LEARNING ABOUT THE FLIGHT STABILITY WITH A TETHERED PAPER PLANE

~LET'S ENJOY TETHERED PAPER PLANE~

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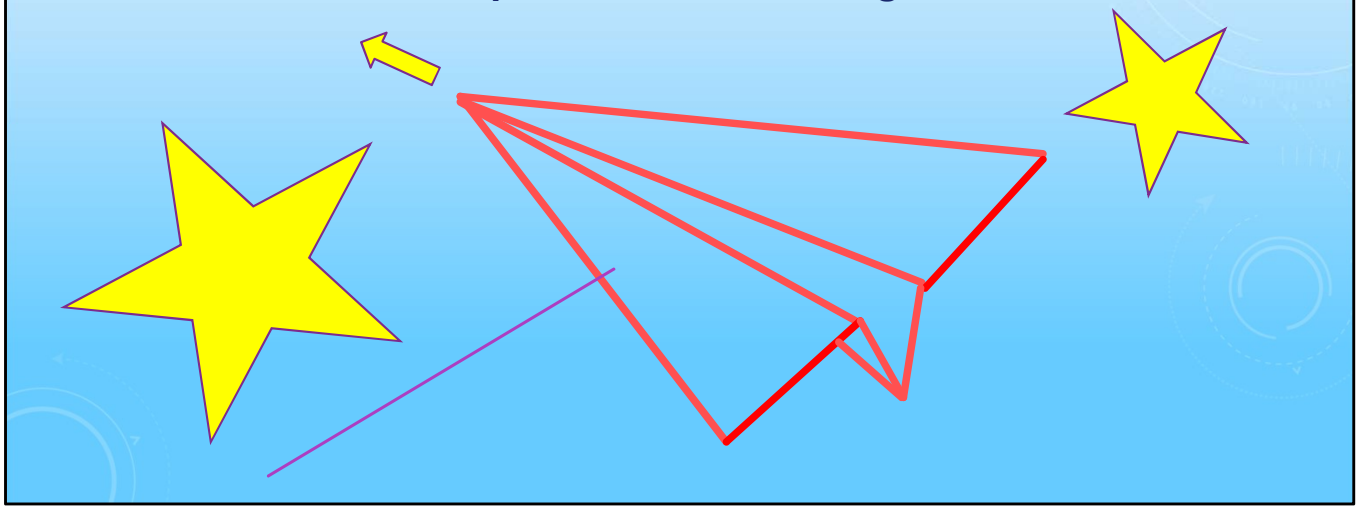
COOPERATORS: 39 STUDENTS, CLASS 1, YEAR 2, OKAYAMA PREFECTURAL TAMANO HIGH SCHOOL

- I have a favor to ask of you before starting this workshop.
- If you can hear this sound, please stop working, and listen to me.
- My name is Manabu Fujita, from Okayama Prefectural Tamano High School.
- Today we will be looking at “Learning About the Flight Stability with a Tethered Paper Plane.”
- I have some second grade science class students who are here to help me.
- They are my homeroom class students.

TODAY'S GOAL IS ...

To make a TETHERED PAPER PLANE, study the flight stability, and draw an interest in the importance of stable flight.



- First, I would like to tell you today's goal.
- You are going to fold paper to make a "tethered paper plane," which is a paper airplane with a tether attached.
- Then, you are going to check flight stability.
- The goal is to draw an interest in the importance of stable flight.
- Finally, I hope this can expand your dream to space.

TAMANO HIGH SCHOOL STUDENTS ARE STUDYING MODEL ROCKETS.

- What triggered me to think up this workshop is the research on model rockets conducted by Tamano High School students.
- What made us start this research is that we were engaged in the Girls' Rocketry Challenge, an undertaking for our female students to learn rocket engineering with the support of Lockheed Martin Corporation last year.
- This shows the rocket launching.
- The rocket flies to a height of about 40 m.

OUR SCHOOL HAS PARTICIPATED IN THE NATIONAL CHAMPIONSHIPS OVER THE PAST TWO YEARS. THIS YEAR OUR WOMEN'S TEAM WON THE CHAMPIONSHIP.

FLIGHT STABILITY IS IMPORTANT TO WIN THE NATIONAL CHAMPIONSHIPS.

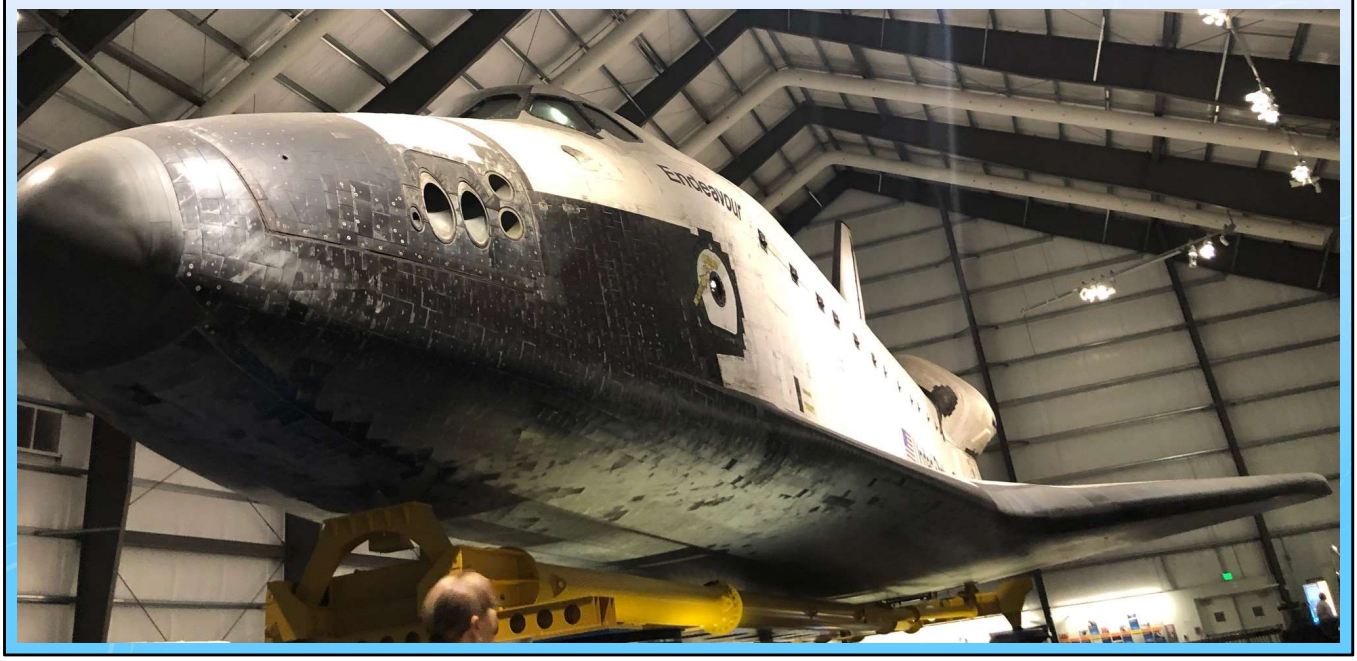
- For the last two years, we participated in the national championships.
- This year, our women's team took first place among all the women's teams in the national championships.
- Flight stability is important to win the national championships.
- This workshop consists of several missions.
- Let's start the workshop!

1st MISSION
Learn about flight stability.

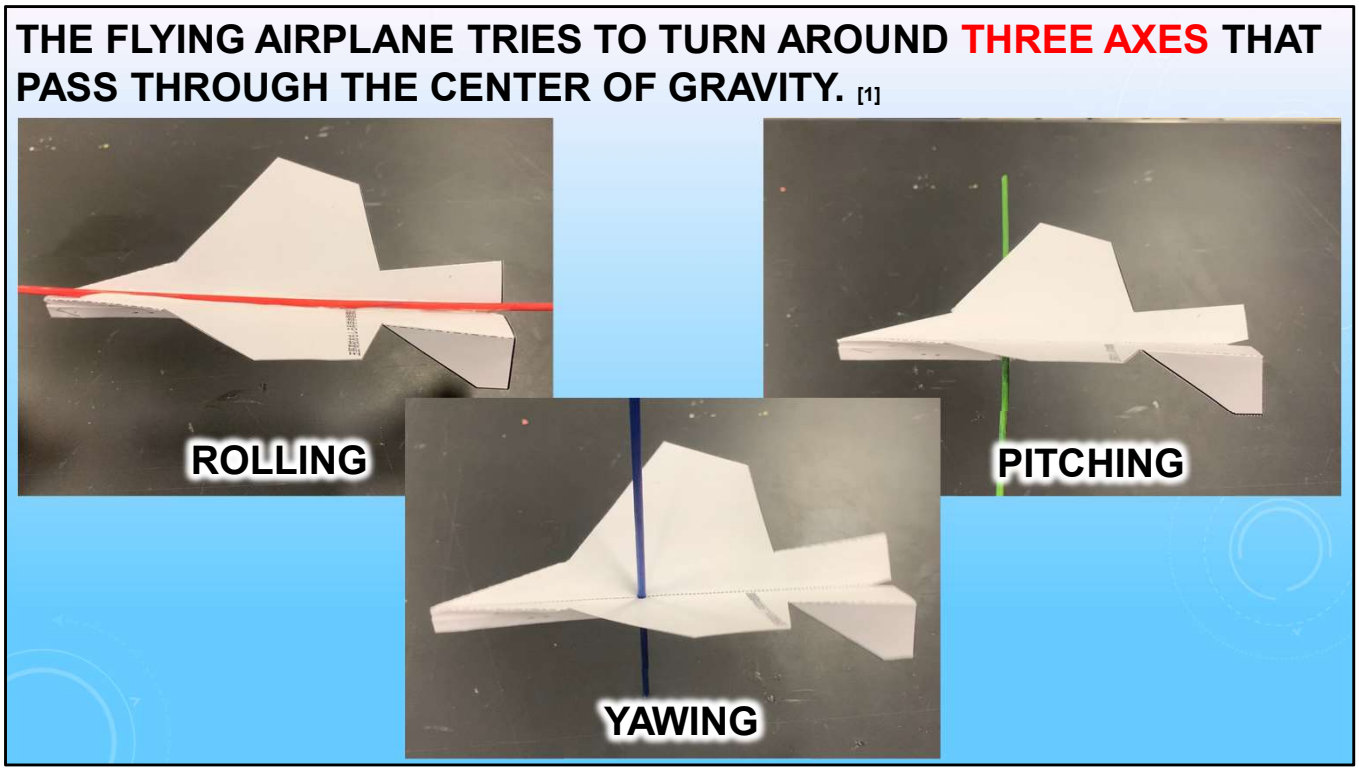
1st mission

Learn about flight stability.

THE WINGS ON THE SPACE SHUTTLES NEED WINGS TO FLY STABLY IN THE ATMOSPHERE.

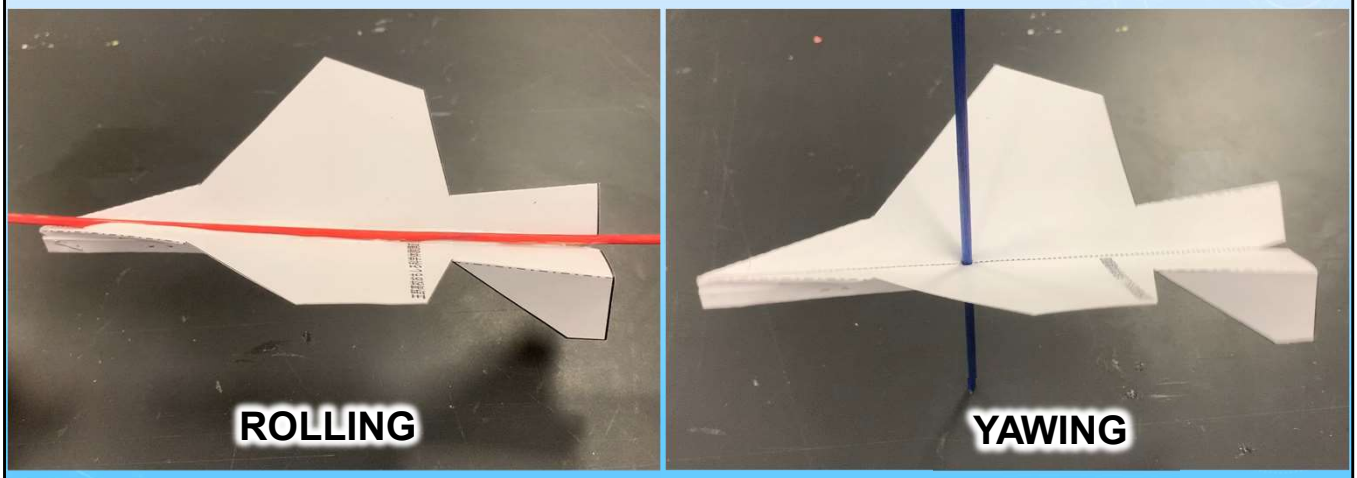


- When I think about NASA, the first thing that comes to mind is this space shuttle.
- I also like the beauty of this body design very much.
- But I do also wonder, why does the space shuttle have wings?
- Wings serve no purpose in space.
- But we know that space shuttles are launched and return to earth many times and that they need wings to fly stably in the atmosphere.
- if the airplane has wings, can it fly stably?
- Let's think about flight stability with paper airplane.

