# How to Fly a Paper Airplane with a PowerUp® Motor

## Experience gravity-defying flight


POWER UP®

The lesson will last for approximately 90 minutes and can be shortened, if necessary, to 60 minutes.

Lesson overview: This lesson is meant for a teacher who wishes to conduct a single classroom lesson. It does not teach aerodynamics; rather, it is targeted toward a simple goal – enabling students to fly a paper airplane for a length of time greater than 15, seconds possibly breaking the current world record of paper airplane flight! Of course, to accomplish this goal, you will need a PowerUp Motor.

**Objectives:** The student will fly a paper airplane for more than 15 seconds using the PowerUp Motor. The student will recognize how to improve flight time by modifying the structure of the paper airplane accordingly.

### Chapter Titles

# Chapter 1: **Lesson Preparation**

In order to conduct a successful lesson, you must follow these guidelines. Please read this document in its entirety before you conduct the lesson.

**Lesson Location:** Paper airplanes are highly influenced by wind. Wind gusts above 5-7 knots will cause turbulence and will not provide a succesfull experience. If possible, book your school gymnasium for this lesson. Make sure that the space is open and free of obstacles. If you have no access to a gym, use an open basketball or tennis court. Avoid areas with trees, airplanes can easily get caught on them. Soft ground (e.g., grass or sand) provides a preferable landing surface. However, concrete and asphalt are acceptable when necessary.

**Practice:** Never present a lesson before you have practiced folding the recomended airplane design and have managed to fly it successfully using the PowerUp motor. Prepare a sample airplane, adjust the model, and attach the motor. Fly the paper airplane at the location where you will conduct your lesson. If possible, conduct your practice lesson at the same time of day. This will provide you with beneficial information regarding the pros and cons of the site that you have chosen.

**Note:** If you experience strong wind on the day that you plan to conduct the lesson, we recommend that you postpone the lesson to a day with more moderate wind conditions.

## Materials List:

- 1 PowerUp kit per student (fig 1)
- 1 PowerUp kit per teacher
- 1 Extra PowerUp kit for every 10 students
- 3 Alkaline batteries (size AA) per student, plus 10% surplus
- 1 Philips screwdriver
- 1-3 Scissors
- 1 Colored pencil for every 2 students
- PowerUp pilot stickers
- Permanent markers

## Handouts:

- How To Fold instructions
- Pre-printed high quality (80-90 GSM / 20 lb) copier paper – Use only the recommended template (A4 or US letter 8.5 x 11inches) (http://www.poweruptoys.com/pages/download-electric-paper-airplane-templates)
- Corrective cycle checklist


(fig 1)

# Chapter 2: **How to Fold the Perfect Paper Airplane**

This model (fig2) is based on the Nakamuru Lock design and was modified to fly perfectly with the PowerUp motor.

### PERSONALIZE YOUR AIRPLANE

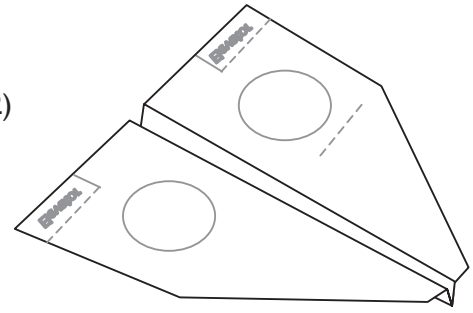
Handout pre-printed airplane templates to all students. Allow students to decorate the airplane in the predefined circles, those which are meant for the squadron symbol and the short dashed line for name tag. Cut the elevators and rudders along the bold line.

### FOLD THE PERFECT AIRPLANE

In the Appendix you will find folding instructions and a template that you can print and handout. Choose the preferred template according to the type of paper you have available - 8.5"X11" US letter or A4 .You can also download and print this template: http://www.poweruptoys.com/pages/download-electric-paper-airplane-templates

Printing tip: Choose the "Fit to Page" option.

