang has the highest aspect ratio wings of any paper aiplane I know, and the underlying strength to hold such wings in an efficient shape.

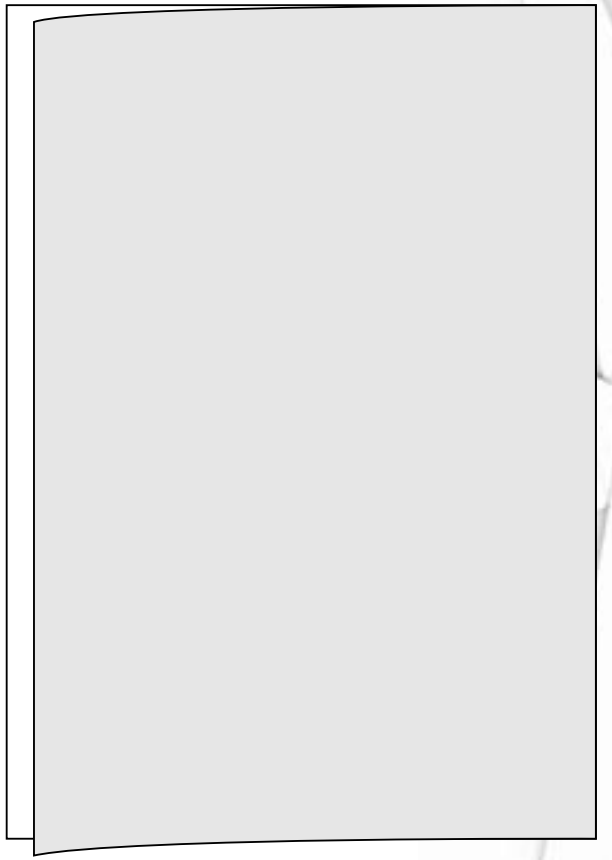
I have measured the glide angle of standard Paperangs at about 10, really well ‘tweaked’ ones at up to 15. This brings it into the same performance envelope as many full-sized aircraft.

Instructions

Step 1

Use light paper: 80g per m^2 or lighter by preference, not more than 100g per m^2. In England, the best paper is sold as ruled writing pads, and is lighter and more resilient than photocopier or laser paper.

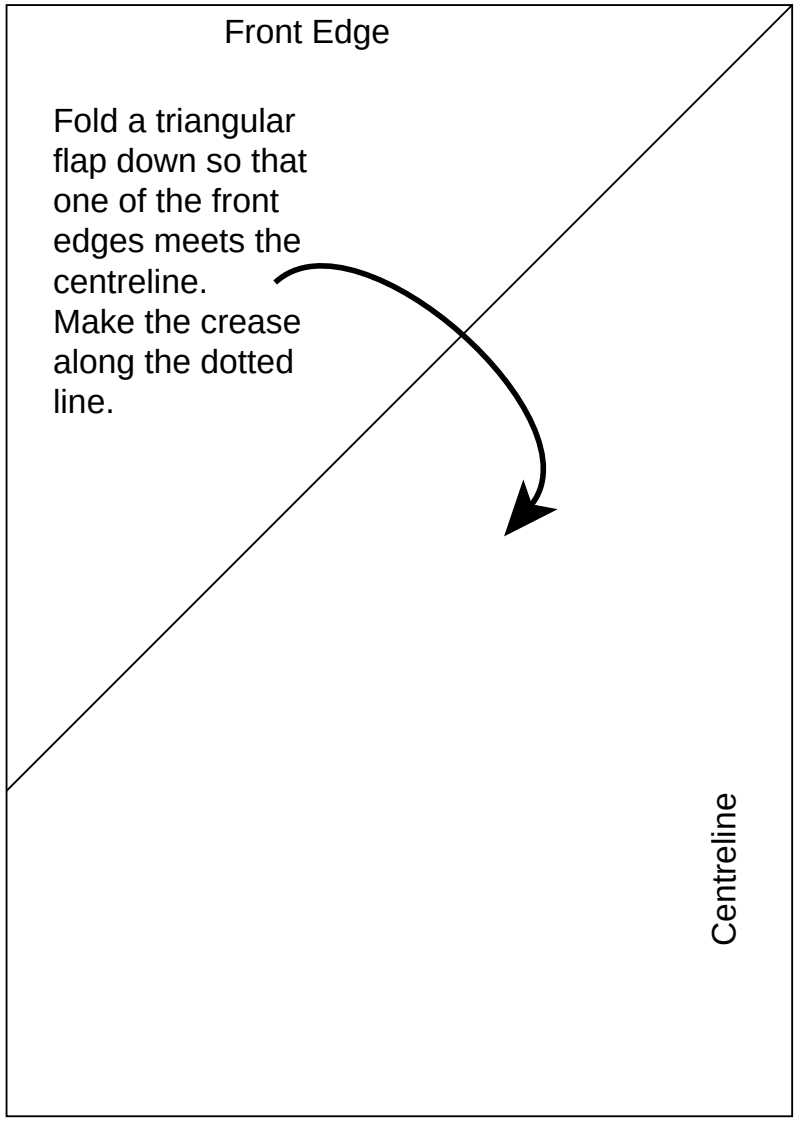


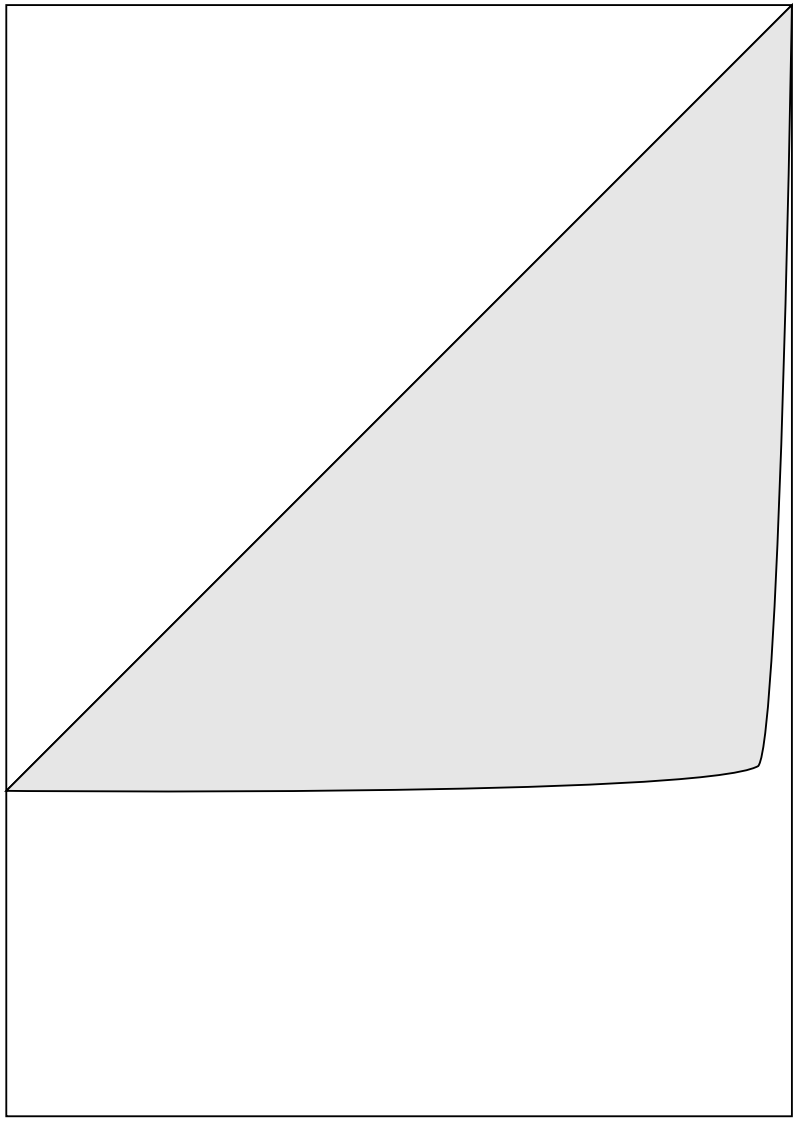


Design Note: *To be efficient, aircraft have to have long, thin 'high aspect ratio' wings. The first step in making the Paperang works towards this by defining the long axis of the paper as the wingspan, unlike ordinary paper 'darts' which have the wingspan along the short axis.*

Step 2

Design Note: *In each of the steps, the first diagram shows the result of the previous step, whilst the second shows the result of the instruction in the current step. The grey feature, if shown, is the part which has moved to a new position, with free edges shown curved if this improves clarity.*