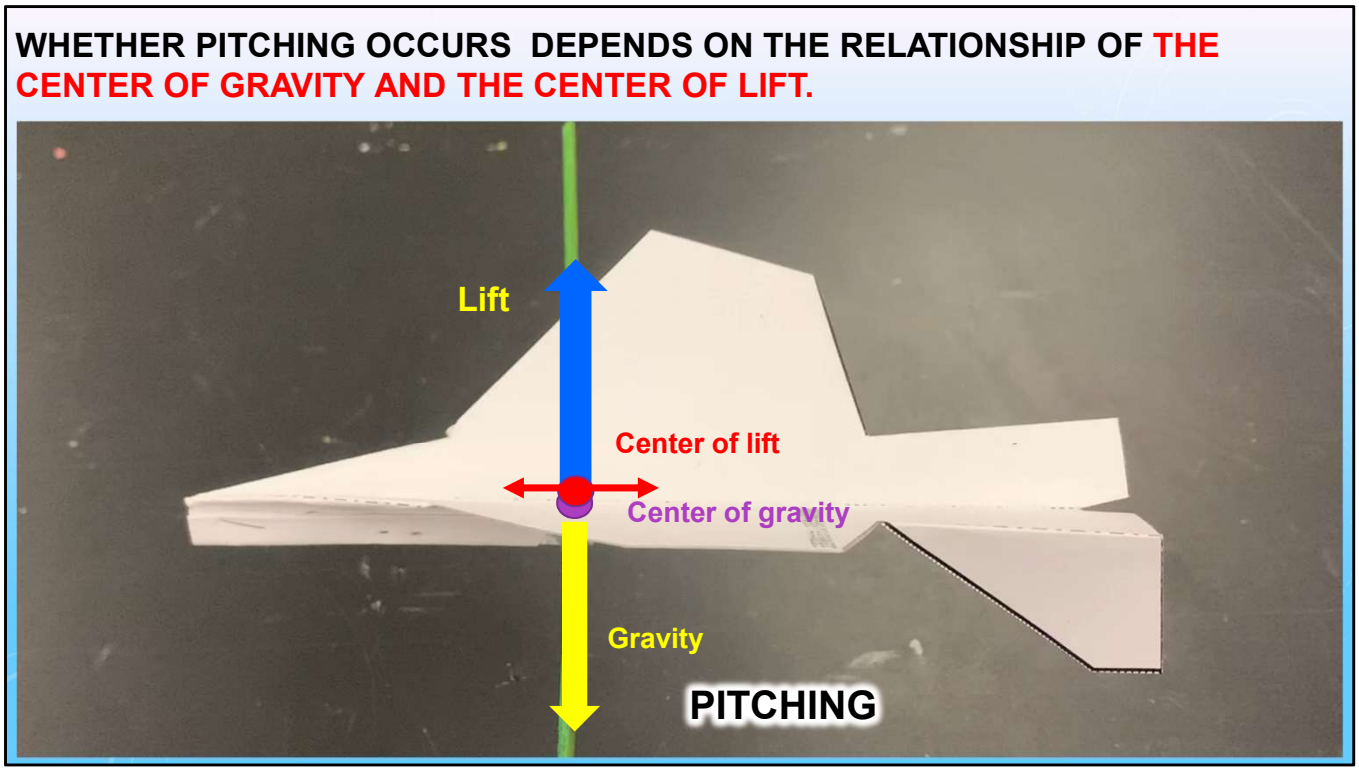


- The flying airplane also tries to turn around three axes that pass through the center of gravity, depending on the force exerted on the airplane.
- These turns are called rolling, yawing and pitching.
- To achieve stable flight, the rotation around these three axes must be suppressed.

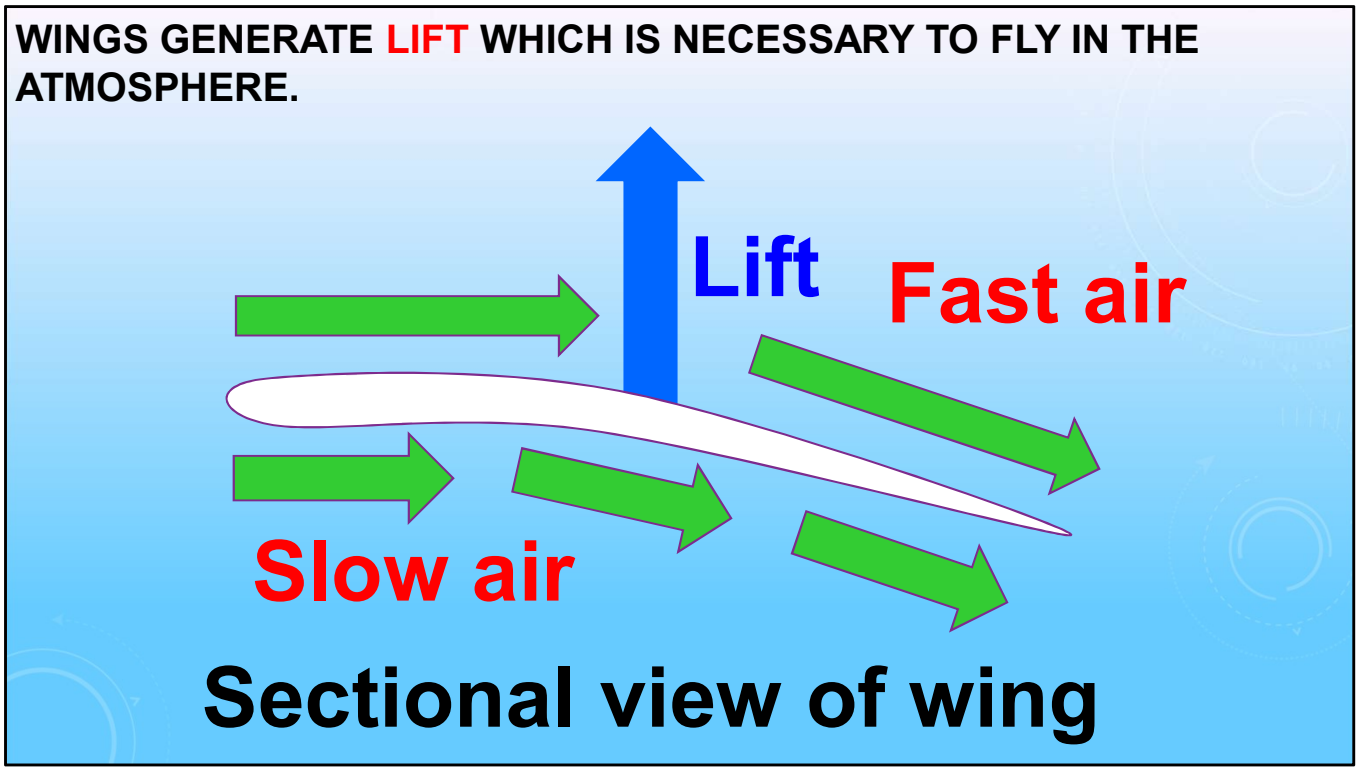
ROLLING AND YAWING CAN BE SUPPRESSED BY MAKING PAPER AIRPLANE SYMMETRICAL.



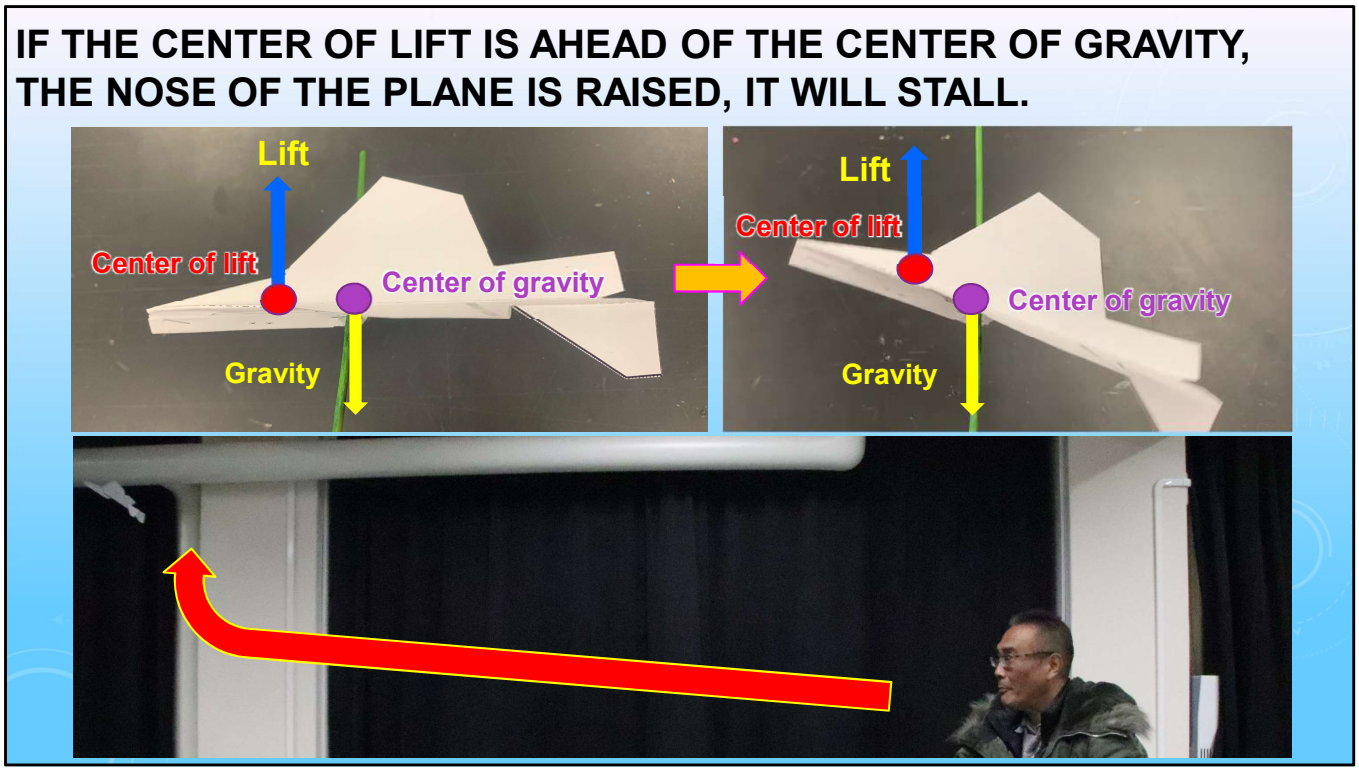
- **Rolling and yawing can be suppressed by making paper airplane symmetrical.**



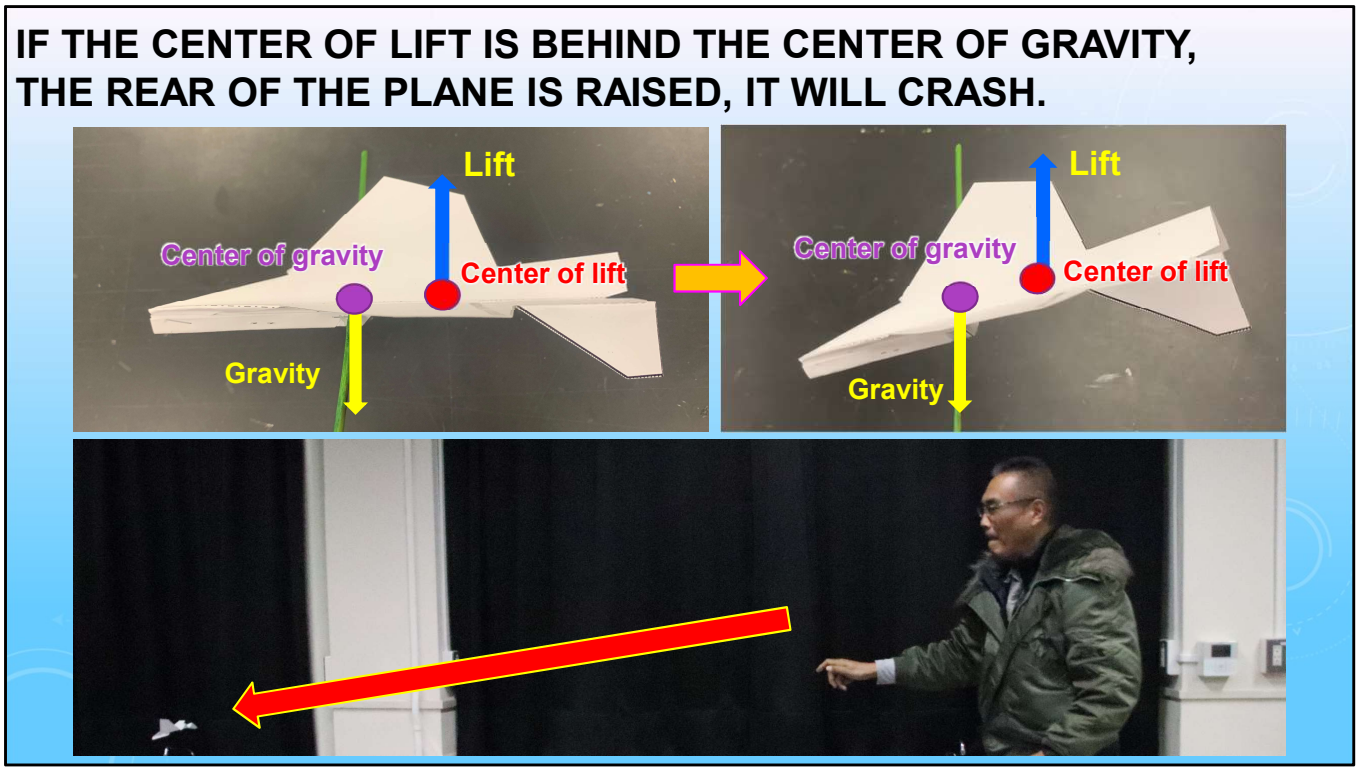
- **Whether pitching occurs depends on the relationship of the center of gravity, at which gravity acts, and the center of lift, at which lift acts.**



- So wings generate lift which is necessary to fly in the atmosphere.
- Lift is the upward force generated by the pressure difference resulting from the difference in the velocity of air flowing over and under the wings.