(fig 2)

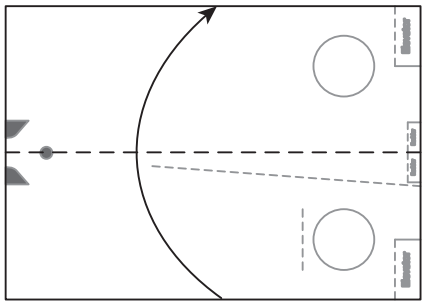


### General Folding Tips:

- Use your fingernails to make hard creases.
- Make sure that flat surfaces stay flat during the folding process.
- Make all folds symmetrical. Note that the printed template may not be centered on the paper. Folding a symmetrical airplane is more important than adhering exactly to the printed lines on the template.

### Handout Diagrams Notes:

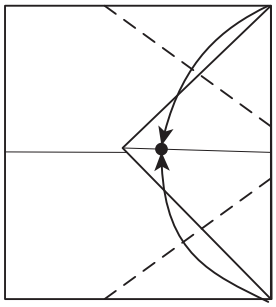
Diagram 1: It is important that students fold the paper in half accurately (fig 3). Make sure that all students fold slowly through this step in order to obtain two identical sides.



(fig 3)

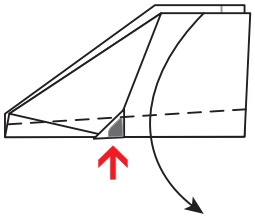
Diagram 2-6 :When folding the arrow head, it is critical to align the edge of the paper with the central fold line. Make sure that students do not pass the center line.You can simplify this step by completing it while the paper is still folded in half.

Diagram 7: Make sure that the corners are folded to the spot marked on the template.This will provide a stable airplane design when using the powerUp System (fig 4).



(fig 4)

Diagram 11:When folding the wings, students must make sure that the fold line of the wings passes through the thick triangle.This triangle will be the holding point of the airplane (fig 5).



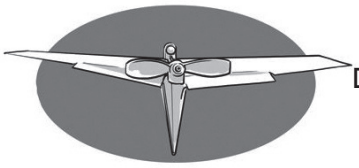
(fig 5)

# Chapter 3: **The Principals of Flying a Paper Airplane**

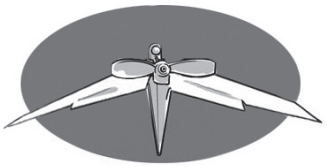
## THEORETICAL KNOWLEDGE

Flying a paper airplane successfully requires adjustments right before launch. The sections listed below will help you control your airplane.

**ANHEDRAL AND DIHEDRAL ANGLE:** The upward angle between the wings is a dihedral angle (fig 5). The dihedral angle eliminates an inverted or spiral flight. You can show the students what happens when you launch an airplane with an anhedral angle (fig 6). Note that because the paper is not stiff, the lift applied to the wing during flight will cause the paper to fold and increase the dihedral angle. To avoid this, always set your dihedral angle slightly lower than desired. An increased dihedral angle wil cause a reduction in lift resulting with a lower flight time in total.

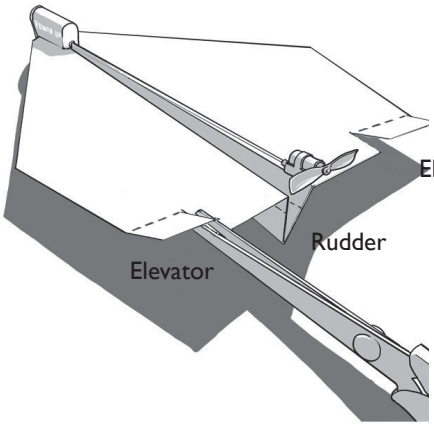


Dihedral (fig 5)



Anhedral (fig 6)

**ELEVATORS:** The elevators are the two flaps located on the rear portion of the wings (fig 7). Simply demonstrate to students that when the air hits the elevator, it creates a force that attempts to unfold the two flaps. For example, if the elevators are pointing up and the paper is strong enough, the momentum created will force the back of the airplane down, causing the nose to pitch up. Note that while this is not an official aerodynamic explanation, it can become a general rule of thumb for students to follow: Elevator Up = Tail Down = Nose Up. While it is possible to adjust the elevators in two opposite directions (e.g., to achieve a permanent roll), do not use this method to adjust an unwanted roll. An unwanted roll is probably caused by an asymmetric fold. It will be easier for you to fold a new airplane than to try to correct the roll using the elevators.




