

Logbook Science Fair 2026

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Topic: Effect of Wing Flexibility on Glider Efficiency

Topic Description: This project investigates how wing flexibility affects the performance. Using small-scale models, we can accurately test wing ratios, gliding, sink rate, and much more.

30/10/2025:

We, Ansh & Chris, both joined the CYSF with intentions of getting experience in the engineering field. After doing the APEGA Science Olympics 2025, we both really enjoyed it but wanted to dive deeper into the realm of STEM based projects, thus leading us to CYSF [1-2].

1/11/2025:

After searching and brainstorming for project ideas, we have come up with these requirements in our project:

- Aerospace engineering related (we both are interested in this field)
- Experimental
- Hands-On
- Relevant in the modern world

Our ideas that we came up with based on these requirements are:

- Angle of attack vs lift
- Winglets and fuel efficiency
- Center of mass and aircraft technology
- Rocket fin design and stability
- Propeller design vs thrust
- Surface texture and drag
- Effect of wing flexibility on glider efficiency

After considering all these ideas, the most hands-on, relevant, and generally intriguing topic for us is "Effect of Wing Flexibility on Glider Efficiency". It speaks to us because it is related to both topics of engineering and aerodynamics. Other topics such as propellers and winglets are already studied [3-4]. Wing flexibility on the other hand, is less obvious but plays a huge role in aerospace. Real aircraft wings are designed

to flex to reduce stress, improve efficiency, and enhance safety, but are rarely explored in less complex models. This experiment allows us to investigate the tradeoff of flexibility and how it can improve and reduce performance.

08/11/2025:

After deciding our topic, we need to research what materials to use. Each material has a different flexibility, enabling us to find an optimal flexibility. Then we could pair the top 3 material's flexibility with materials used in industrial gliders and flying machines, thus giving us the best and optimal flexibility. We actually have decided to use 3 materials, but each material will have 1-3 layers, giving us a spectrum of flexibility. When we figure out which amount of flexibility is the most optimal in our experiment, we will find possible materials that can be used and also have the same amount of flexibility as the material in our experiment. Using this video, we know flexibility has been researched in commercial planes: <https://www.youtube.com/shorts/59wPLzyn408>

For example, a Boeing 787's wing maximum flexibility is nearly 26 feet [5-6]. With each wing being around 87 feet, we can determine that the flexibility is:

$$Fr \text{ (Flex Ratio)} = \frac{\text{Deflection at tip } (\Delta y)}{\text{Wing length } (L)}$$

$$0.2989 = \frac{26 \text{ ft}}{87 \text{ ft}}$$

Now how did I even get this formula? Well I created it. Using sources that describe that deflection is movement and directly correlates to flexibility [7-8]. Critical thinking skills asked me to question, what if I decided to use the max flex divided by the length of the wing to create a unitless number that fundamentally allows me to measure the flexibility ratio of a massive plane like a 787 compared to a miniature glider. The unit can be anything, as long as they are the same, which is another reason why this formula may be life changing. I coin the variable Fr flex ratio as it keeps it simple, steering it away from the unit force but making sure that the F and R don't look

like they multiply. Δy is the change in deflection at tip, from at rest to maximum flexibility. I named the deflection at tip Δy because it represents the change from rest to max, and why y , because it reminds me of a wing. L is obvious because it indicates length. Dividing it by the length of the wing gives us a reliable understanding and number of flex ratio, the higher the ratio, the higher the flexibility and vice versa. I would say though that as the experiment continues, I will divide the flexibility ratio into three groups. Stiff, medium-flexible, and high flexibility. These groups will be based on the ratio, for example anything below 0.05 may be stiff (again just example don't quote it). However this formula is of course not exactly accurate as some wings have a curvature when they flex, and throughout this project we will use this formula and other engineer verified formulas for each flexibility test. This formula works by calculating the diagonal/straight line from the deflections of tip and the start of the wing. I would say since most wings actually bend; $\Delta y < 25\%$ of L , this works accurately as there isn't enough bend to deter the final number.