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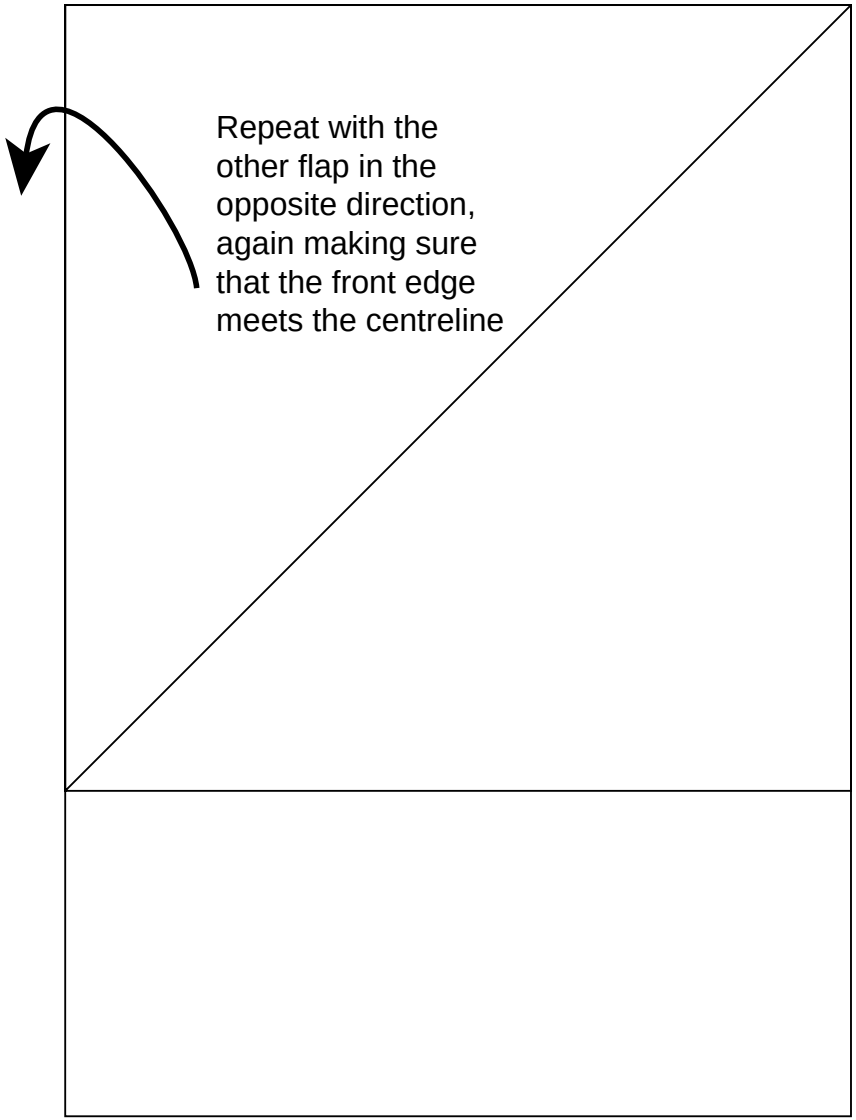
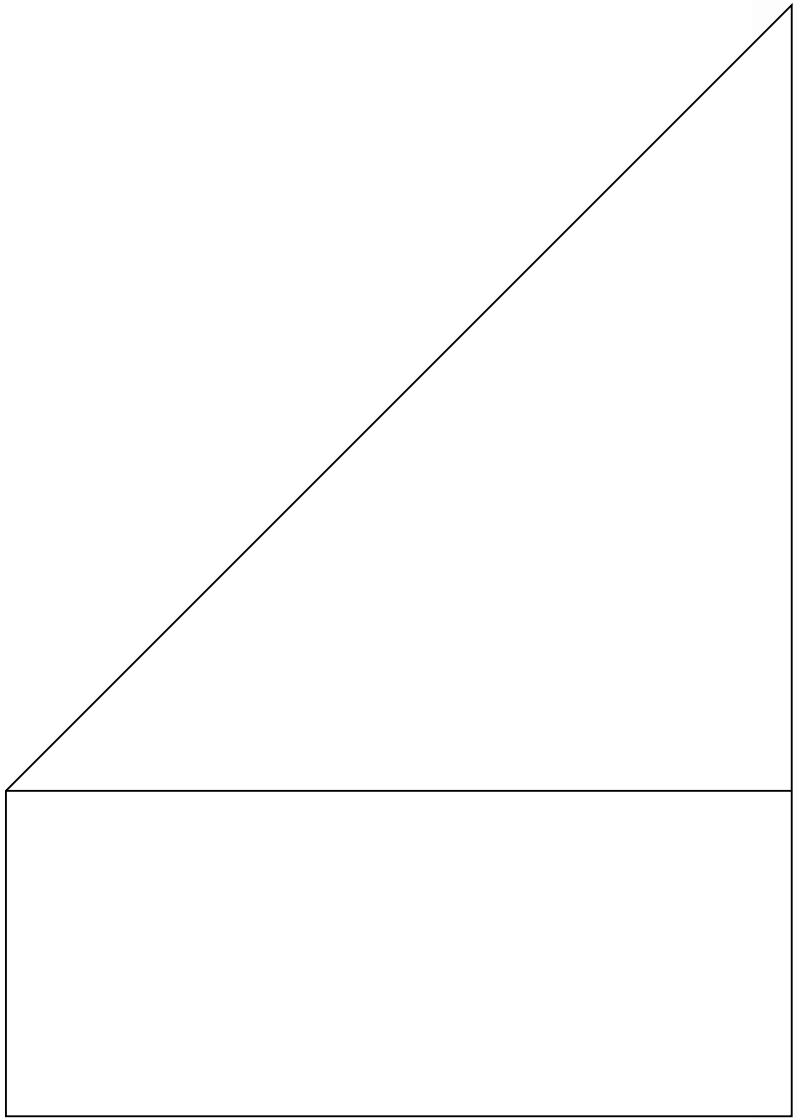
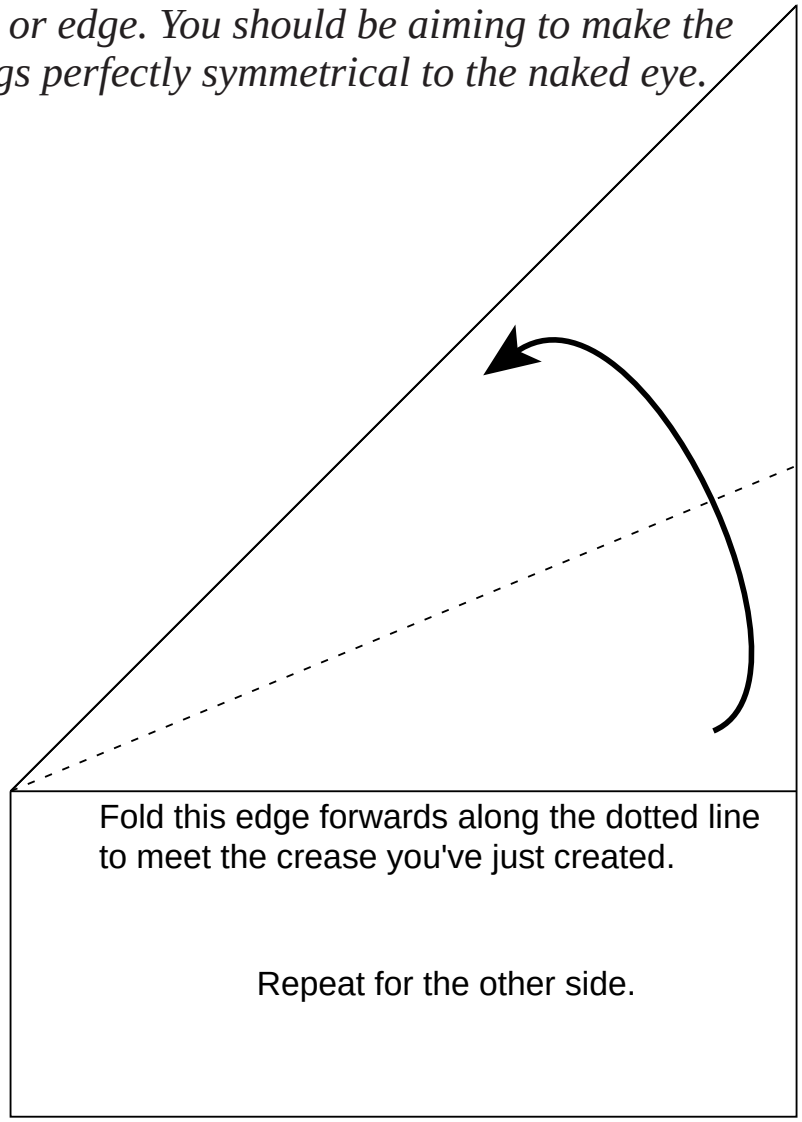
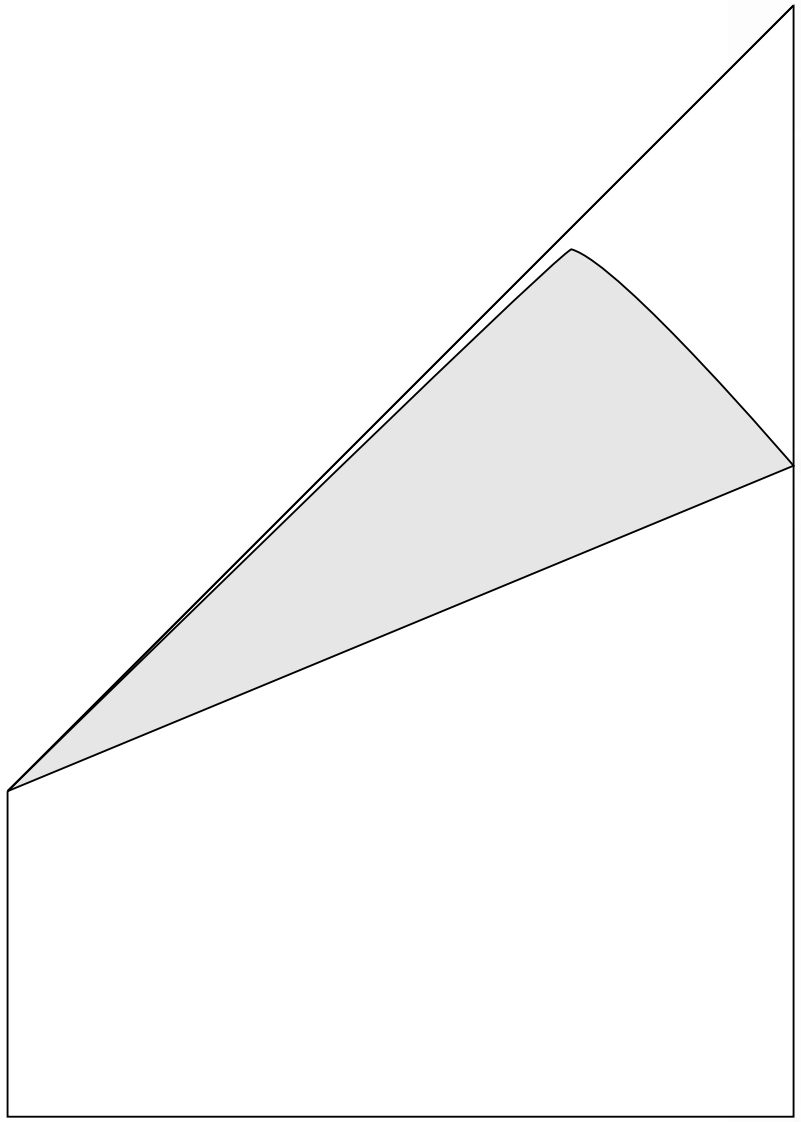