(fig 7)

**RUDDER:** The rudder is the vertical flap at the rear end of the airplane (fig 7). The rudder is similar to an elevator that stands on its side. Move the rudder left to force the tail to the right and the nose of the airplane to the left. Rudder left = nose left.

**LAUNCHING**: Before starting this phase, gather all of your students together and brief them. Describe your objectives for this phase, explain the steps that you will go through, and remind them the principles of adjusting the airplane which you recently showed them. Remember that briefing and debriefing are major tools in improving your flying skills.

# Chapter 4: **How to Fly a Paper Airplane without a Motor**

**STEP 1: Adjust** – Level all control surfaces. Make sure that you begin with zero influence from rudder and elevators. Set the dihedral according to the diagram, just a little above the horizon (fig 8).

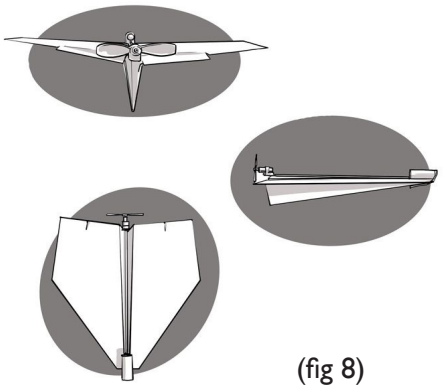
**STEP 2: Wind Check** – Lift is generated when air flows on the wing. When you hold the airplane facing the wind, lift will be generated even before you launch it. This is why you must launch into the wind. In order to determine wind direction, you may wish to make your own wind sock. There are other ways to determine wind direction, such as watching sand drift from your fingers, wetting a finger and holding it up or observing smoke or flags to determine wind direction. If you are conducting the lesson in a closed space, select the longest available path for flight.

**Step 3: How to Hold Airplane** – You must hold your airplane very close to the center of gravity. With this model, you will grasp the airplane at the small multi-layered triangle, just a bit to the front from the center. Hold the airplane between the thumb and index finger of your strongest hand.

**Step 4: Launch** – Never throw an airplane. Launching a paper airplane is more like pushing a boat through the water. Keep your airplane level, your hand close to your face, 'push the boat' forward, and let go at the end of your hand movement.

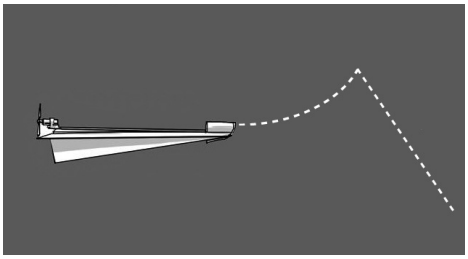
**What happened? The Corrective Cycle**

In most cases you will not achieve a straight and level flight. One or more of the phenomena described below will occur. Observe carefully to determine which phenomena occur so that you can debrief the pilots at the end of each launch. During debriefing, make sure to ask students for their insights into correcting errors.



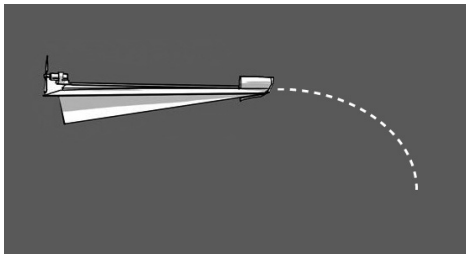
(fig 8)

**PHENOMENON 1: Stall** – When the nose of the airplane pitches up, beyond a certain point, the airflow may detach from the upper surface of the wing causing turbulence and dramatic reduction of lift followed by a nose down dive (fig 9). Demonstrate this phenomenon to your students with a paper airplane in hand. To correct a stall, adjust the elevators sligtly down. A stall is unlikely to occur unless the elevators were folded up by mistake. The basic behavior of the NAKAMURO airplane model is very stable. Such a mistake can occur if a student diverts significantly from the template or dramatically alters the distance between the center of lift and the center of gravity. If this occurs, suggest that the student folds another airplane.