But what materials will we use? We need 3 materials we can use that vary in flexibility and qualities, and are available in a household. Again, the best flexibility will be paired/matched with an industrial material of the same flexibility [9-10]. We will also calculate the weight to flexibility ratio to find out the optimal flex. Again our materials need to have these requirements:

- Available in a household
- Varying flexibility and qualities

After much discussion and consideration, we have agreed on these 3 materials [11-15]:

1. Regular Paper - Very high flex, extremely bendy and moldable
2. Thin Cardstock - Medium-Low, holds shape
3. Thin Poster Board - Low, Stiff, hold shape firmly

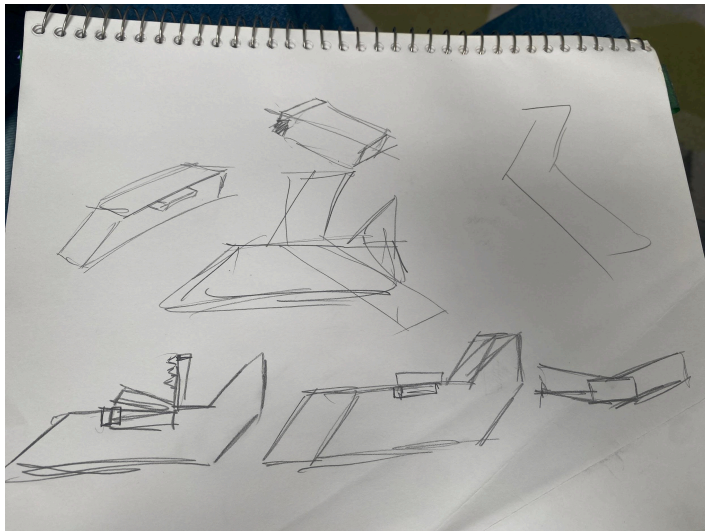
Now these materials have been picked for their varying flexibility, however it hasn't actually been calculated. All the wings will be the same dimensions, minimizing that the only manipulated/responding variable is flexibility (other than the material of course).

15/11/2025:

Now we need to find a way to make the actual glider with a some requirements:

- Main body is separate than wings
- Has detachable wings for easy switching
- Main body has to be light (light materials)

We were deciding on how we can have one main body that can be used for all the different wings. Why do we even need a singular main body? This is because we want the main body to be a constant variable, and keeping it the same, it removes any



difference there may be if we use many similar but not exactly the same gliders. What material should we make the main frame out of? However we stumbled upon a problem. We needed to be able to attach the wings without it affecting the flexibility. Our first idea which was using tape is not a good idea as it can lead to no accurate results and can have a different effect on each material. So we

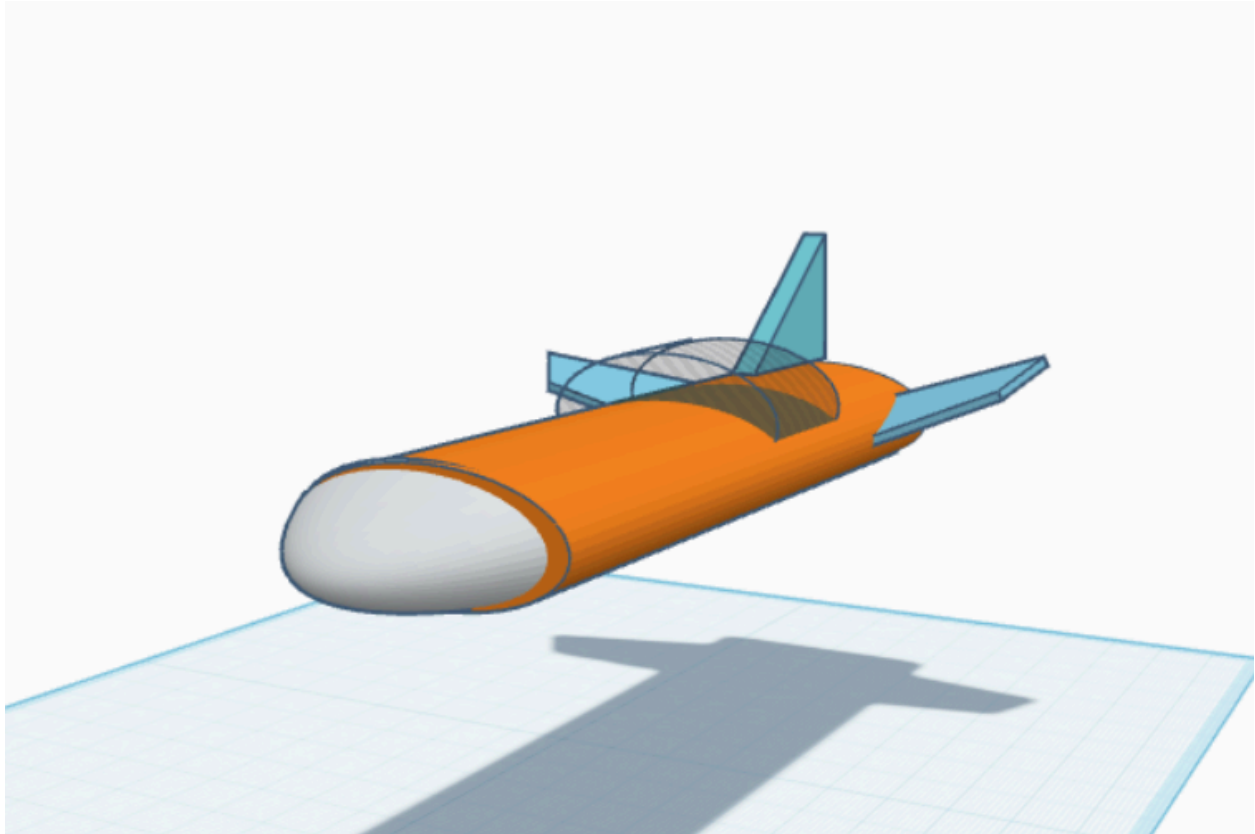
thought of using magnets or velcro or even a hatch system. Although these are flashy, they may not be the best practical version. Using a slot, where the wings can slide through, is a much simpler and stress free design while also keeping the final result without change to the actual plane. This way the wings can be taken off and attached easily. We decided to make the main body by manually building it with a 3D printed design due to its light weight and simplicity [16-17]. The body will resemble an ordinary plane but without the wings [18-19].