Step 4

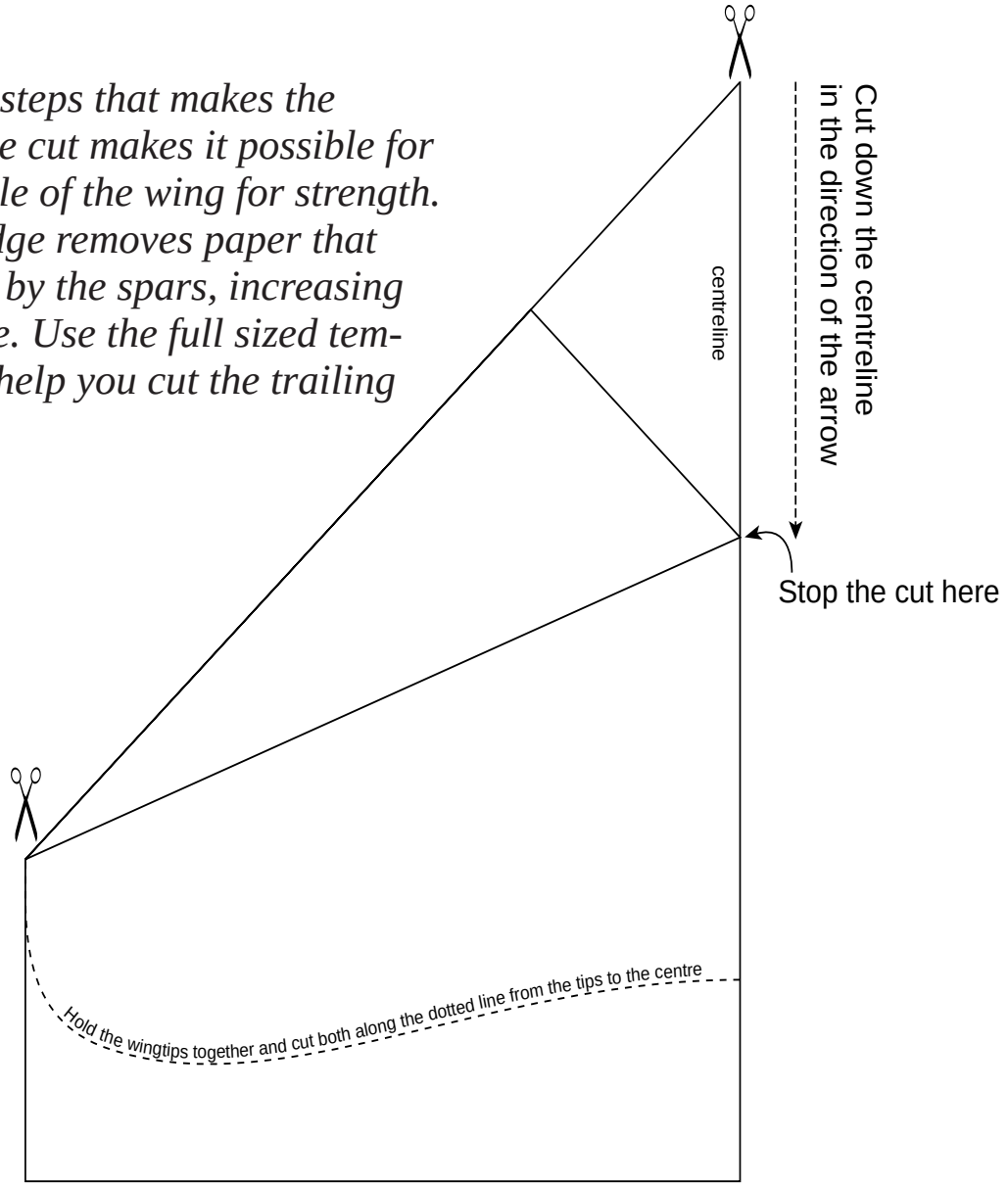
Design Note: *Try and make the folds as accurately as possible. This version of the Paperang is 'self-templating', meaning that each fold lines up naturally against another fold or edge. You should be aiming to make the wings perfectly symmetrical to the naked eye.*