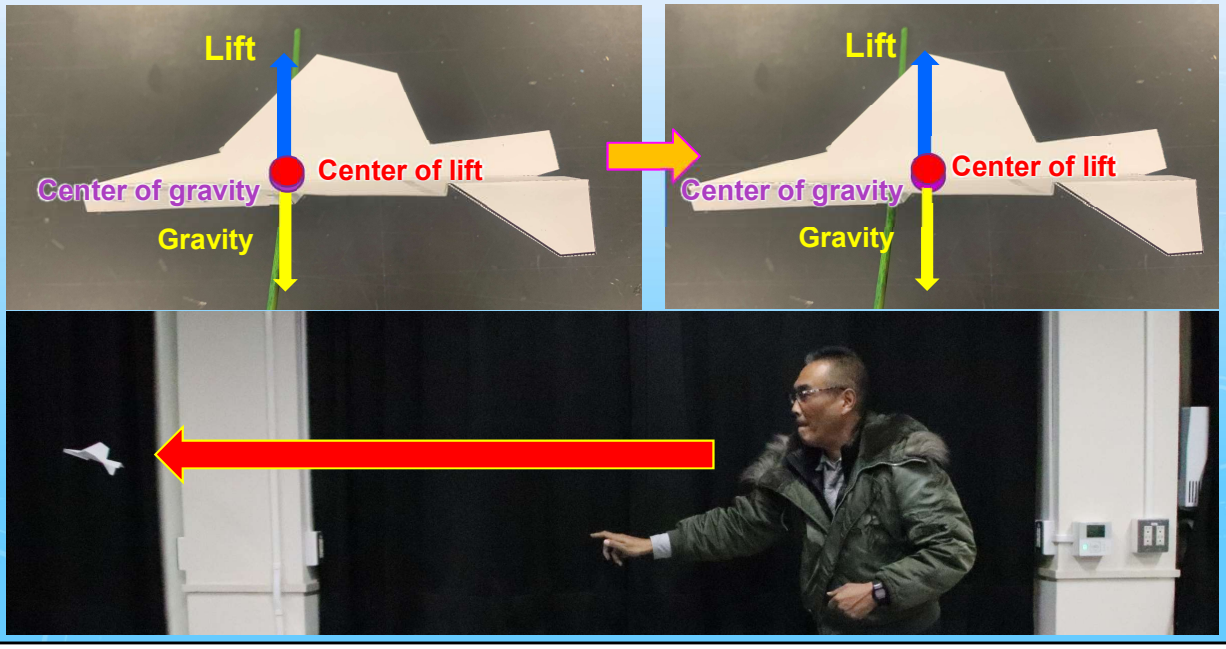


- **If the center of lift is ahead of the center of gravity, the nose of the airplane is raised, and it will stall.**



- **If the center of lift is behind the center of gravity, the rear of the airplane is raised, and it will crash.**

IF THE CENTER OF GRAVITY MATCHES THE CENTER OF LIFT, THE AIRPLANE FLIES STABLY WITHOUT PITCHING.



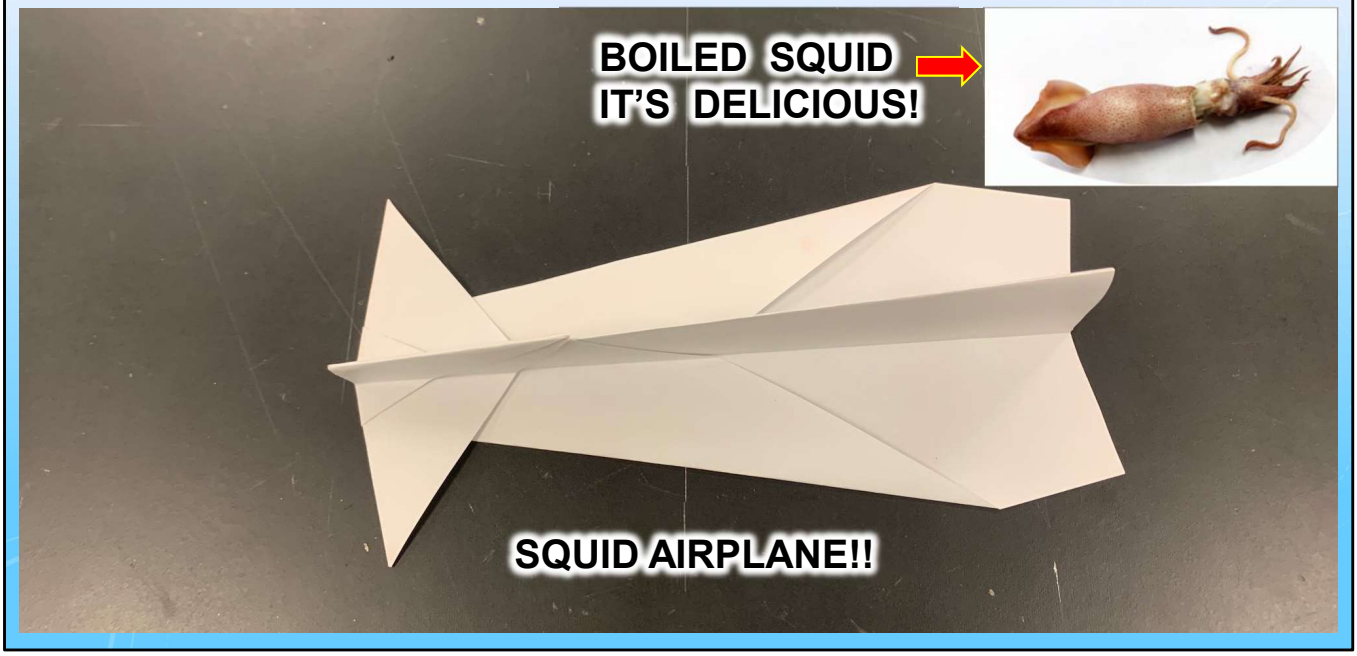
- If the center of gravity matches the center of lift, the airplane flies stably without pitching.
- How can make a paper airplane which does not occur pitching.

2nd MISSION
Make a paper airplane.

2nd mission

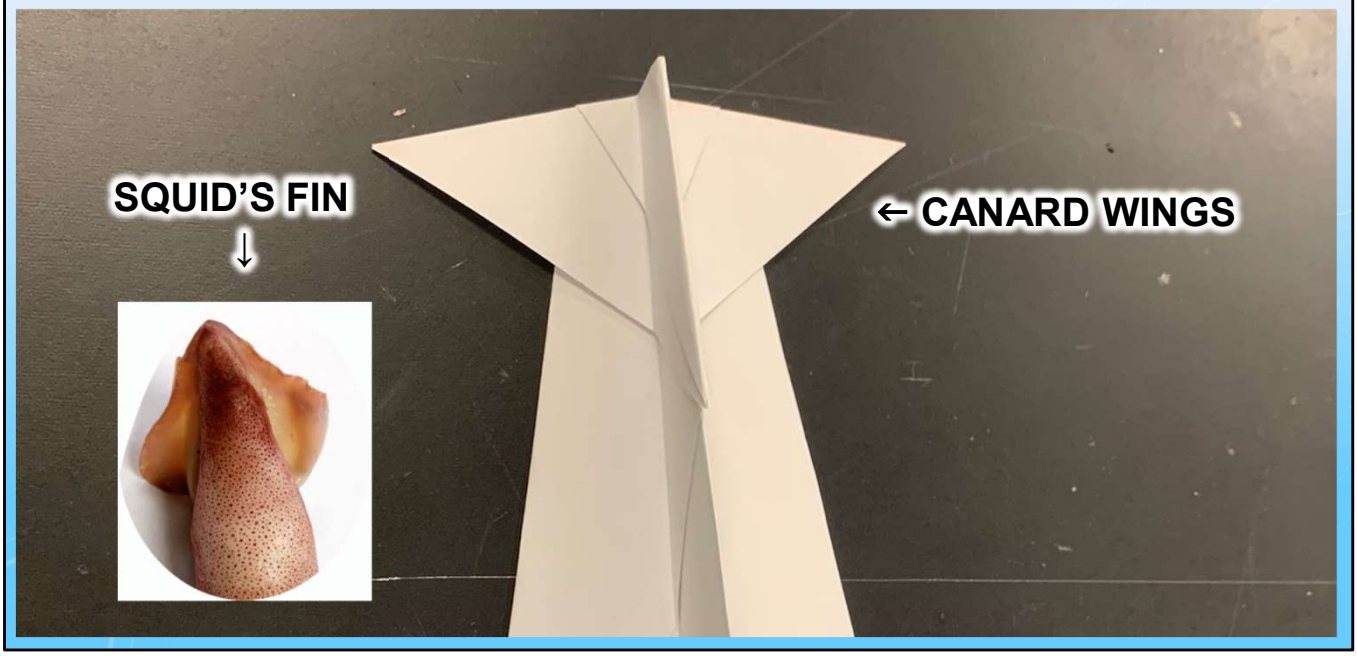
Let's Make a paper airplane!

YOU ARE GOING TO MAKE THIS TRADITIONAL JAPANESE PAPER AIRPLANE.



- Today, you are going to make this traditional Japanese paper airplane
- And check flight stability with this paper airplane.
- By the way, this paper airplane is called a squid airplane.

THIS PAPER PLANE HAS A UNIQUE SHAPE. IT HAS CANARD WINGS AT THE NOSE OF THE PLANE.

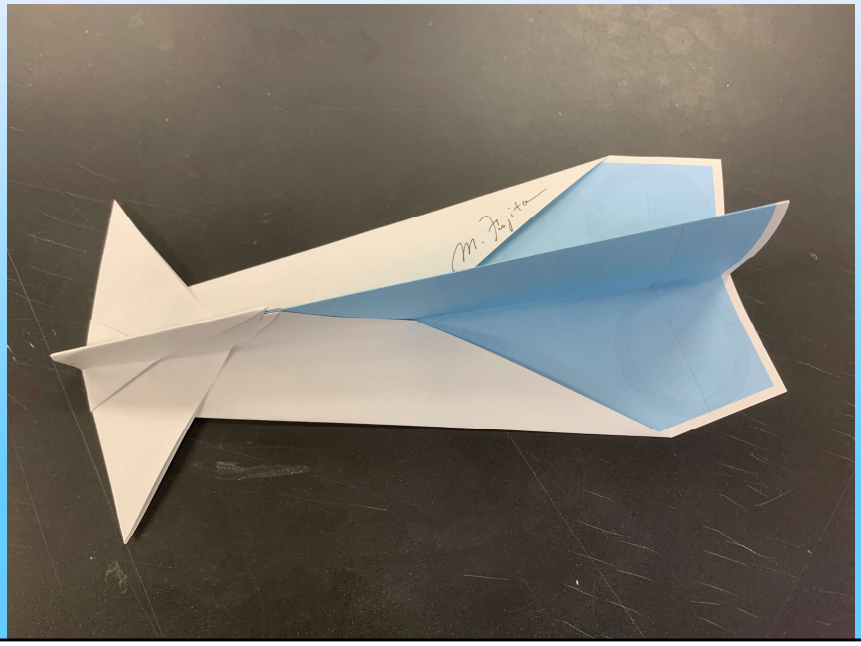


- I chose this paper airplane because it has a unique shape.
- It has small wings near the nose like squid's fins, which are called canard wings.
- Lift acts on these canard wings in addition to the main wings behind them.
- This means it will be difficult to achieve balance between gravity and lift with this type of plane.