**Stall** (fig 9)

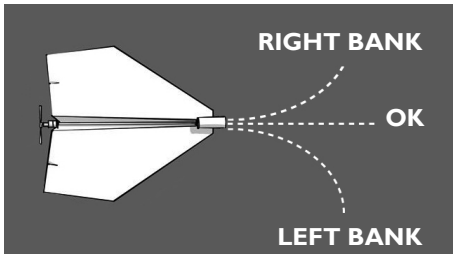
**PHENOMENON 2: Dive** – A dive occurs when the airplane loses height quickly and the nose suddenly points toward the ground. (fig 10) To correct this phenomenon, evenly adjust the elevators upward.



**Dive** (fig 10)

**PHENOMENON 3: Inverted flight** – This can occur when the airplane flips over and flies with its underbelly pointed up. An inverted flight indicates a problem with the angle between the right and left wings. Show the students the airplane from the front and ask them whether the wings are horizontal, pointing up (dihedral angle) or pointing down (anhedral angle). A dihedral angle provides the airplane with stability, as both vectors of lift are pointing sligtly inward. An anhedral angle causes every slight change in the roll angle to increase until the airplane is inverted. In this new inverted position, the airplane has achieved a dihedral angle and is once again stable. To correct an inverted flight, make sure that your airplane wings form a dihedral angle.

**PHENOMENON 4: Bank** (left or right) – A bank is a steady turn. During a bank, the lift vector is no longer pointing up causing a slight decent. To correct an unintentional bank, use the rudder. The rudder is the V-shape located on the lower back part of the tail. The rudder tends to stay open, by slightly bending the rudder to the left or to the right you can correct your airplanes banking phenomenon (fig 11). Later on you will see the benefits of a steady bank – you can adjust your airplan to bank and return right back to your hand, or you can bank your airplane to stay in the air for a while in one area. For now, however, you want your students to achieve a straight and level flight.




Banking (fig 11)

**PHENOMENON 5: Spiral Dive** – The combination of a dive and a bank causes a spiral dive. To correct a spiral dive, use the tools described above for both phenomena. You may also want to increase the dihedral in order to reduce the effect of the spiral dive.

# Chapter 5: **How to Fly a Paper Airplane with PowerUp Motor**

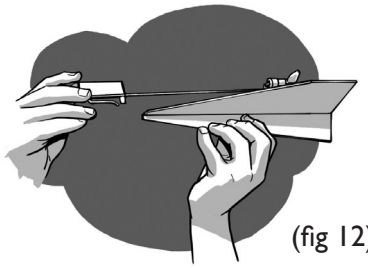
Up to this point, we have been flying paper airplane gliders. We will now add a motor to our paper airplanes. The principles that you learned earlier in the lesson will not change. How will a motor affect our airplane? A running motor provides constant thrust. If the airplane is trimmed correctly, the thrust provides a major component for a successful first flight. The motor will add some weight to the paper airplane, approximately an addition of 0.2 ounces or 6.5 grams. This extra weight means that your airplane will need more lift. The higher speed provided by the motor will create the necessary additional lift. In order to quickly attain this higher speed, you will launch the airplane a bit stronger. The rotation of the propeller will create yaw momentum. This is nothing to worry about, as it can be fixed with a little adjustment in the rudder. Brief your students about the changes that occur when we add a motor.

Stop here and ask for full attention now, as you are about to talk about SAFETY!

**Safety first** – The PowerUp motor meets all 8+ (ASTM, EN71) safety standards, nevertheless make every effort to take the precautions listed below.

**1.** Individuals with long hair should pull hair back and fasten it with a rubber band. If hair becomes caught in the propeller, detach the propeller from the motor inorder to release the hair.
**2.** Never allow the propeller to get close to the eyes.
**3.** In order to extend the lifespan of the motor, do not charge the motor for more than 20 seconds at a time.
**4.** After a full charge (20 seconds) allow the motor to cool down for two minutes.
**5.** Any time that you adjust or hold the airplane, stop the rotor by using the "Propeller Stop" feature on the charger.