22/11/2025:

Today, we decided to get started on our 3D print of a glider. The requirements of the glider are:

- 3D printed
- Lightweight
- Detachable wings
- Under 20 cm long and 5 cm wide

We have been designing the glider for some time now and this is what we came up with.



There are problems with this design. First of all, there isn't an actual way to attach the wings or slide them in. The nose is too heavy and the main body is also extremely dense, increasing weight. The horizontal stabilizer is actually too angled, and we can not find a way to fix it.

05/12/2025:

Research:

Airplanes are a huge contributor to global carbon emissions, mainly because of the fuel needed to overcome "parasite drag" and the weight of an aircraft [20-21]. Historically, wings have been designed to be stiff to ensure stability. Rigid wings bring the issue of being inefficient because they cannot adjust to

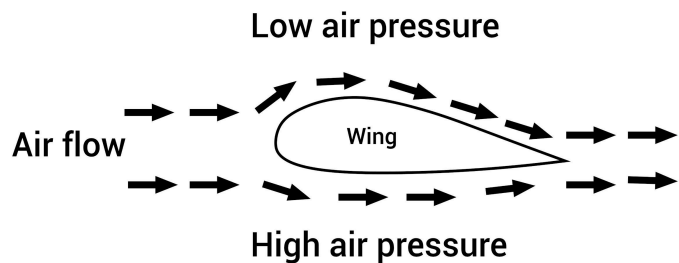
changing air pressure during flight.

Recently, aerospace engineers are shifting towards biomimicry; which is studying how birds use flexible wings for optimal flight [22-23]. Understanding Aerolasticity can greatly help in designing gliders that have flexible wings to increase the Lift-to Drag ratio. This will lead to benefits such as reduced fuel consumption, and minimal environmental footprint.

While researching this we found important principles and air fluid dynamics such as Bernoulli's Principle, and Young modules.

Bernoulli's principle states that "An increase in the speed of the fluid occurs simultaneously with a decrease in pressure or a decrease in the fluid's potential energy" [24-25].

This means the higher the velocity of a fluid, the lower the pressure. In flight, air moves faster over the curved top of a wing, which is known as the camber, creating lower pressure above and higher pressure below, resulting in lift.



Young's Modulus is a mathematical value that measures a material's rigidity. In this experiment, the independent variable is the Young's Modulus of the wing material.

When designing wings there is a "Sweet spot" which can be found through a process called Aeroelastic Tailoring. This is where the material is flexible enough to change under air pressure but rigid enough to maintain its structural integrity.