JAPANESE PEOPLE ARE SQUID LOVERS AS THEY CONSUME ONE QUARTER THE WORLD'S SQUID. [2]

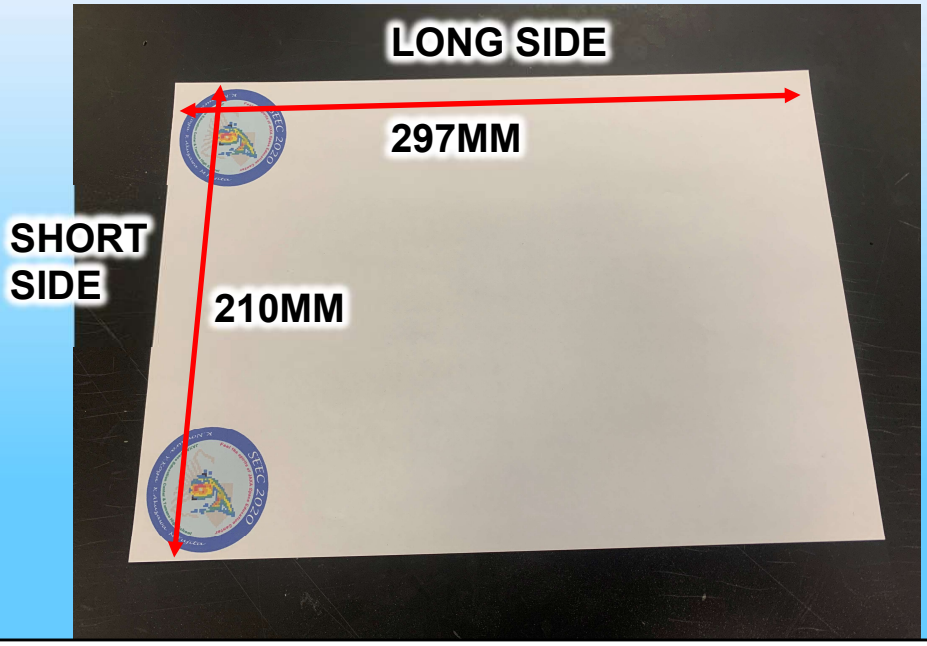
- Another reason is that Japanese people love squid.
- They consume about one quarter of the world's squid.
- Lots of fresh squids are sold at the fish market near our school.

LET'S MAKE A SQUID AIRPLANE TOGETHER!



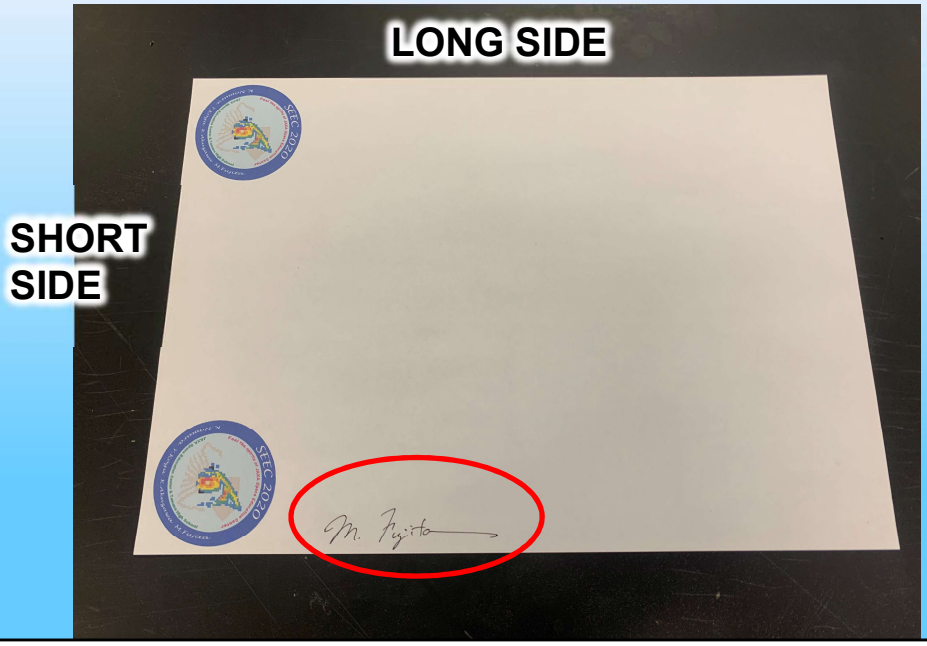
- **Now, let's make a squid airplane together, step-by-step.**

1) PREPARE AN A4 (210 MM X 297 MM) PAPER SHEET.



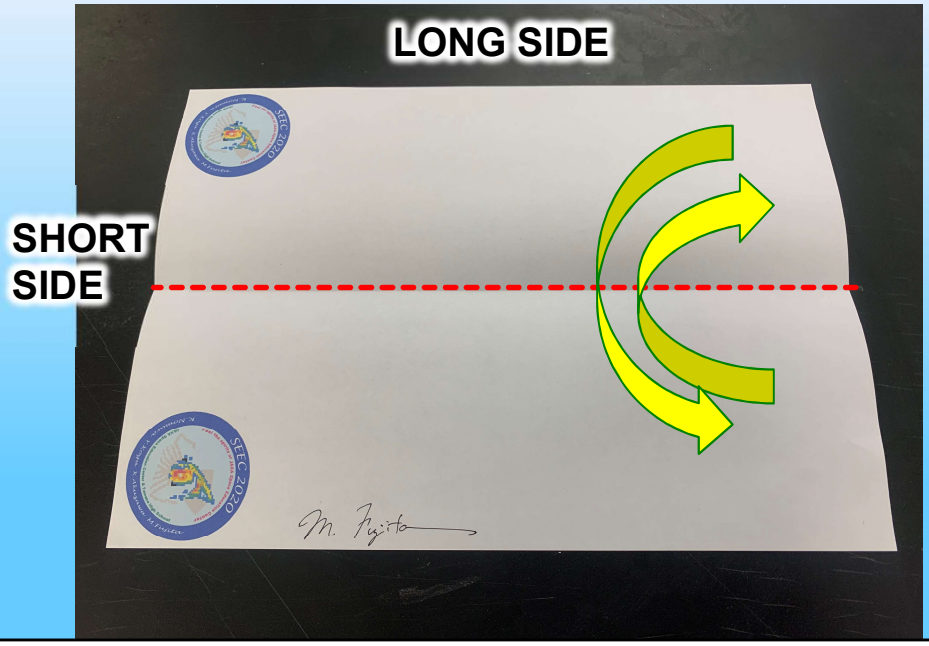
- The size of the paper is standard copy paper available in Japan.
- Put a paper sheet on the desk like this picture.
- You can also use letter size paper sheets.

2) WRITE YOUR NAME ON THIS PAPER SHEET.



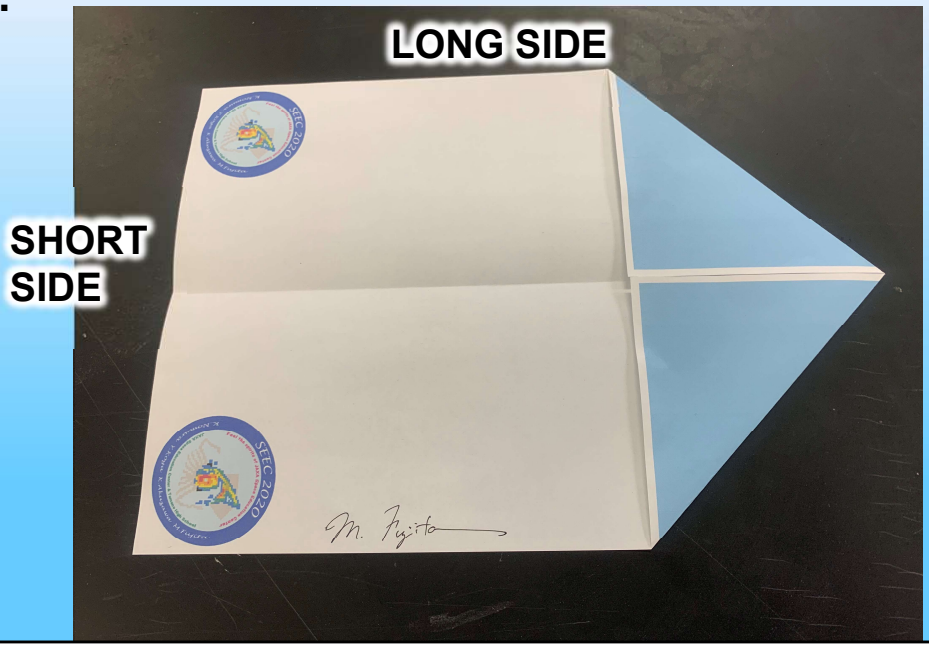
- **Write your name on this paper sheet.**

3) MAKE A LINE IN THE CENTER OF THE SHORT SIDE.



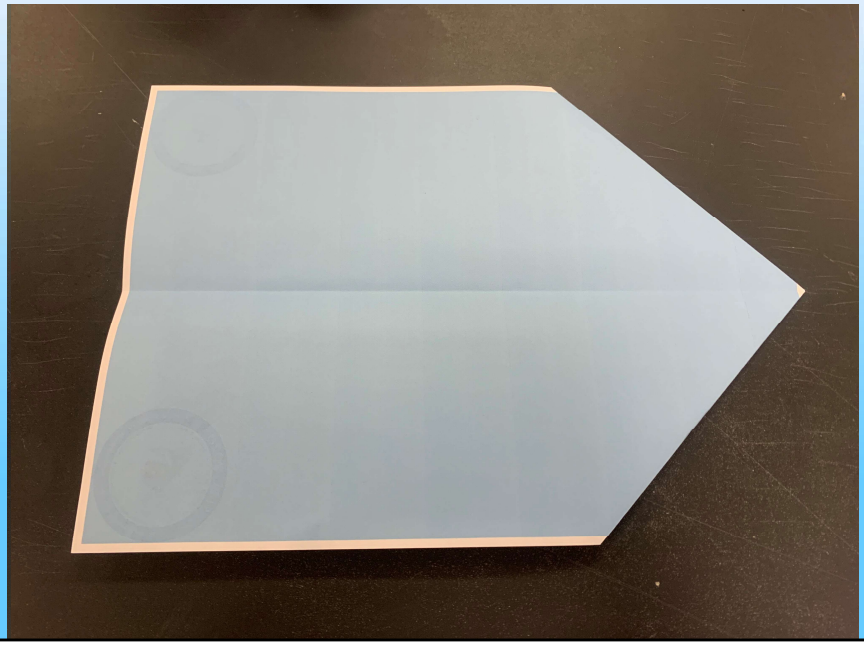
- **Make a line in the center of the short side.**

4) FOLD TWO SMALL TRIANGLES TOWARDS THE CENTER LINE.



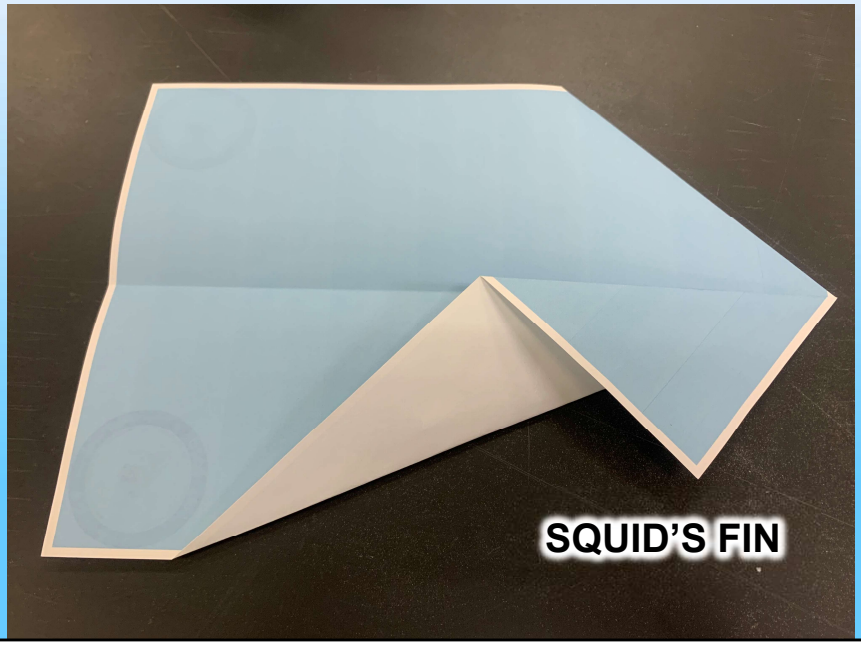
- Fold two small triangles towards the center line.

5) TURN IT OVER.



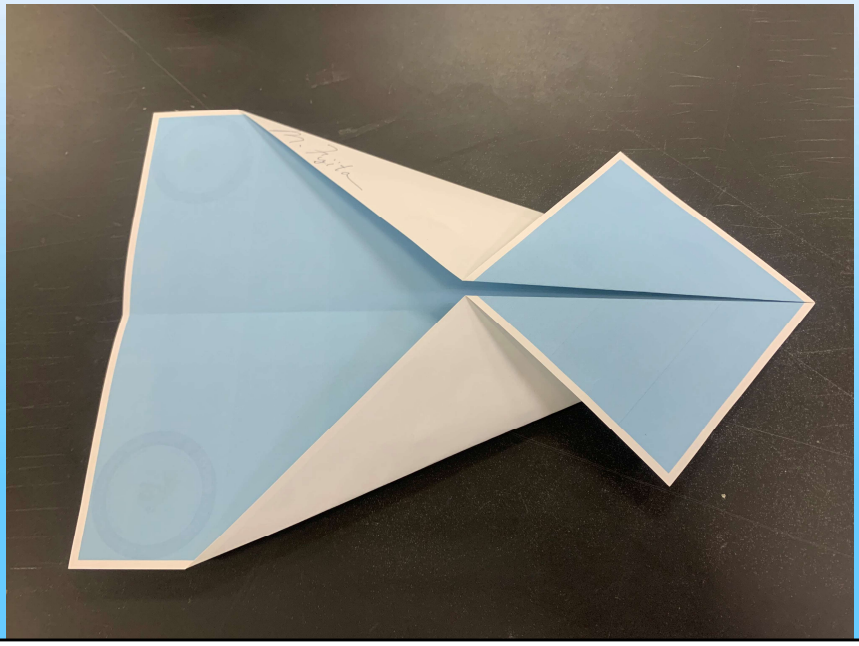
- **Turn it over.**

6) FOLD THE DIAGONAL SIDE TO THE CENTER LINE. THEN PULL THE SQUID'S FIN OUT.