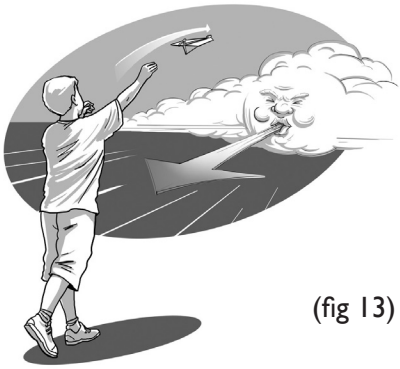
**Step 1: Install the Motor** –Handout PowerUp motor sets to the students. Show them how to attach the motor and the underside fin to the airplane with the clips (fig 12); refer to the instructional manual included in the kit). Make sure that the units have been installed properly.



(fig 12)

**Step 2: Dry Launch** – Test-fly the aircraft without running the motor. Adjust airplane control surfaces until you obtain a steady descending flight (fig 13). Remind students about important launching features, including wind, adjustments, and launching force.

**Step 3: Ignition** – Hold the aircraft with your throwing hand. Use the other hand to plug the battery pack into the charging port tightening. Listen to the propoller wooshing sound as the main indicator for the increase of thrust. Count from 21 to 27 (7 seconds), the goal of the first flight is simply to observe the flight path. Do not hesitate after charging! Launch immediately.



(fig 13)

**Step 4: Launch** – If the wind is strong (5mph), there is no need to apply force. During launch you can simply hold the nose heading into the wind and release the airplane gently, providing only a tiny push forward. Please make sure to pick up the airplane carefully so as to avoid any warping to the wings. It is best to hold the airplane either by the nose piece or by the body of the airplane.

**Step 5: Applying the Corrective Cycle** – Upon failure, children as well as adults tend to repeat their last action with more force. Extra force will not help in this situation. Each student must identify and understand the phenomena that the airplane experienced. Students may continue on to the next step after describing what they learned. This is the Corrective Cycle in use: observe, identify, correct, try again. Some students will experience stalls; some students will achieve wide banks. Encourage students to identify the phenomena and share how they corrected.

**Note:** recharge your motor before every launch!

**Step 6: Stall** – It is considered good practice to begin by stalling your airplane. A stall is a definite situation, and it is easier to get into a stall than to find the right trim for straight and level flights. In order to stall your airplane, fold up the elevators. Do not over-fold the elevators, as this will cause air breaks. Allow students to try their settings. This process will allow students to adjust the rudder and create a stalled flight pointing straight.

**Step 7: Straight and Level Flight** – to correct the stall, gently lower the position of the elevators.

**Step 8: Banking** – This step is made available for advanced students. Students that have maintained the straight and level flight can try now to attain a gentle bank by trimming the rudder. A successful flight will enable the airplane to return to the hands of the pilot.

# Chapter 6: **Common Mistakes and Tips**

**Common Mistakes**

1. Poor folding / asymmetric structure
2. Warping the paper during the folding process
3. Flying on a windy day
4. Excessive airplane adjustments
5. Applying too much force when launching
6. Not launching into the wind
7. Lifting the airplane by the wing, thus changing the wing structure
8. Trying again and again without applying a corrective action and understanding the reasons for a flight pattern

**Note**: A10 seconds charge will be sufficient for most flights.

**Tips**

1. First launches may not be successful . Encourage your students to learn from each launch, identify, adjust and try again.
2. Always use fresh batteries, never use rechargeable ones, since the voltage will be to low.
3. landing on hard floors can cause the propeller to detach from the motor. If that happens, stop the motor with the charger and re-install the detached propeller when the concave side is pointing backwards.
4. when flying inside a gym, make sure the air conditioner doesn't cause turbulences. If so, ask to turn it off.
5. When all else fails, fold a new airplane

# Chapter 7: **Conclusion & Final Competition**

## FINAL COMPETITION

At the end of the day, all of the pilots will gather in the briefing room. This will be an important time when the flight cadets are learning and affixing their new knowledge. Debriefing starts by identifying positive points. Students will gain knowledge when they recognize the aspects of a successful flight. Try to focus only on the three major points that were observed, this will make it easier for the students to remember what they have learned from the process.