These are some factors that play when trying to achieve the "Sweet spot"

Passive morphing is when air naturally pushes the wing into the optimal curve. This creates a higher camber, which leads to an increase in lift without the need and assistance from artificial

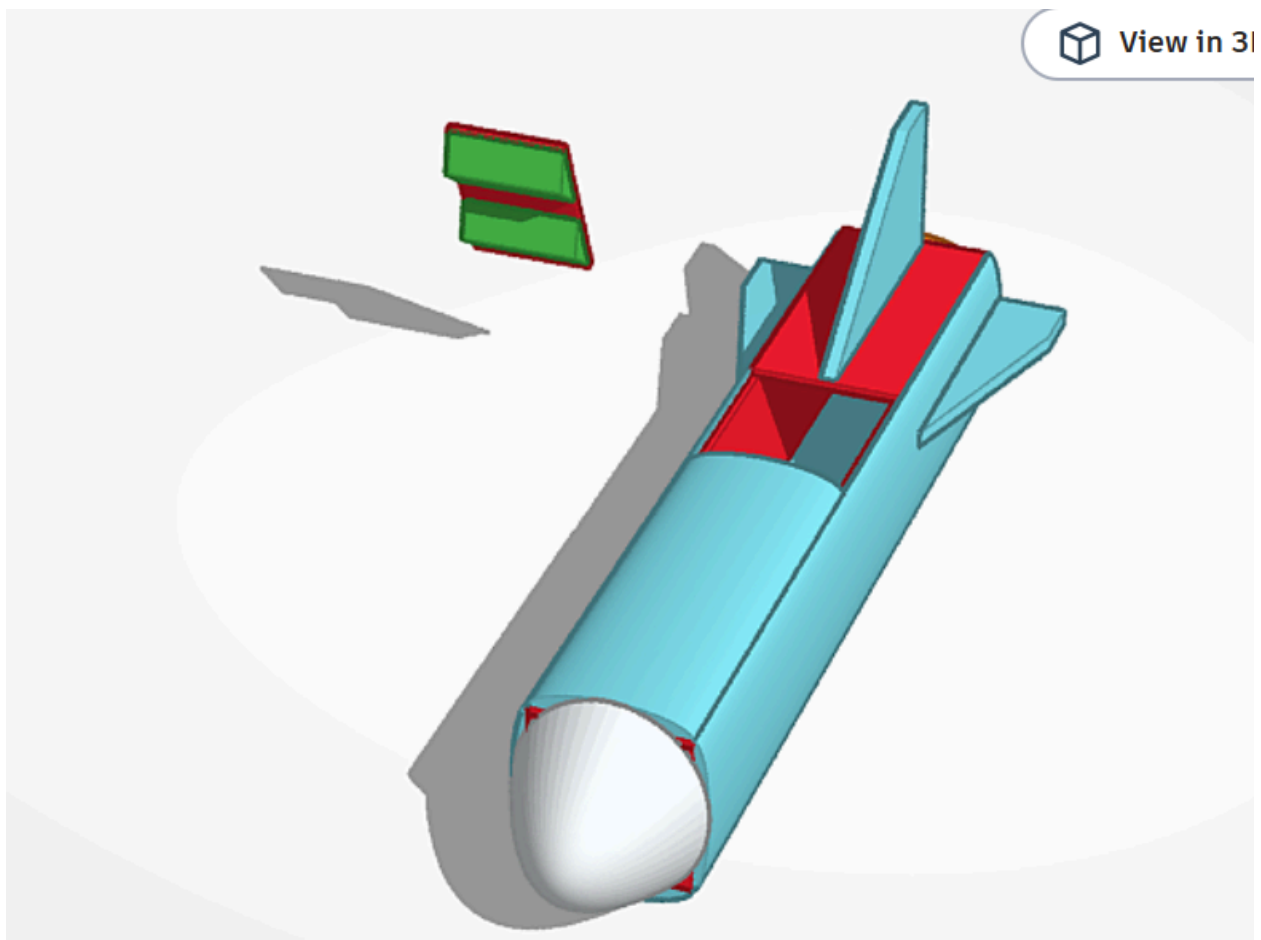
and mechanical flaps [26-27].

Materials that have a high Young's Modulus stay flat [28-29]. The airflow is not smooth at low speeds and requires more force to stay aloft and creates drag.