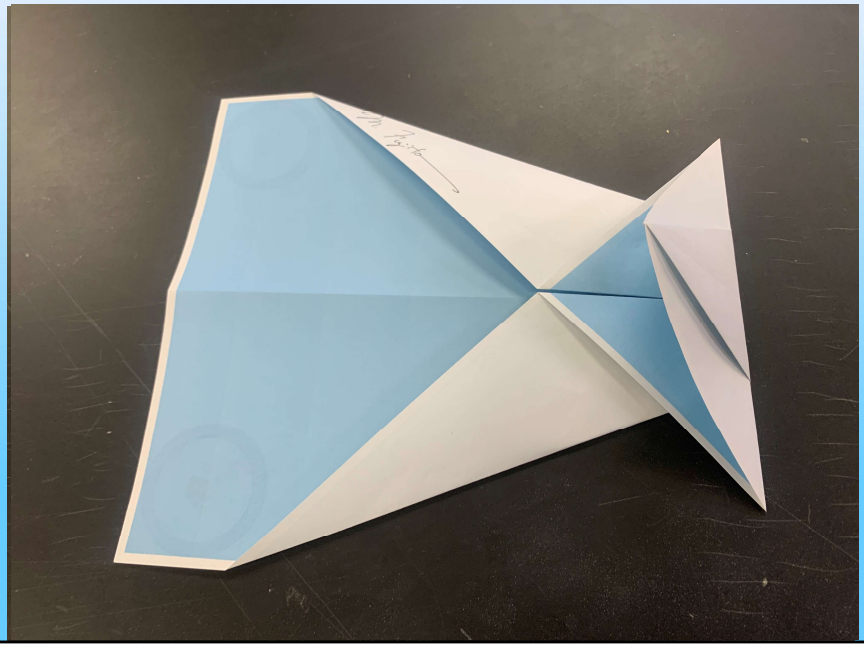
- **Fold the diagonal side to the center line.**
- **Then Pull the squid's fin out.**

7) FOLD THE OTHER SIDE THE SAME WAY.



- **Fold the other side in the same way.**

8) FOLD THE FINS IN HALF.

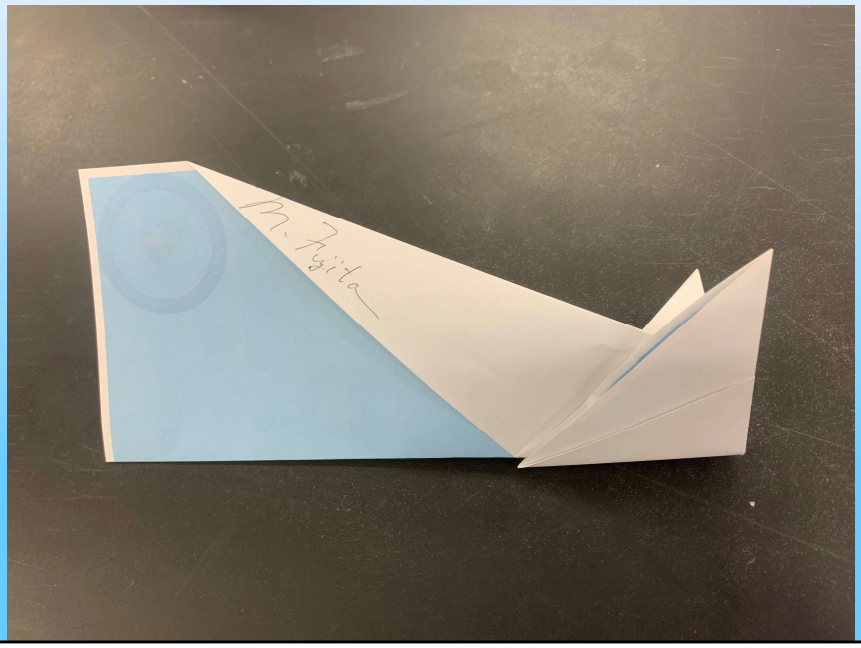


- **Fold the fins in half.**

9) TURN IT OVER AGAIN.

- **Again, turn it over.**

10) FOLD THE PLANE IN HALF ALONG THE CENTER.

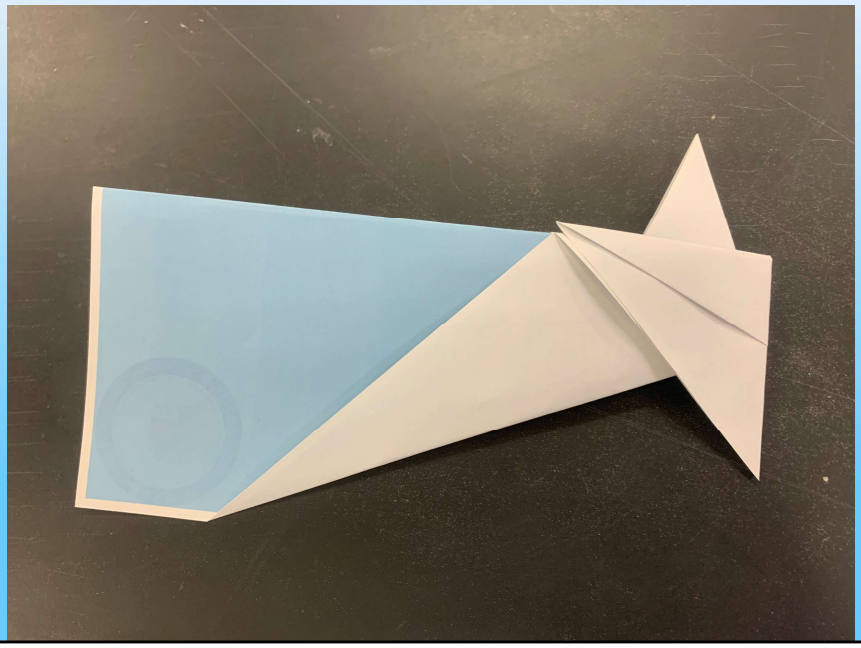


- **Fold the plane in half along the center.**

11) FOLD THE WINGS.

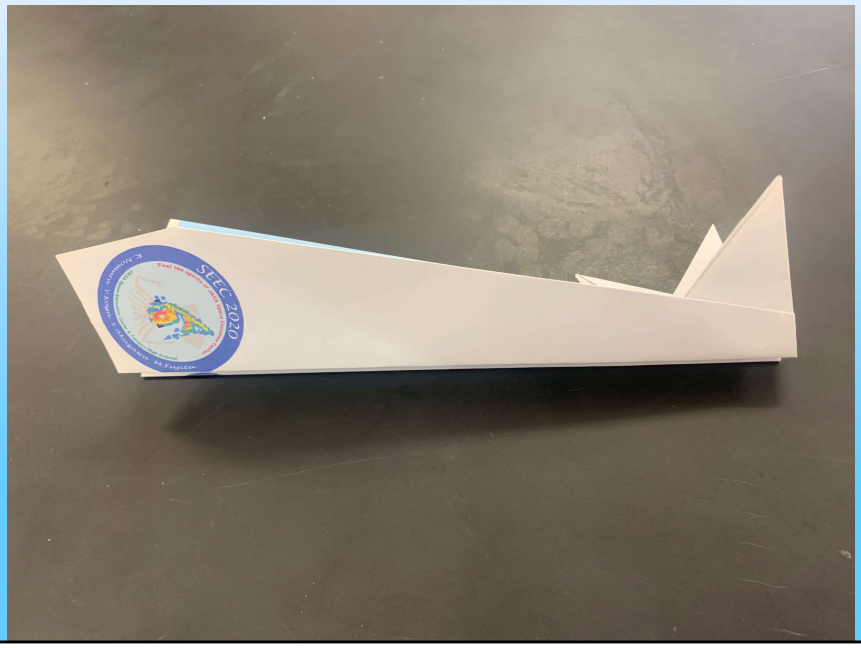
- **Fold the wings so that the diagonal side overlaps the center line.**
- **The important point to remember here is to fold the part including the fins made earlier.**

12) TURN IT OVER.



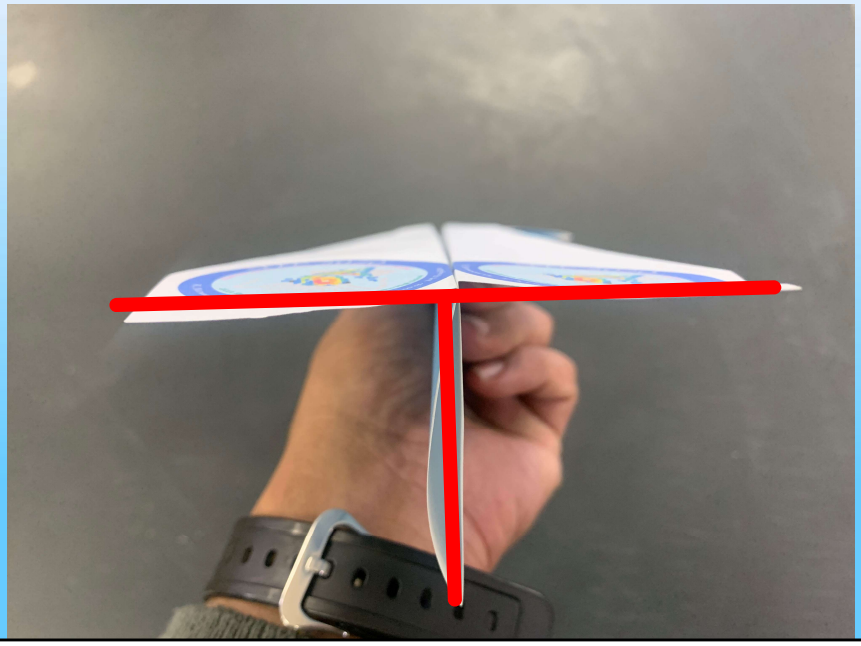
- **Turn it over.**

13) FOLD THE OTHER WING.



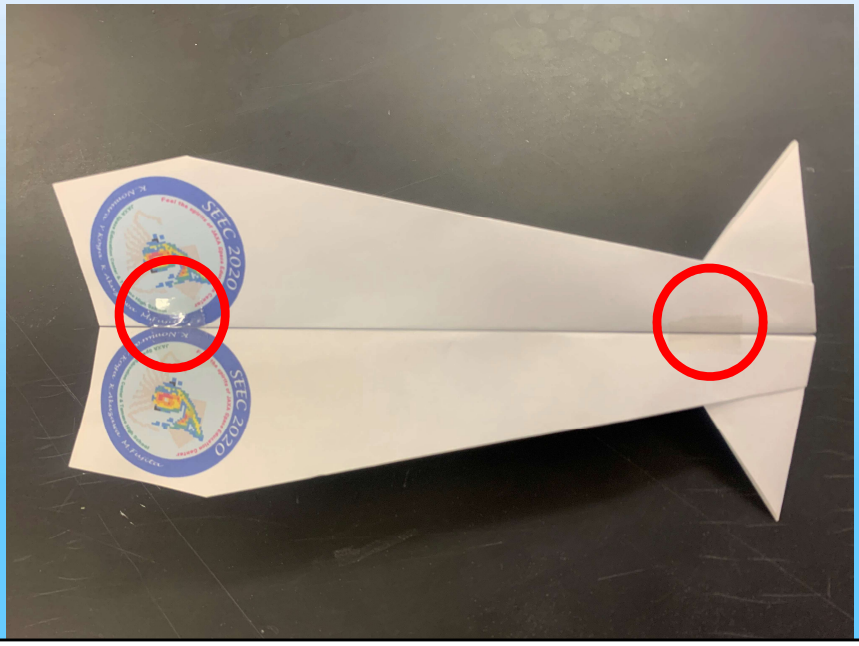
- **Fold the other wing.**

14) OPEN THE WING SECTION.



- Open the wing section.
- The point here is to check if it creates a T shape when seen from behind.

15) PLACE TAPE ON TWO PLACES.