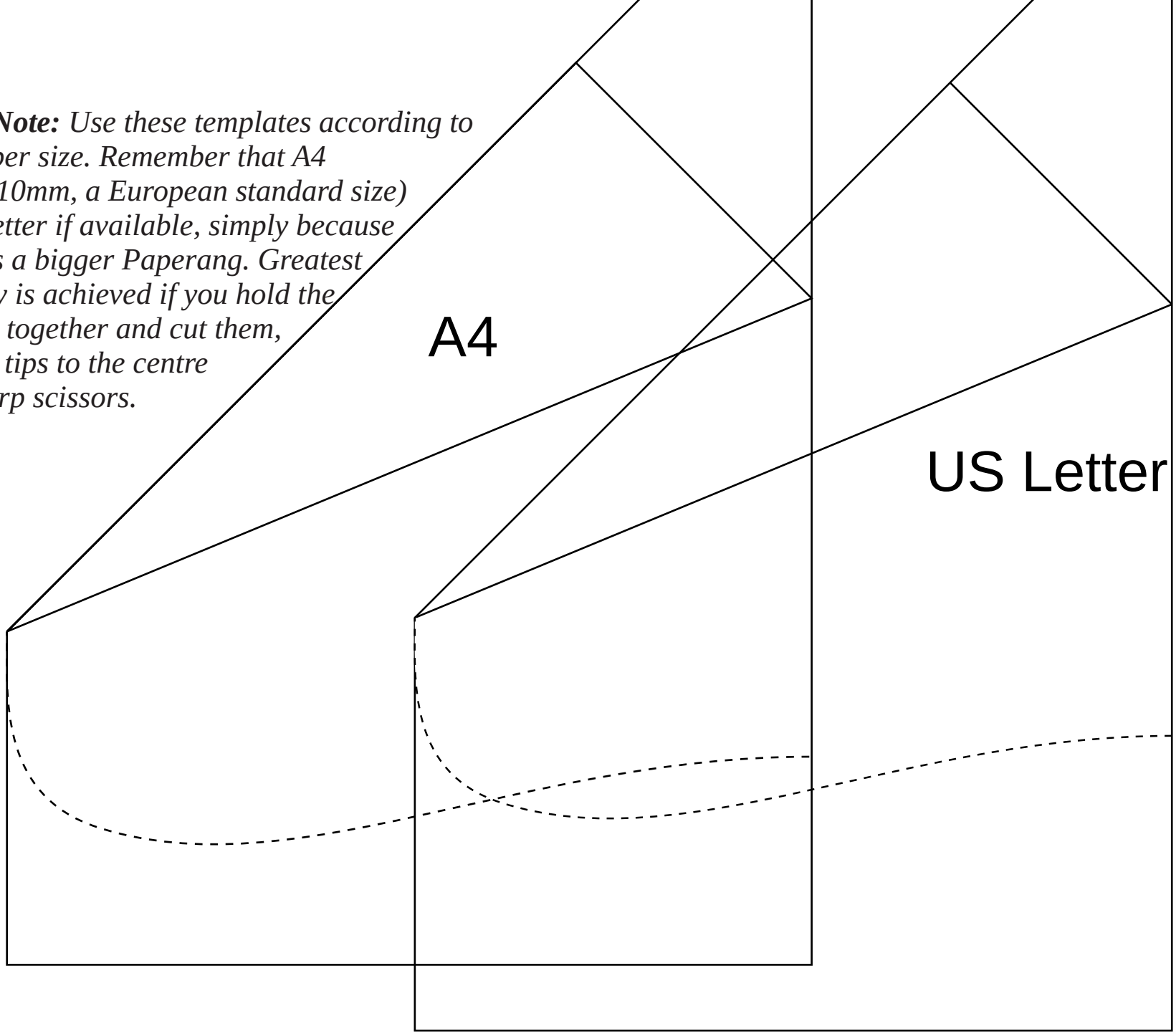
Step 5

Design Note: *This is one of the steps that makes the Paperang unique. The centerline cut makes it possible for the spars to overlap in the middle of the wing for strength. The curved cut in the trailing edge removes paper that cannot be accurately supported by the spars, increasing the aspect ratio at the same time. Use the full sized templates on the following page to help you cut the trailing edge.*



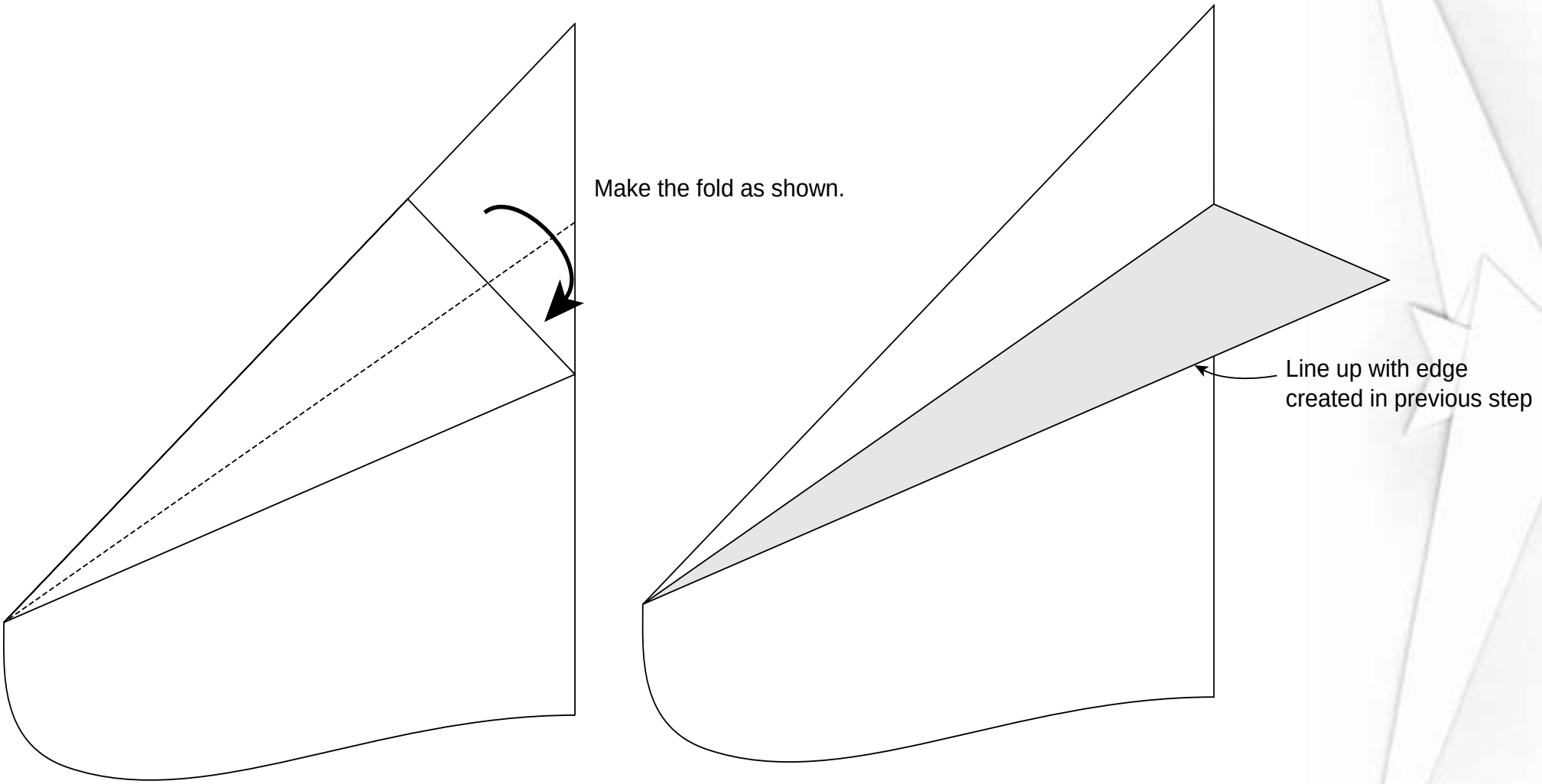
Step 6

Design Note: *Use these templates according to your paper size. Remember that A4 (297 x 210mm, a European standard size) works better if available, simply because it makes a bigger Paperang. Greatest accuracy is achieved if you hold the wingtips together and cut them, from the tips to the centre with sharp scissors.*