## CONCLUSION

If you still have time, you can arrange a competition. The activity addresses flight duration rather than flight distance.

1. Divide the students into groups of four.
2. Ask them to choose a squadron logo and decorate new templates.
3. Allow each squadron to use paper in different colors.
4. The competition is completed in sections. Choose a pilot from each squadron and set them in a row.
5. Set time for starting ignition by calling out, "get ready to ignite in 4, 3, 2, 1, Take off!
6. Do not measure time; rather, identify the landing order.
7. Give 7 points to the plane that flew the farthest, 5 points to the second place finisher, and 1point to others.
8. Repeat this process with all pilots.
9. At the end of the project, reward all pilots with the Solo Pilot Sticker.
10. Present trophies to winners.


POWER UP®

Happy Flying

Need help? Call 7866001752
http://www.www.poweruptoys.com

## Flight without a motor

Check:

- Align elevators - ☐
- Align rudder - ☐
- Make a slight dihedral - ☐
- Check wind direction - ☐

**What happened?**

| *Round* | Stall | Dive | Bank L | Bank R | Flip over |
|---|---|---|---|---|---|
| *1* | ☐ | ☐ | ☐ | ☐ | ☐ |
| Change | ElevatorE | levator | Rudder | | Dihedral |
| *2* | ☐ | ☐ | ☐ | ☐ | ☐ |
| Change | ElevatorE | levator | Rudder | | Dihedral |
| *3* | ☐ | ☐ | ☐ | ☐ | ☐ |
| Change | ElevatorE | levator | Rudder | | Dihedral |

## Flight with a motor - stall

Check:

- Elevators - slightly up ☐
- Align rudder - ☐
- Make a slight dihedral - ☐
- Check wind direction - ☐

**What happened?**

| *Round* | Stall | Dive | Bank L | Bank R | Flip over |
|---|---|---|---|---|---|
| *1* | ☐ | ☐ | ☐ | ☐ | ☐ |
| Change | ElevatorE | levator | Rudder | | Dihedral |
| *2* | ☐ | ☐ | ☐ | ☐ | ☐ |
| Change | ElevatorE | levator | Rudder | | Dihedral |
| *3* | ☐ | ☐ | ☐ | ☐ | ☐ |
| Change | ElevatorE | levator | Rudder | | Dihedral |

## Flight with a motor - leveled

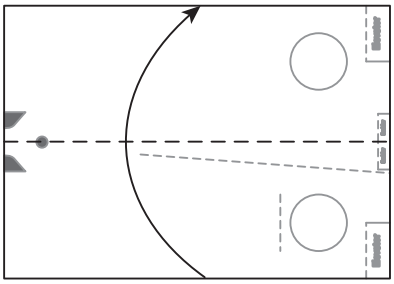
Check:

- Align elevators - ☐
- Align rudder - ☐
- Make a slight dihedral - ☐
- Check wind direction - ☐

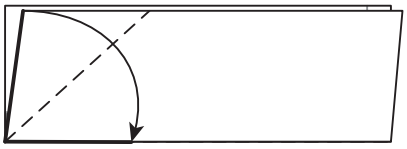
**What happened?**

| *Round* | Stall | Dive | Bank L | Bank R | Flip over |
|---|---|---|---|---|---|
| *1* | ☐ | ☐ | ☐ | ☐ | ☐ |
| Change | ElevatorE | levator | Rudder | | Dihedral |
| *2* | ☐ | ☐ | ☐ | ☐ | ☐ |
| Change | ElevatorE | levator | Rudder | | Dihedral |
| *3* | ☐ | ☐ | ☐ | ☐ | ☐ |
| Change | ElevatorE | levator | Rudder | | Dihedral |

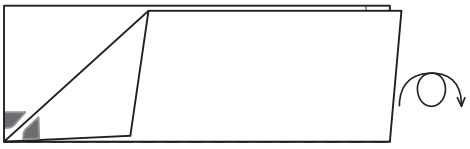
How to fold the best PowerUp paper airplane



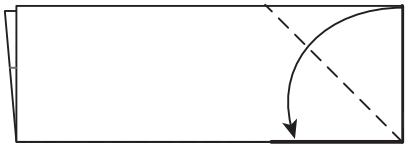
1. Start with the printed template face up. Fold in half, the lower edge to the top edge.