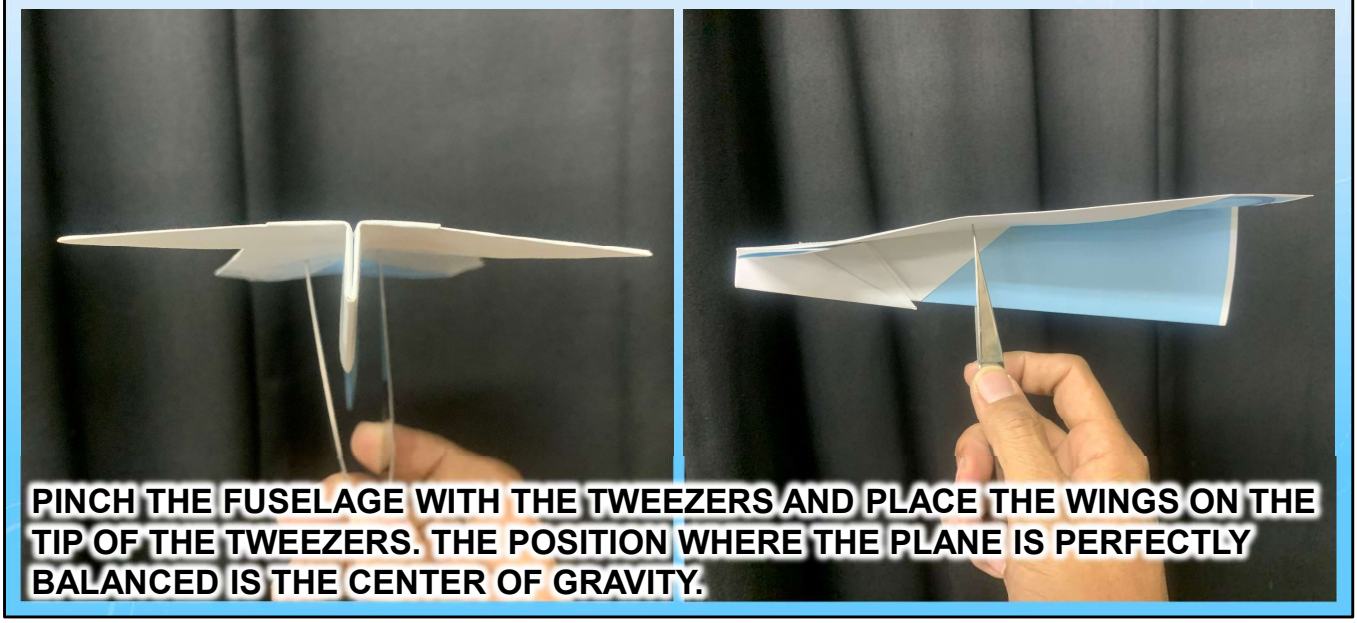


- **Place tape on two places so that the airplane won't open when you attach the tether and swing it around.**
- **It's done.**

3rd MISSION
Find the center of gravity.

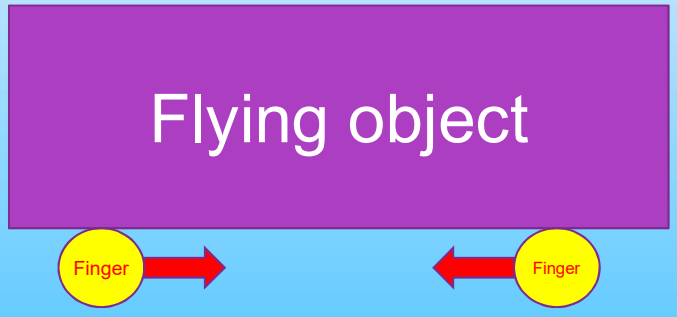
- **Find the center of gravity of squid airplane.**
- **Here are two methods to do that.**

LET'S PLACE THE PLANE ON A PAIR OF TWEEZERS AND FIND THE CENTER OF GRAVITY.



- The first method, you use a tweezers.
- Pinch the fuselage with the tweezers and place the wings on the tip of the tweezers.
- The position where the plane is perfectly balanced is the center of gravity.

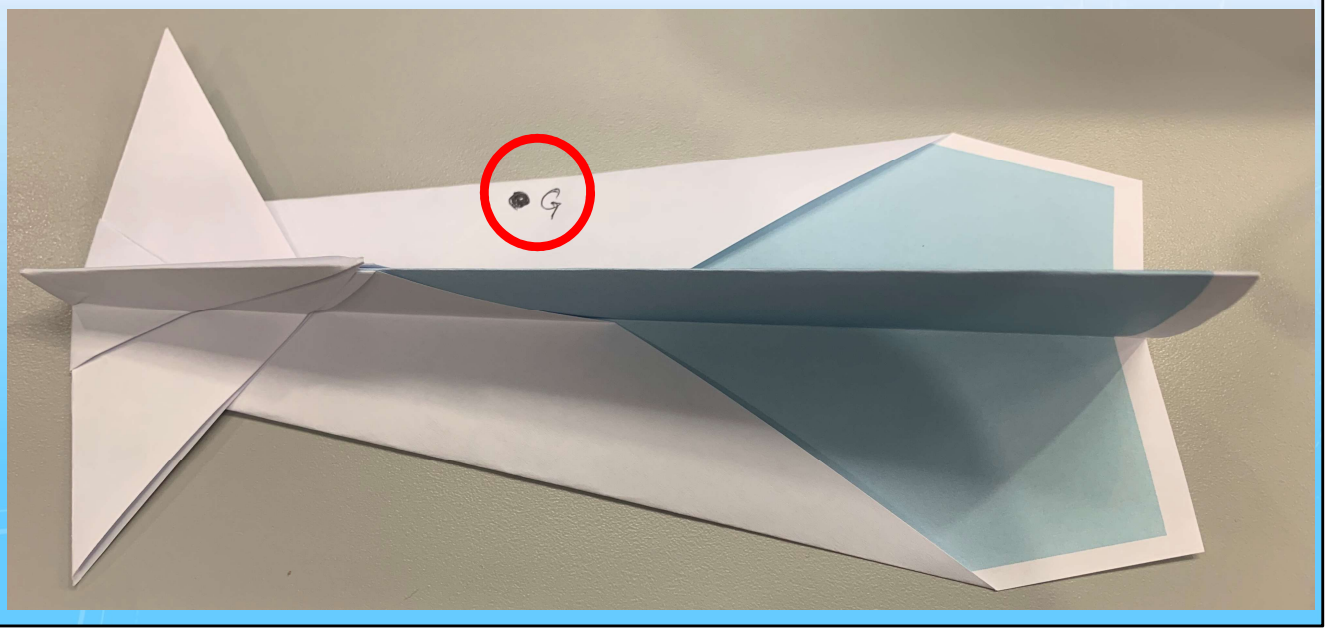
IF YOU CANNOT PINCH IT WITH TWEEZERS, USE TWO FINGERS TO FIND THE CENTER OF GRAVITY.



Move slowly to find the center of gravity.

- **The second method, you use two fingers.**
- **Place squid airplane on two fingers and slowly bring your fingers together.**
- **The center of gravity is where the two fingers meet.**

MARK THE END OF THE WING WHERE THE CENTER OF GRAVITY IS LOCATED.



- **Mark the end of the wing where the center of gravity is located.**
- **Let's find the center of gravity of your squid airplane using 1st or 2nd method.**

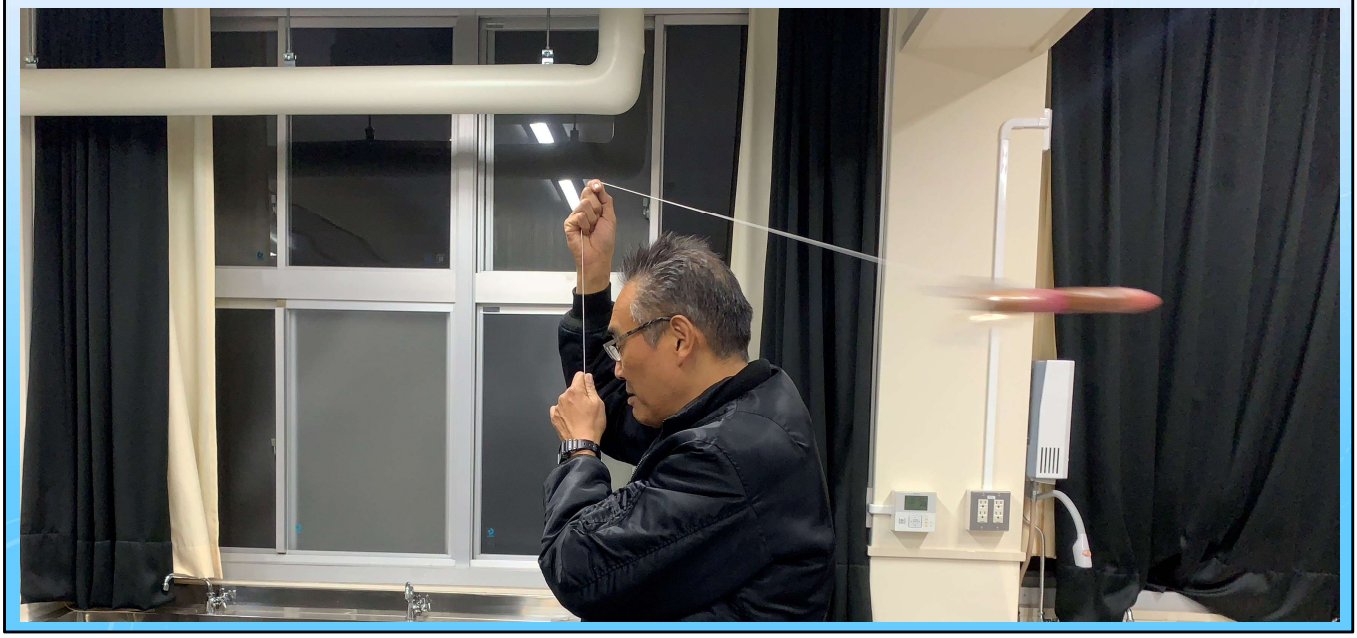
4th MISSION
Conduct the swing test.

4th MISSION
Conduct the swing test.

HOW CAN YOU CHECK FOR PITCHING WITHOUT TEST FLIGHT?

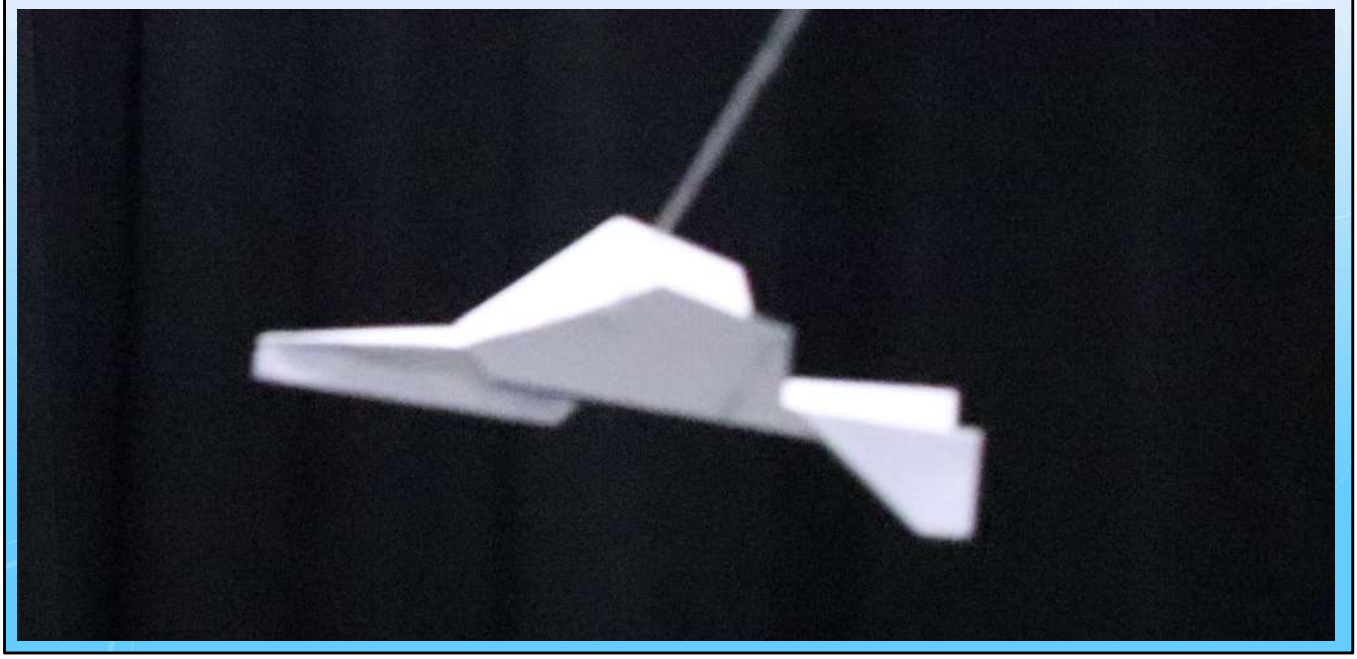
- So I'm going to ask you a question
- If you can't take a test flight, how can you check for pitching without test flight?
- For example, there is no place to fly or it costs money to fly like a real rocket or a model rocket.
- This is the theme of this workshop.

IN THE CASE OF A MODEL ROCKET ONE WAY TO CHECK FLIGHT STABILITY IS THE SWING TEST.