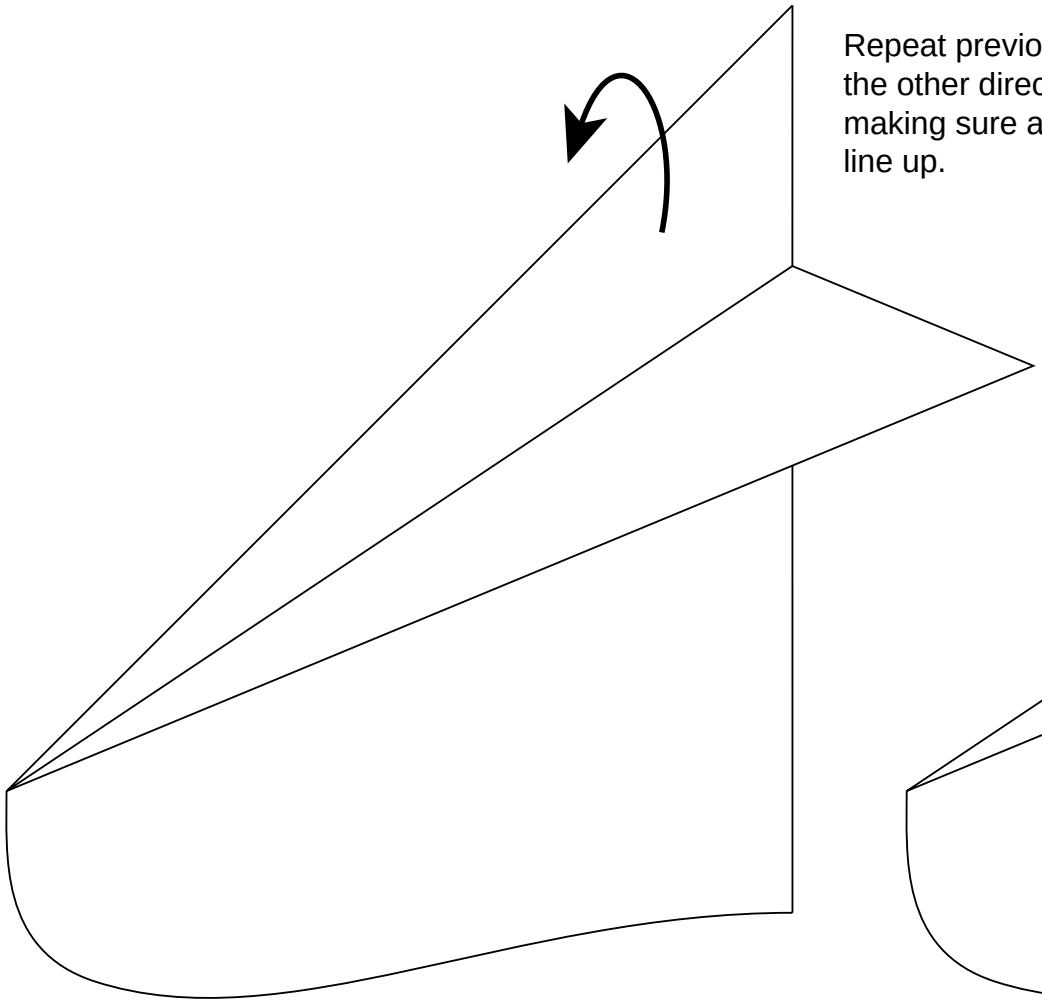


Step 7

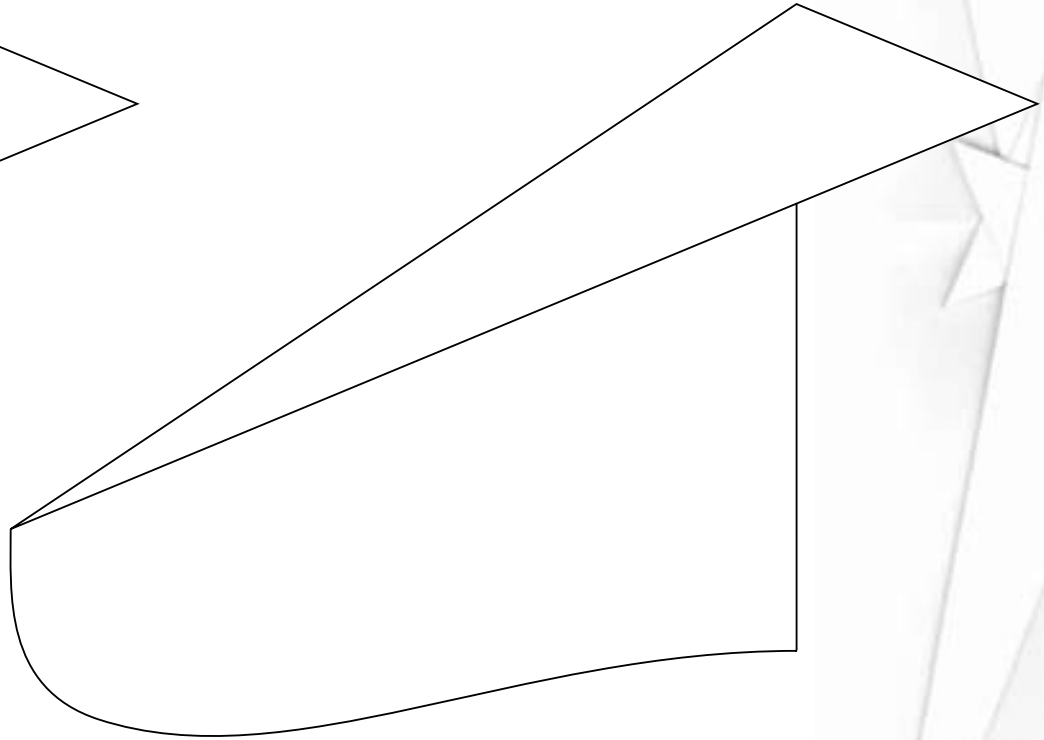
Design Note: *With this step, you are building up the tapered spars that give the Paperang its remarkable strength.*



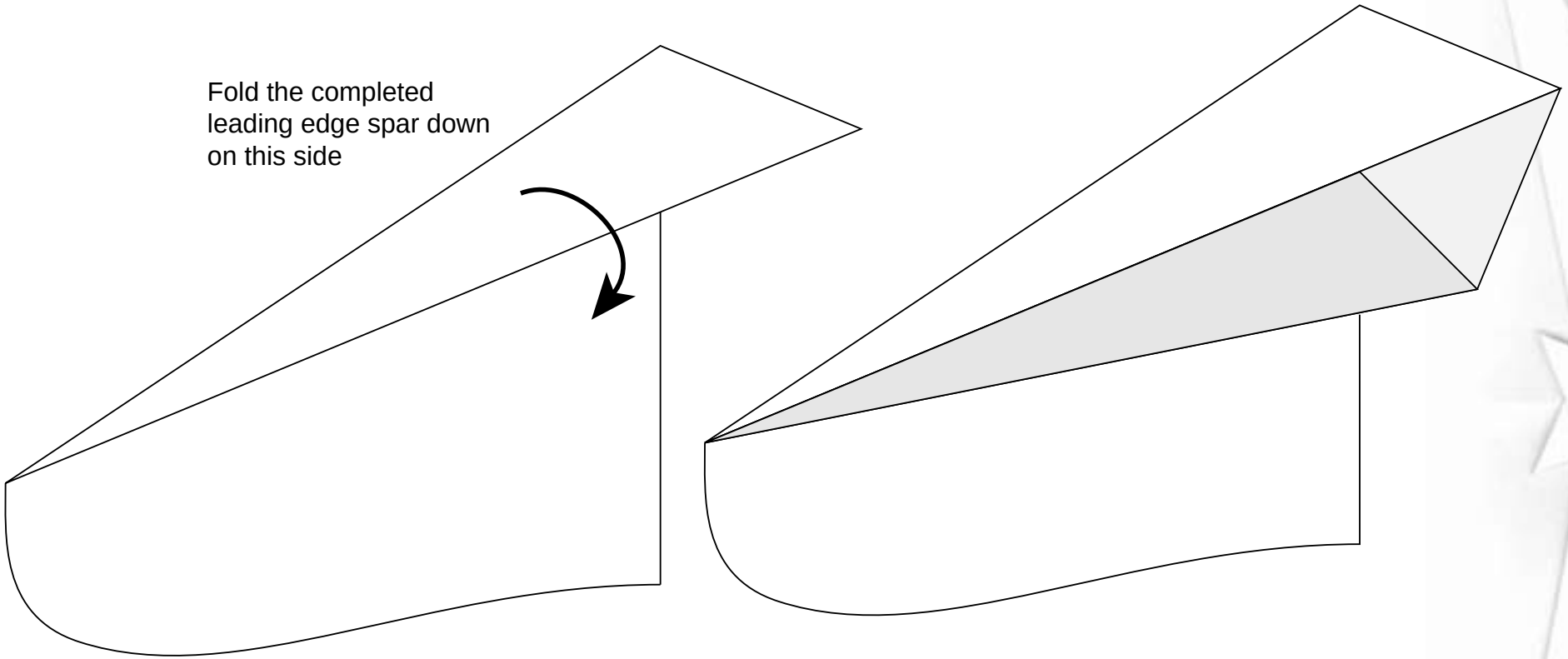
Step 8



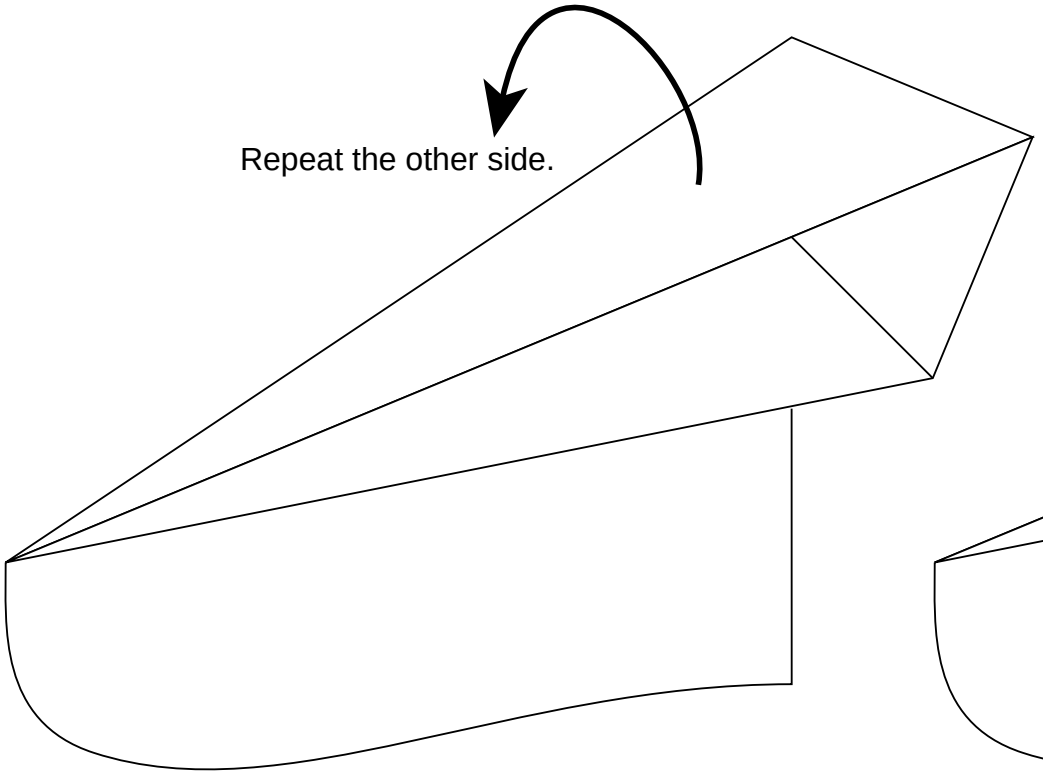
Repeat previous step in the other direction, making sure all edges line up.