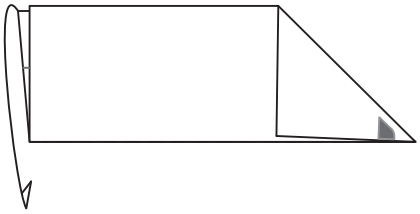
2. Make an Arrow Head by folding the left edge to the bottom edge (both are marked by thick lines).



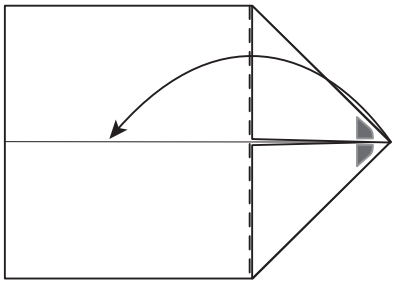
3. Turn over the model.



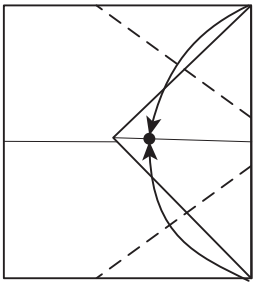
4. Repeat step 2. on this side.



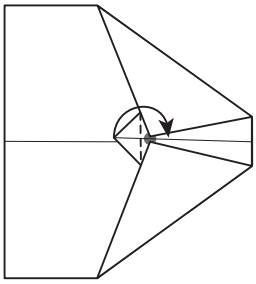
5. Spread the paper (unfold only the center line).



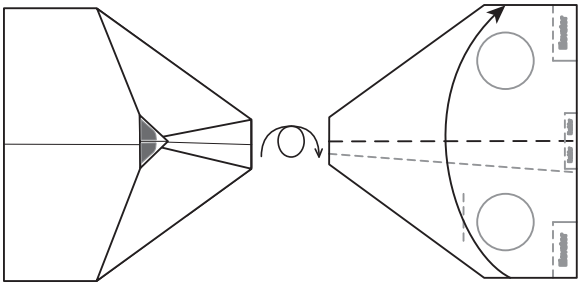
6. Fold the right corner to the left; refer to the base of the triangle as your guiding line.



7. Bring both marked corners to the black dot.

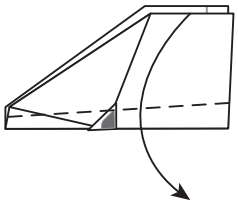


8. Lock the corners by folding the little triangle on top of the two corners.

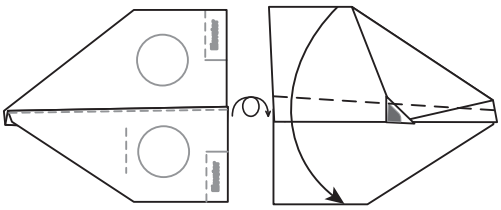


9. Lock the corners by folding the little triangle on top of the two corners.

10. Fold the model in half by aligning the wings. Note the dashed line in the lower wing.

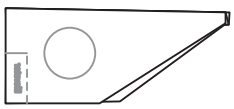


11. Fold the wing down along the mentioned dashed line.

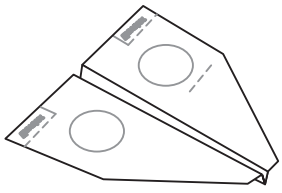


12. Turn the model over.

13. Fold the other wing and align it with the first wing.



14. Spread the wings to the sides.



15. Your airplane is ready!

You can download the A4 Template here
http://cdn.shopify.com/s/files/1/0165/4322/files/Nakumura_template_for_PowerUp_A4.pdf?1647

The best Template for the PowerUp 2.0
Electric Paper Airplane Conversion Kit
Paper Type - 20lb stock
Paper size - US letter 8.5"X11"
Printer Setting - Scale 100% borderless

www.poweruptoys.com



How to fold video

Wing folding line

Elevator

Rudder

Rudder

Elevator

# PowerUp rewards