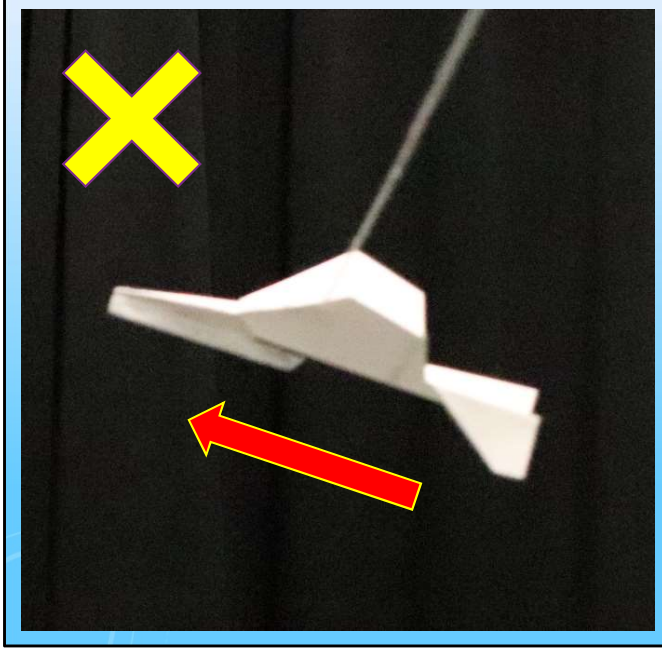
- In the case of a model rocket, one way to check flight stability is the swing test.
- We attach a tether to the rocket's center of gravity or behind the center of gravity and swing it around above our heads.
- Let me show you.
- What can you learn by attaching a tether to a paper airplane and doing the same test?

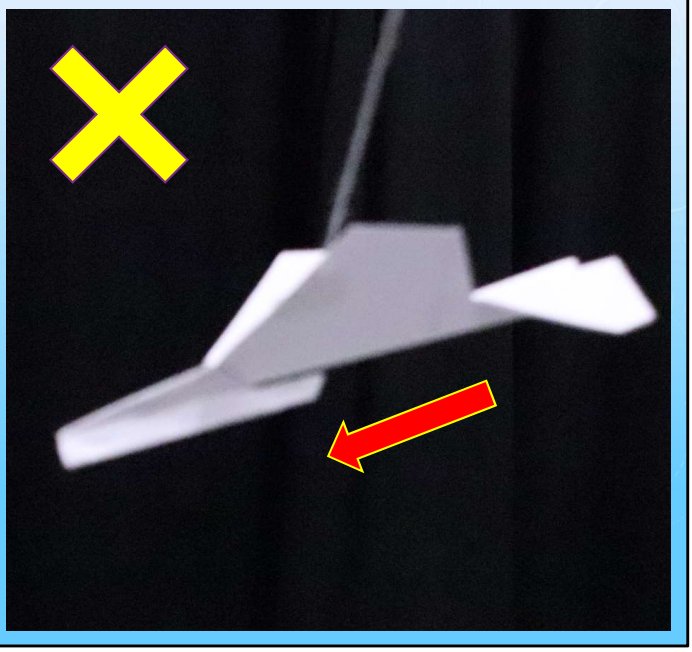
BY ATTACHING A TETHER TO A PAPER AIRPLANE AND DOING THE SWING TEST, WE CAN CHECK FOR PITCHING!



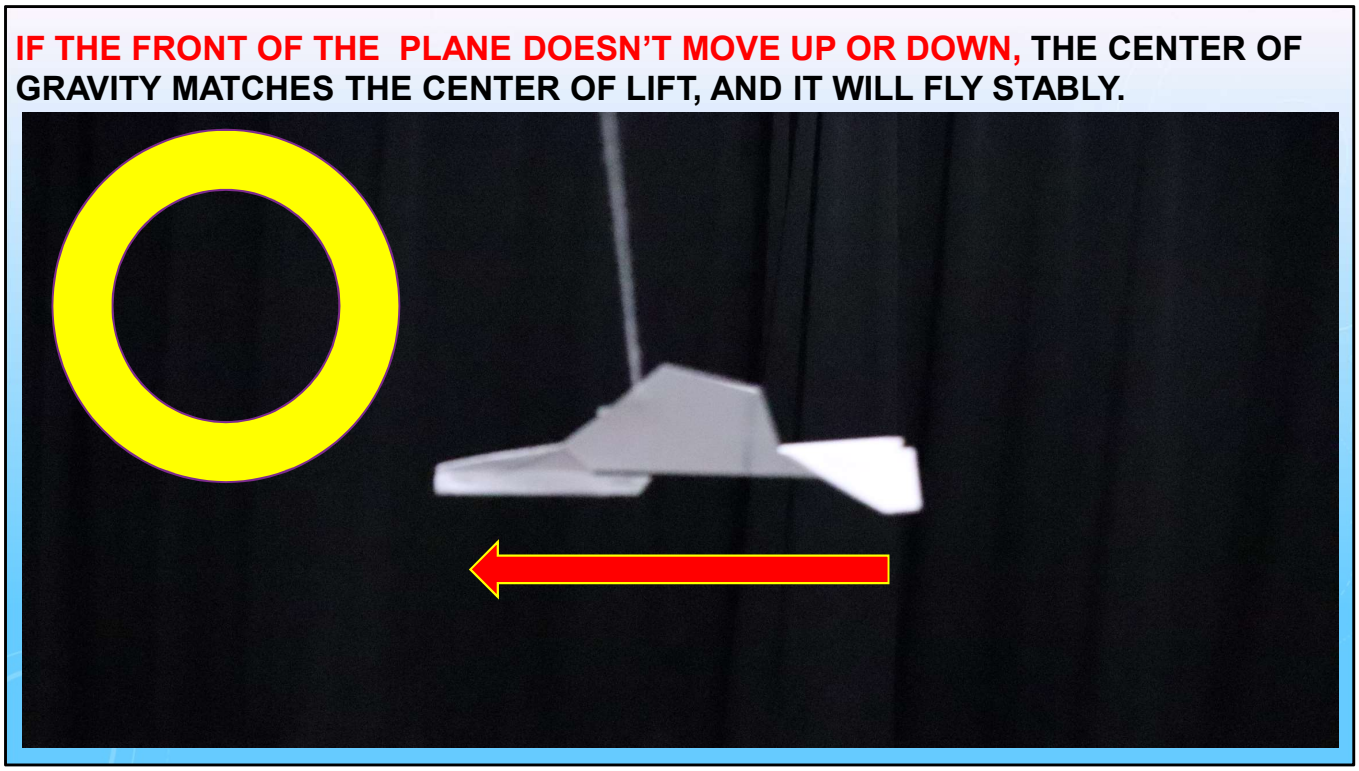
- **By attaching a tether to a paper airplane and doing the swing test, we can check for pitching!**
- **We attach a tether to the airplane's center of gravity and swing it around above our heads.**
- **And you can feel the flight stability directly through the tether.**

IF THE NOSE OR REAR OF THE PLANE IS RAISED, THE PITCHING IS HAPPENING.



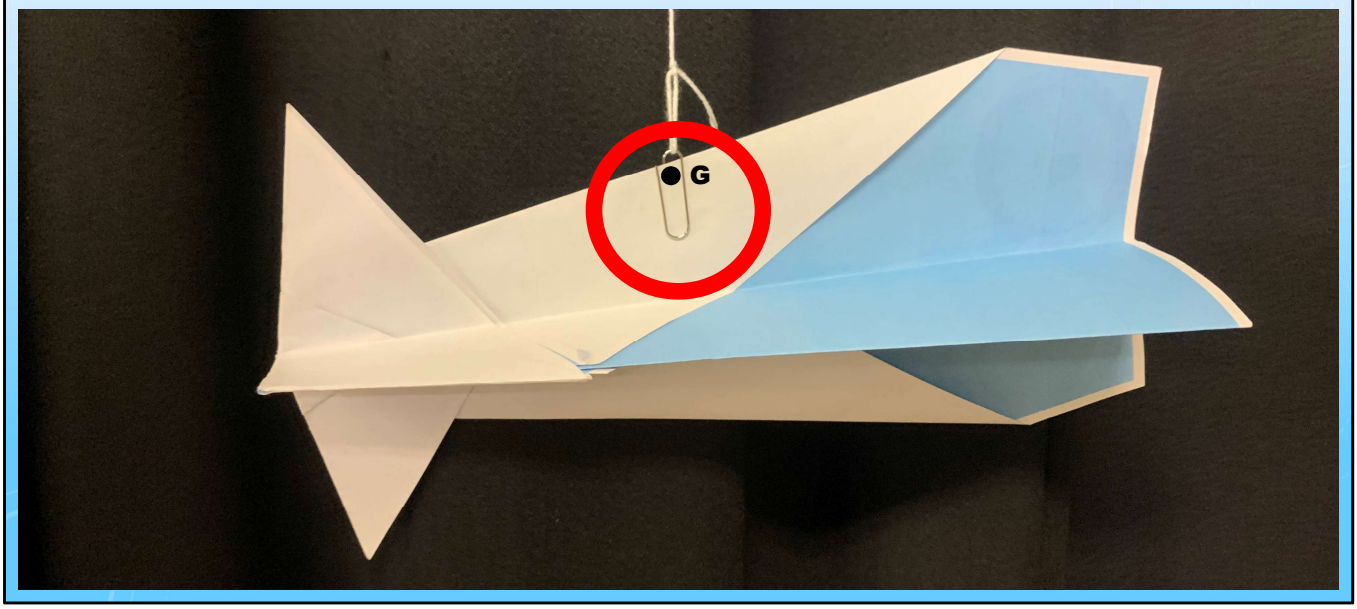


- **Here are the bad results of the swing test.**
- **If the front or rear of plane is raised, the pitching is happening.**



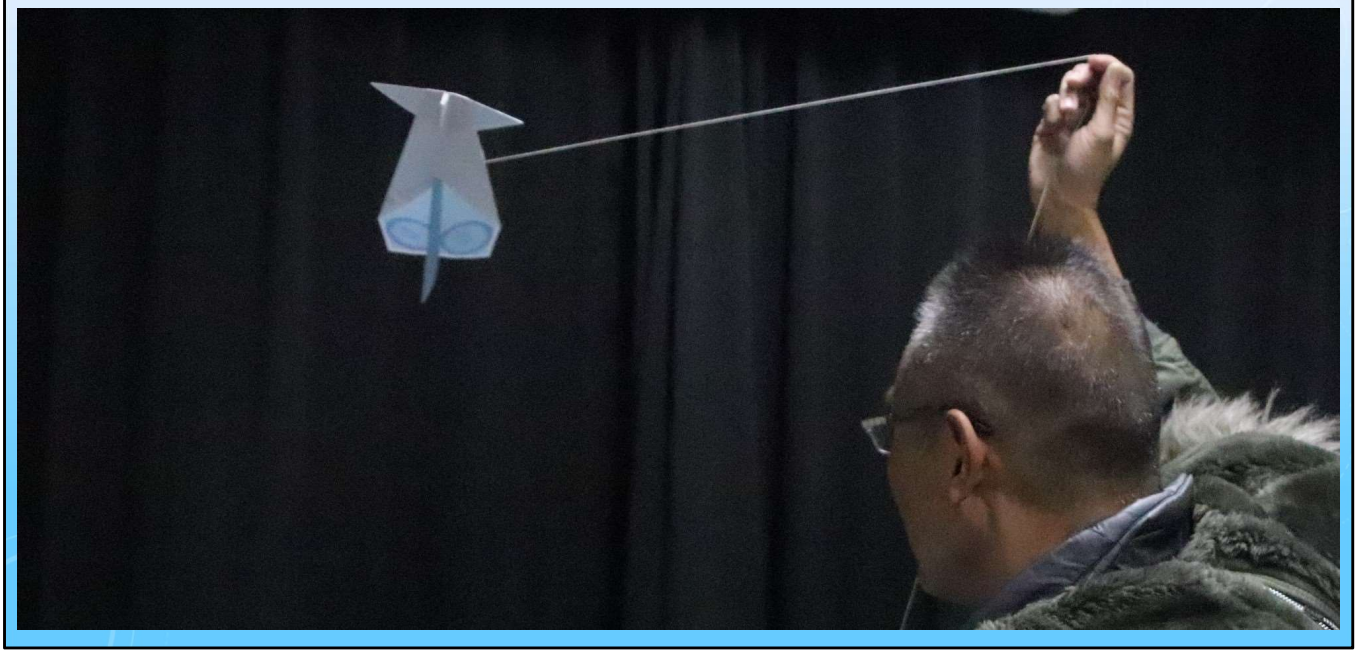
- **If the front of the plane doesn't move up or down, the center of gravity matches the center of lift, and it will fly stably.**

ATTACH A CLIP WITH TETHER TO THE END OF THE WING WHERE THE CENTER OF GRAVITY IS LOCATED.