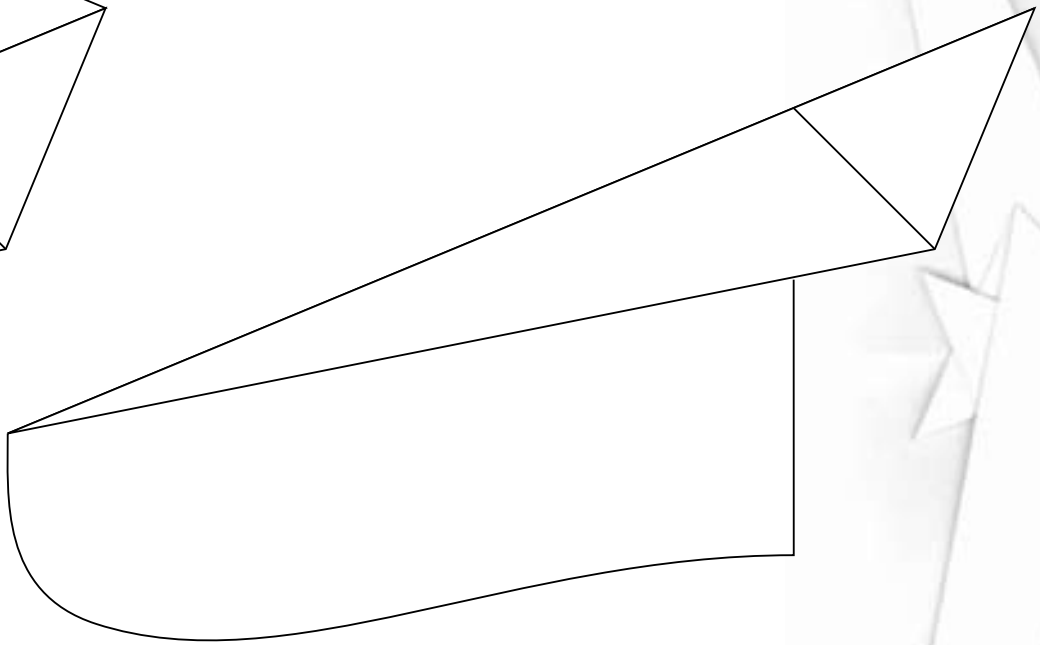


Step 9

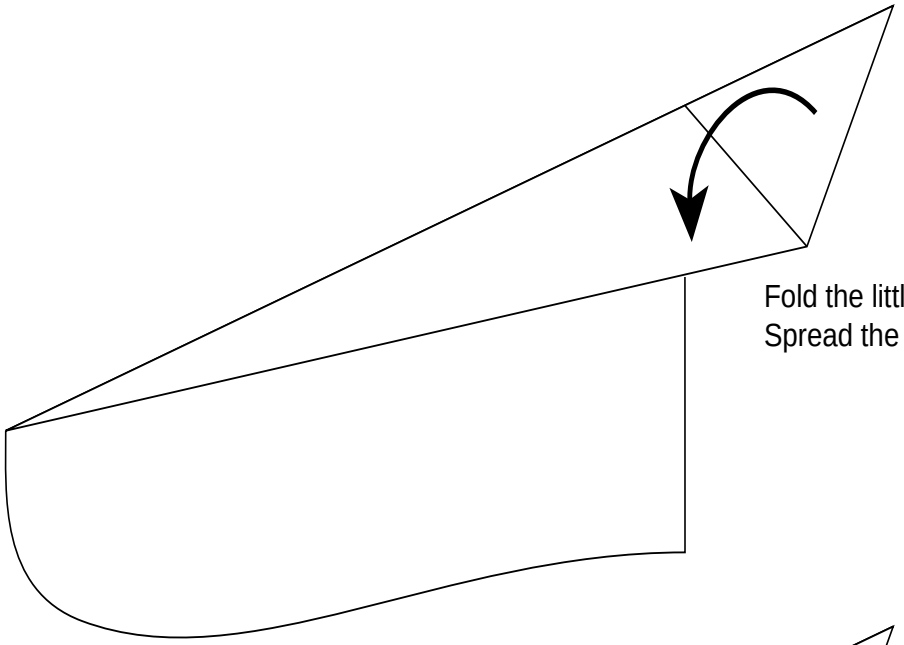


Step 10

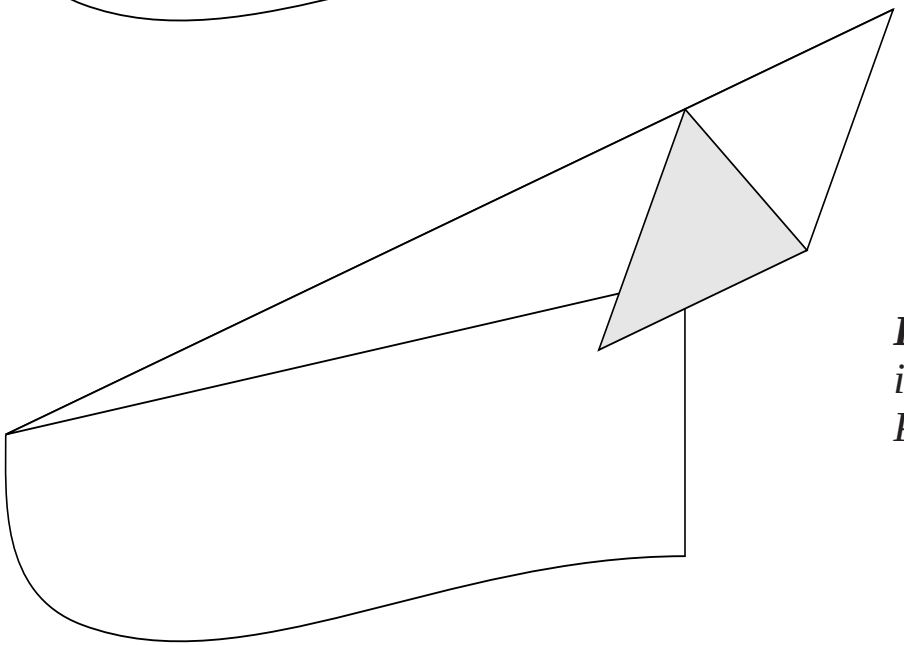




Step 11

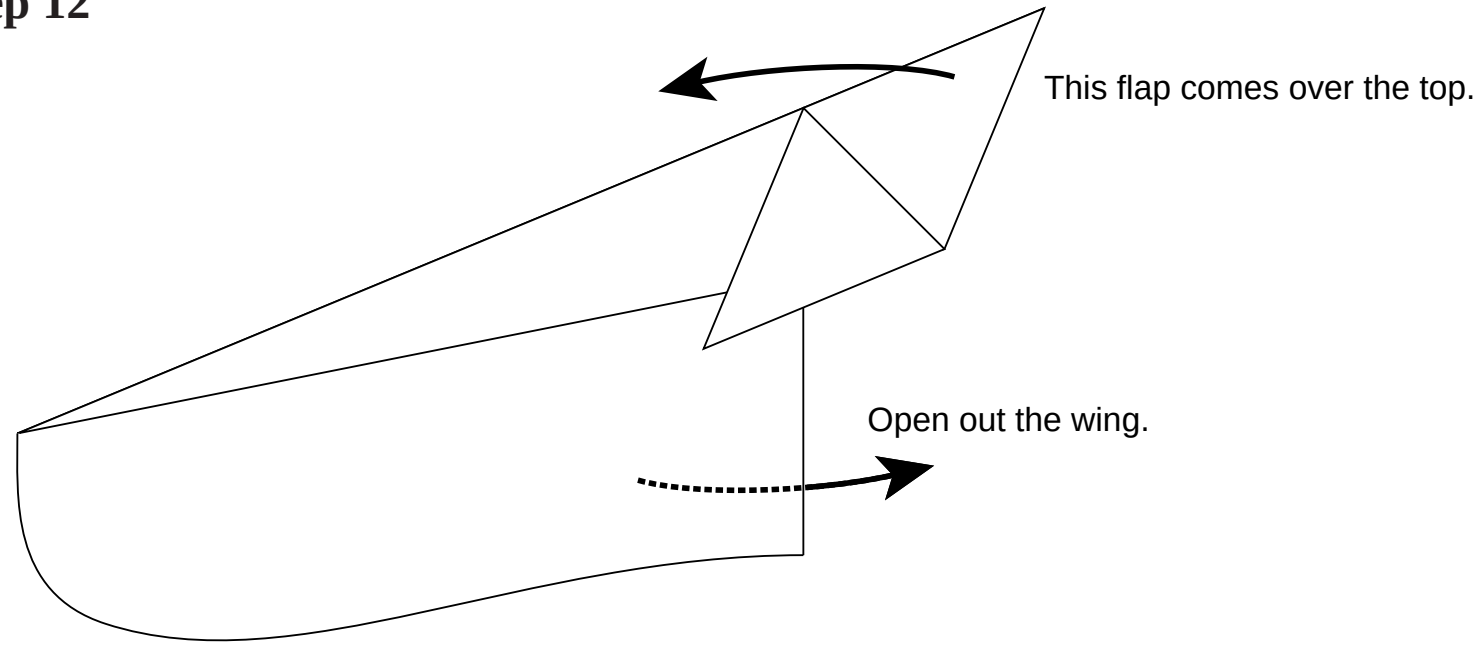


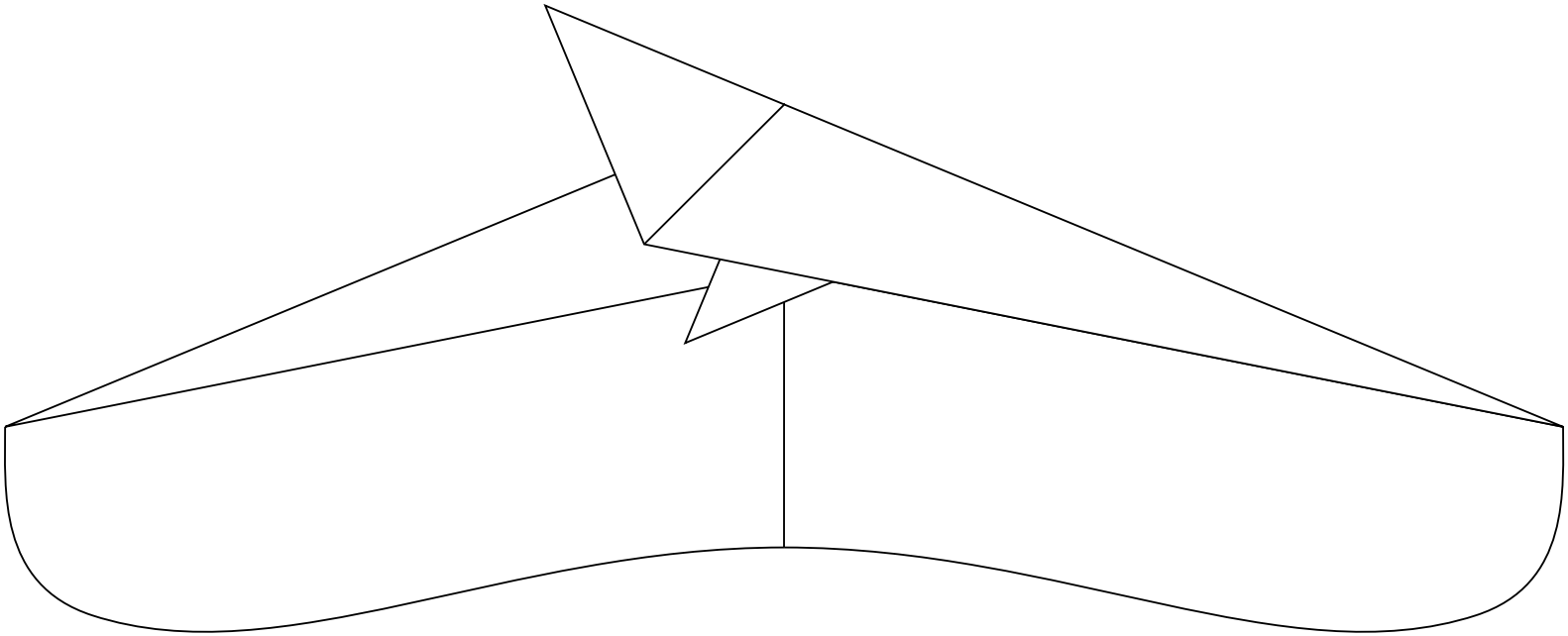
Fold the little tab over on this side, but not the other.
Spread the wings apart as shown in the next step.



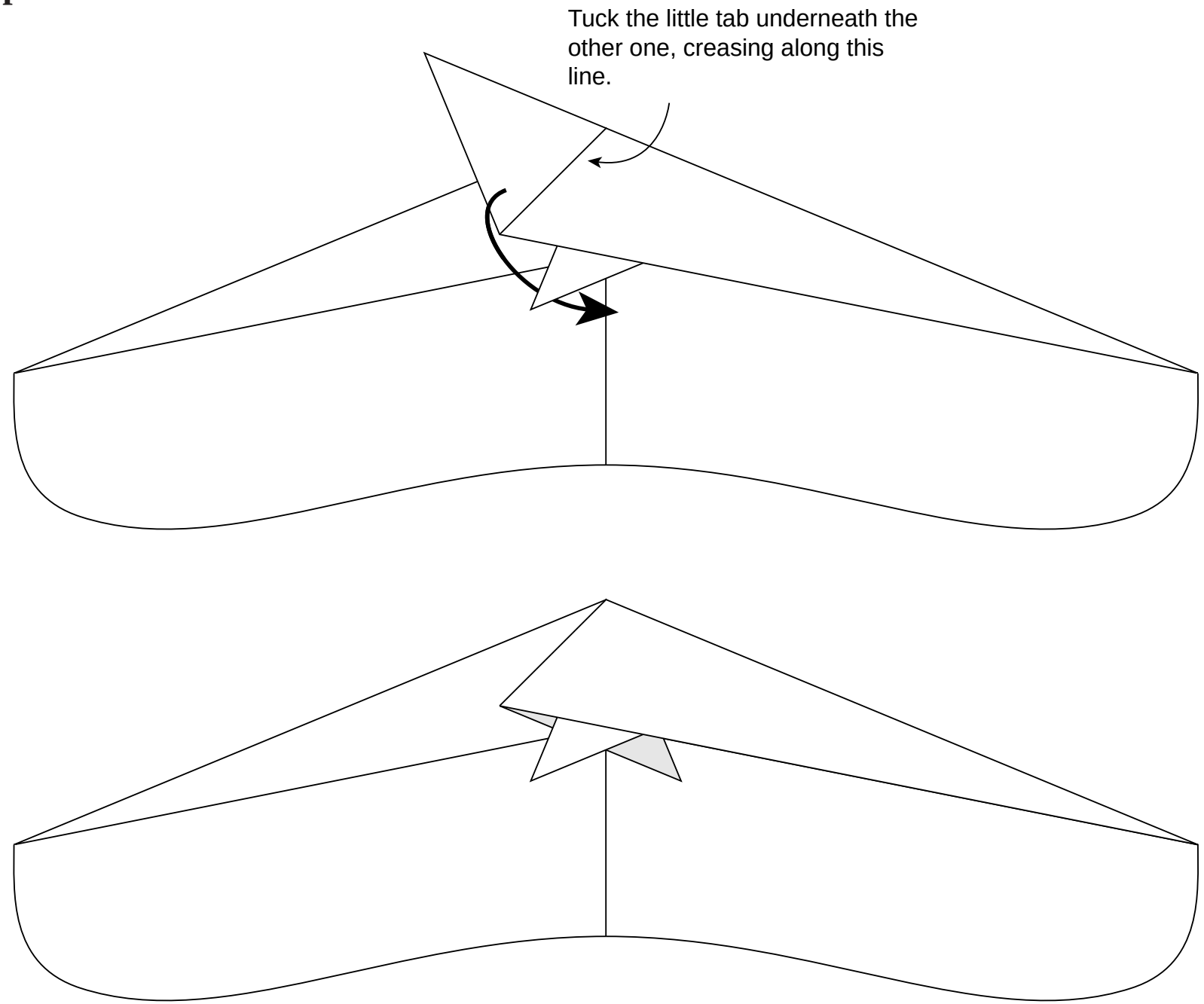
Design Note: *The triangular flaps created in this (shown in grey) and the next step are optional. To make a lighter Paperang, you can cut them off.*