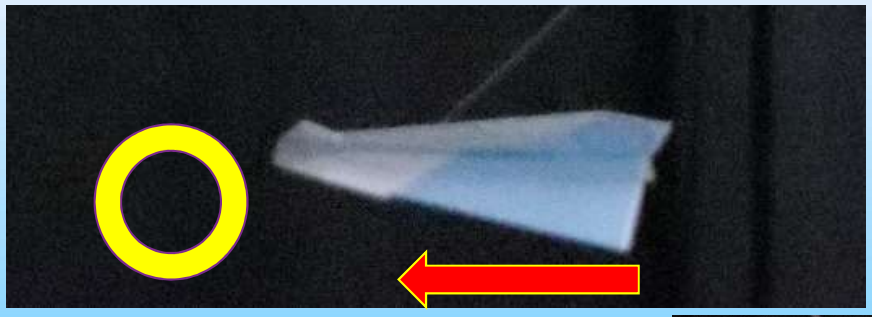
- **Attach a clip with tether to the end of the wing where the center of gravity is located.**
- **If you cannot attach a clip, you can attach the tether with tape.**

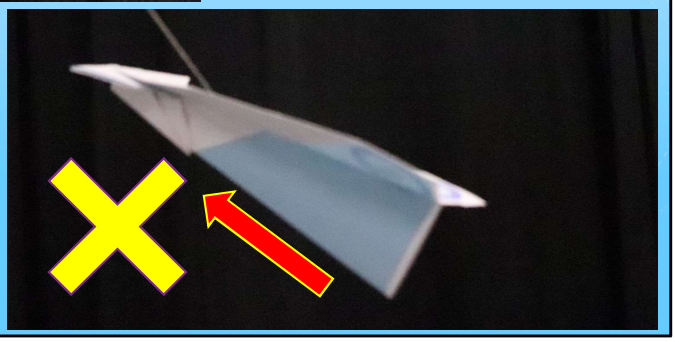
CHANGING THE SPEED, CHECK IF YOUR PLANE FLIES STABLY.



- Check to see if the plane remains stable, especially when swinging it around slowly.
- Let's conduct a swing test with changing the swing speed, and check the flight stability.

HOW CAN WE MAKE THE PLANE FLY STABLY?



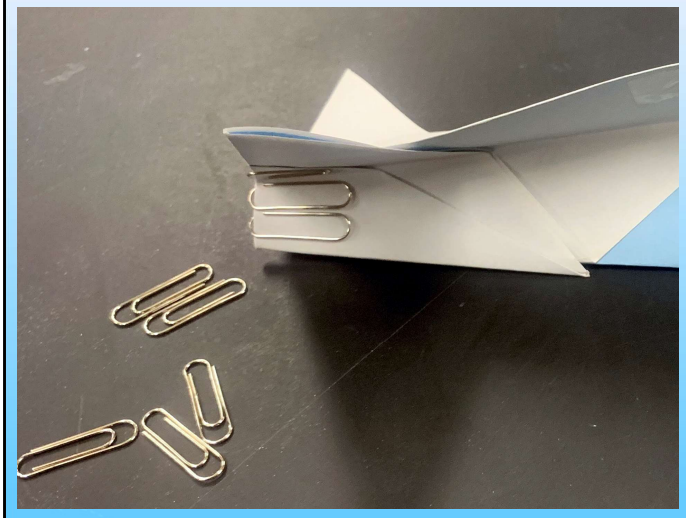


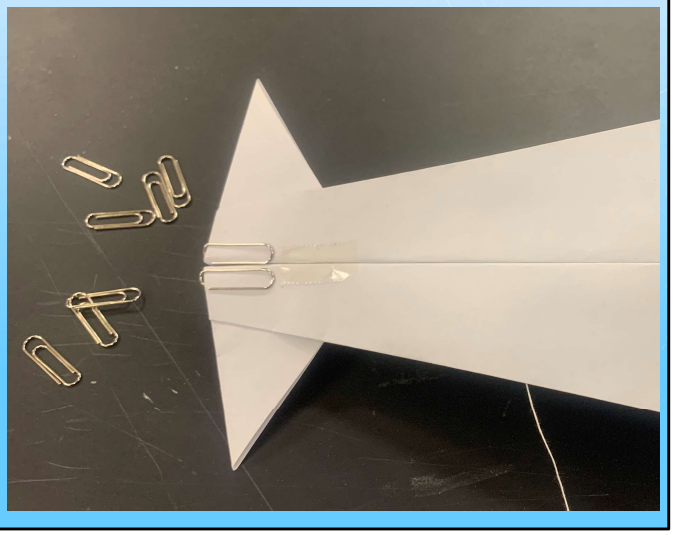
- What was the results of the swing test?
- The top picture shows a stable flight.
- The bottom picture shows this squid airplane almost stalling as its nose rises, particularly when the speed slows down.
- Then, I will fly my squid airplane.
- It stalled as expected.
- What do we need to do to make our squid airplane fly stably as shown in the top photo?

5th MISSION

Let's make some adjustments.

LET'S CHANGE THE POSITION OF THE CENTER OF GRAVITY USING PAPER CLIPS.





- **Attach paper clips to the nose of airplane to move the center of gravity forward to prevent the nose from rising.**
- **Let's make some adjustments while increasing the number of paper clips and conduct the swing test to check if squid airplane flies stably.**
- **How many paper clips do you need?**
- **Let's try it!**

TODAY'S LAST MISSION

Let's fly your squid airplane.

WHEN YOU ARE SURE THE PLANE SWINGS AROUND STABLY IN THE SWING TEST, REMOVE THE TETHER AND TRY TO THROW IT.

- **When you are sure the plane swings around stably in the swing test, remove the tether and try to throw it.**
- **Make sure you do not throw it at anyone!**
- **Push straight ahead.**

HOMEWORK

- **Here, I will give you some homework.**

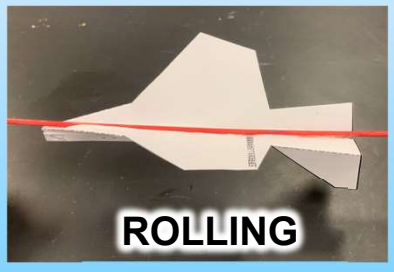
HERE, I WILL GIVE YOU SOME HOMEWORK.
LET'S TRY THE SWING TEST USING VARIOUS FLYING OBJECTS.

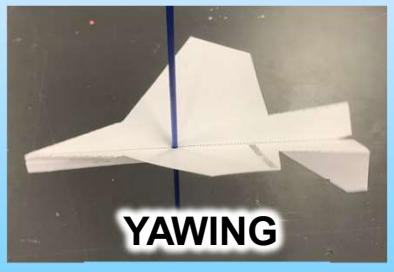
- Let's try the swing test using various flying objects.
- Then, find some stable flying objects.
- You can also use letter size paper sheets.

REVIEW OF TODAY

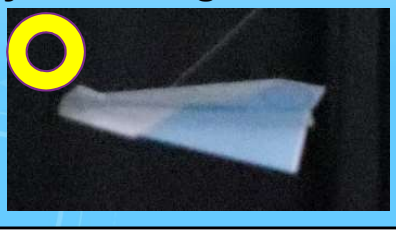
TO ACHIEVE STABLE FLIGHT, WHAT YOU NEED IS ....

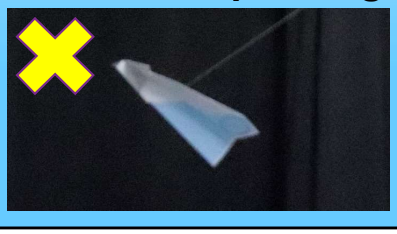
Control of rotation of the flying object around these axes.





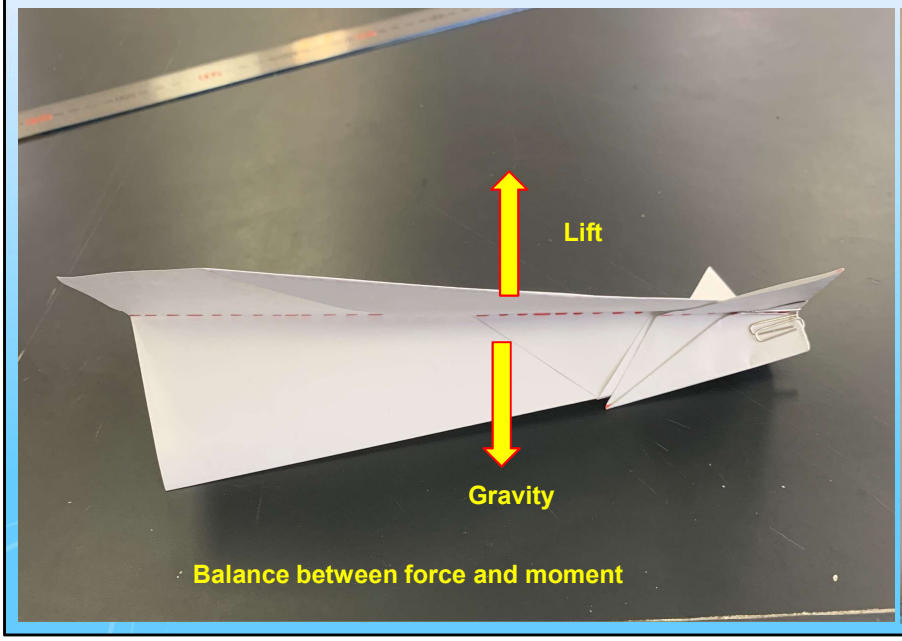
By the swing test, we can check for pitching.





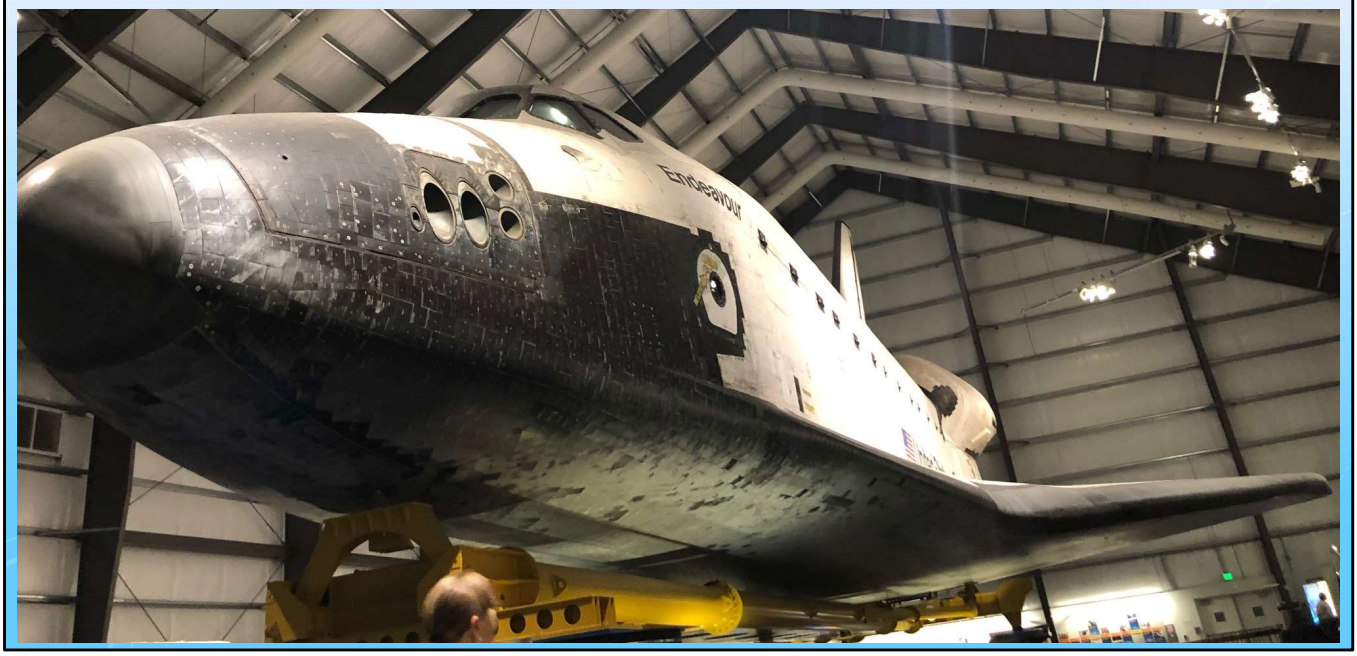
- **Let's go back over the conditions required to achieve stable flight.**
- **To achieve stable flight, what you need is control of rotation around these axes.**
- **By the swing test, we can check for pitching without test flight and feel the flight stability directly through the tether.**
- **It is very important to repeat the test many times.**

I ALSO APPLY THIS IN MY CLASSES.



- I am a physics teacher, and I use these principles in the field of dynamics, such as force, moment equilibrium, or circular motion.

I HOPE YOU CAN EXPAND YOUR DREAMS TO SPACE.



- **Today you made your tethered paper plane and conducted the swing test.**
- **Did these activities help to create an interest in the conditions necessary for an airplane to fly stably in the atmosphere?**
- **I'd be very happy if you came to draw an interest in this study, and to expand your dream to space through this workshop.**

[REFERENCE LITERATURE]

[1] “Learning the Principle of Flight from Paper Airplanes” authored by Akio Kobayashi

Kodansha BLUEBACKS (1988)

[2] The National Cooperative Union of Squid Processors

http://www.zen-ika.com/ika/ika-to-nipponjin.html

- Here are some references.

Thank you for your attention.

This is a mission patch designed for this workshop.
(It contains hurricane and squid.)
Did you notice?

- **Thank you for your attention.**