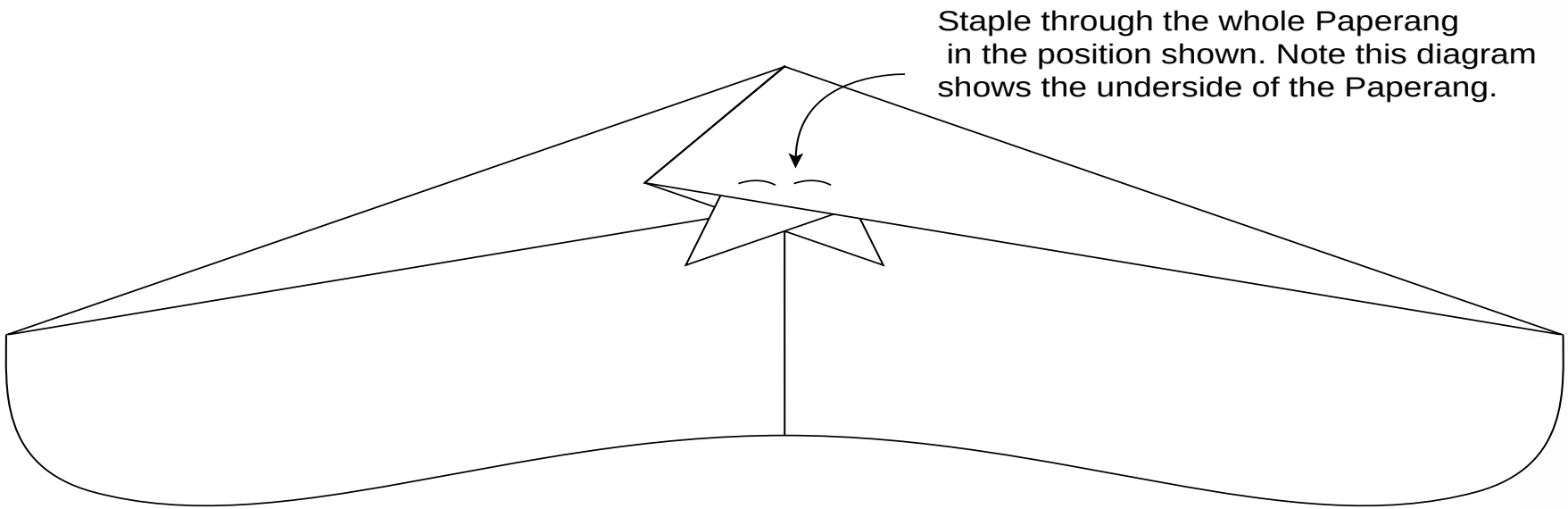
Step 12





Step 13



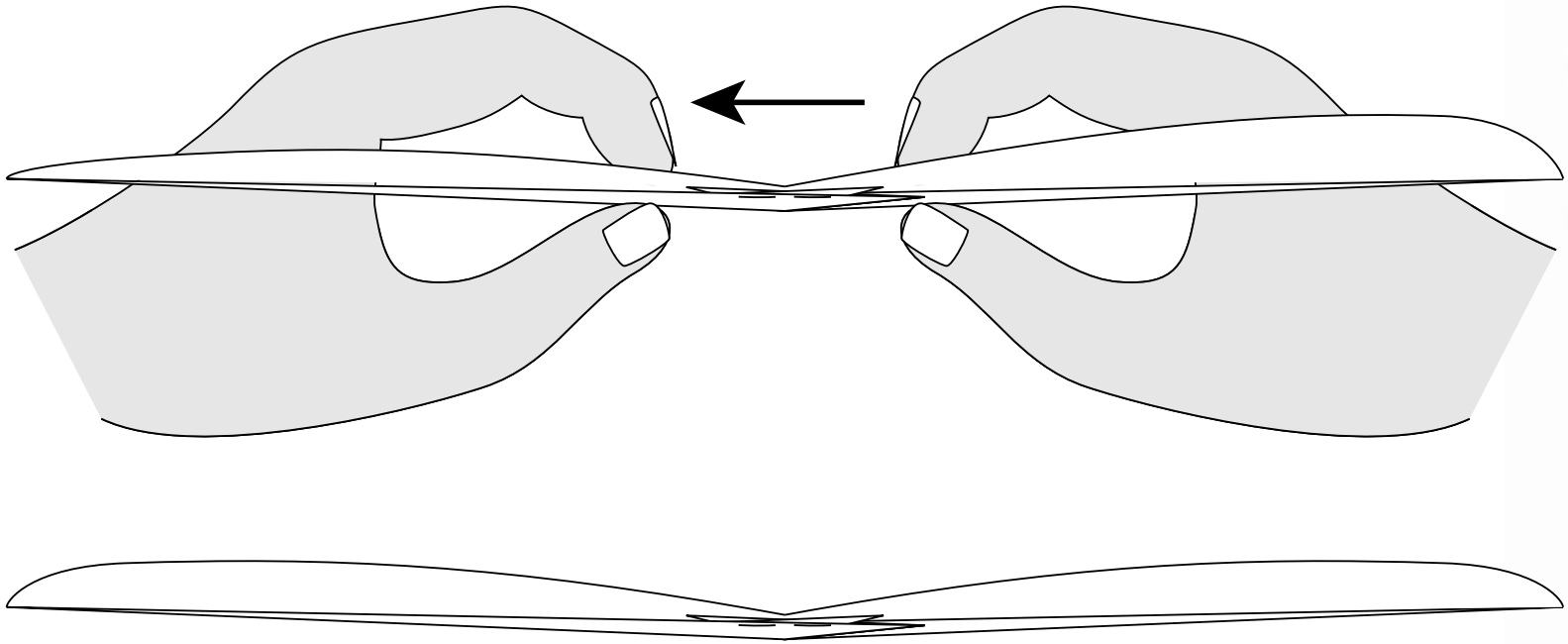


Design Note: *The performance of a Paperang is determined by its shape when you staple it. Please make sure that all the folds are equally flattened, and that both wings are straight and symmetrical. Place the Paperang in the jaw of the stapler and grip lightly. Check everything is in alignment again before finally stapling through from the top surface down. (Note above diagram is the view from below.) Use a good quality stapler and staples– sometimes the economy types will not fasten properly with both prongs.*

Step 15

Design Note: *When you are satsified that the wings are symmetrical, bend the staple into a slight V shape to give the Paperang a little 'dihedral', that is, so that the wingtips are held a few millimetres higher than the center section. This improves the stability of the Paperang.*

Hold the Paperang by the staple in both hands, nose pointing away from you, thumbs below and forefingers above.
Sighting from behind, check that the curve, or billow, in the wings is symmetrical.
If one wing is curved and the other flat, ease the wing top surface towards the flatter side. The staple allows some adjustment.



Flying the Paperang

The long, thin wings of the Paperang allow it to fly much further than other paper airplanes, but it requires careful trimming and launching because there is no V-shaped centre section for you to hold.

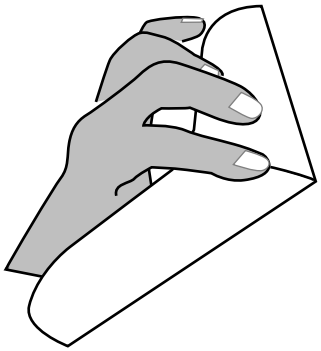
Handle the Paperang by its strong centre section only. For the first flights, use a large, draught-free indoor space such as a basketball court. The average Paperang has a glide ratio of about 10, so from a shoulder - high launch you can expect a 10-15m flight when properly trimmed.

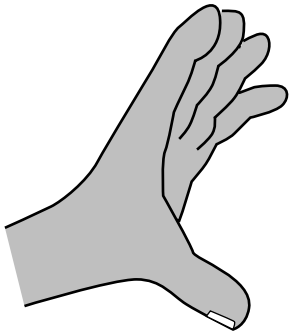
Launch

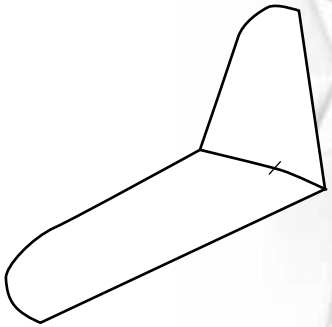
Hold the Paperang from behind using your thumb below and forefinger above, by the staple. Keep the wings level and nose pointed slightly downwards. If you open your thumb and forefinger wide when you release it, you will avoid brushing the trailing edge of the wing as you launch, which can spoil the flight.

The goal is to launch at the Paperang's natural flying speed, which you will be able to judge after a few tries. It flies a little faster than you would expect.

If you have built it accurately, it will fly in a beautifully straight line, to come to a sliding stop more than 10 metres away (about double the distance that a paper dart would fly if launched from the same height). If it doesn't do this, it should be trimmed.







Trimming

Go back to step 13 and check carefully that the wings are symmetrical. If not, gently ease the wing surface at the staple in the direction of the flatter wing. If you have difficulty, and the Paperang turns in different directions after successive adjustments, bend the staple more, so that the wingtips are higher than the centre section. (This is

called increasing the dihedral).

If the Paperang is flying straight but dives, give it more dihedral– this has the additional effect of creating more ‘billow’ in the wings, which in turn should cure the dive. If the Paperang is stalling, flatten the billow by gently flattening the leading edge fold.

If the Paperang doesn’t respond well to these trim adjustments, build another rather than persevering with trim adjustments. It doesn’t take long. Remember that accurate folding is the key to Paperang performance, and this comes only with practice.

Aerobatics

Once you’ve trimmed your Paperang, experiment with its aerobatic abilities! If you launch it firmly, with the wings banked, it will fly in a circle and come back to your hand. If you launch it hard with wings level, it will loop! Try holding it by the nose in front of you, pointing vertically upwards with the upper surface facing away from you. Launch upwards.

I hope you enjoy the Paperang. Please check back at the website (see address below) regularly for new developments in Paperang design and flying.