When a material is too pliable, it reaches a point called flutter. The wing flaps can become uncontrollable and can disrupt Laminar flow, turning into Turbulent Flow, which has a negative impact on lift and causes stalling [30-31].

15/12/2025:

Scratched the whole entire 3D model. We need something new. Using a rocket ship as a reference, we have come up with this design:



Figured out a solution to the problem of detachable wings, but the overall design of the model is too complex, and the wings on top are actually going to affect the outcome a lot.

05/01/2026:

Experimental Variables

Independent Variable (The Cause)

The flex ratio (flexibility) of the wing material. We are trying this with 3 different materials.

Dependent Variable (The Effect)

Collected glider efficiency data. In the logbook we stated that we want to include other performance metrics such as lift-to-drag (L/D) ratio, glide distance, and sink rate, but ultimately we are trying to find the "optimal flexibility".

Controlled Variables (The Constants) [32-33]

- In order to conduct a fair test, we have controlled a number of variables.
- Main Body (Fuselage): We will use a 3D printed frame for all the tests, so that the base is the same in all the frames.
- Wing Dimensions: The wings will ALL be of the SAME dimensions & shape (surface area S) regardless of the material.
- Attachment Method: We will use the same position & orientation to attach each wing to the body.
- Launching: Even though the human arm cannot replicate and exact the amount of pressure every time, the height and position will be the exact same. Minimizing the difference in the outcome, however this can also be quantified as a confounding variable.

Confounding Variables

- These are factors that are not obvious but could unintentionally impact our results if not controlled carefully.

- Wing Weight: Unfortunately, not every material has the same amount of weight. It is a variable that cannot be controlled but we chose dimensions over weight. This is because dimensions matter more on how wind flies around the material rather than just more mass.
- Surface Texture (Skin Friction): We spoke about "surface texture and drag" as a previous thought. Each of your 10 materials (eg. wax paper vs. foam sheets) is different, so the change in "parasite drag" could simply be due to the roughness of the material [36-37].
- Laminar vs. Turbulent Flow: At large enough flexibilities (e.g., normal paper), the wing may undergo "Aeroelastic Flutter". This leads to turbulence and an aerodynamic stall, potentially complicating the assessment of the pure effect of flexibility versus the effect of structural failure.
- Humidity/Environmental Factors: Since many of our materials are paper (coffee filter, cardstock, construction paper), they may gain moisture from the air during the experiment and change in weight or stiffness [34-35].
- Launch Consistency: If not using a mechanical launcher, the initial glide velocity and angle of attack will differ for each glide, affecting the Lift Equation. However it will be repeated a number of times to minimize the difference in outcome.

12/01/2026:

Procedure:

Materials list:

- Group 1 (Ultra-Light): 1 layer, 2 layers, and 3 layers of regular a4 paper.
- Group 2 (Mid-weight): 1 layer, 2 layers, and 3 layers of thin cardstock.

- Group 3 (Heavy-Duty): 1 layer, 2 layers, and 3 layers of thin poster board.
- The Hybrid: 3 different wings of different layer combination of each material

Phase 1: Wing Standardization

1. Template (Using a template, we can make the surface area constant). This template will be 30cm x 3cm.
2. Cutting the wings will leave us with a finished ready to use product.
3. Measuring each and every wing to put into a graph demonstrating the weight penalty, even if it is a confounding variable.
4. Attachment Setup: Using a 3cm slit we can slide the wing in, allowing us to start the experiment. If there is space between the wing and the hole making it loose, we will add a little small piece of crumbled paper, ensuring basically no weight change and wing misalignment.

Phase 2: The Bench Test

1. Rest 15 cm of the wing to the edge of a flat elevated space(ex. table), making sure the wing sticks out horizontally
2. Measure the edge of the wing to the floor(y_1).
3. Apply a weight (10 cent coin/2 grams) to the edge of the wing. Measure the new height [38-39].
4. Calculate the change in deflection which is second height subtracted by first height($y_2 - y_1 = \Delta y$).
5. Now apply it into the formula $F_r = \Delta y / L$ (where L is the length of the wing).
6. Use the formula $EI = PL^3 / 3\Delta y$ [40-44]
7. It allows us to also verify our formula and ensure a more accurate way of measuring flexibility.
8. Repeat this for all the different materials and layers and record their flexibility.

$$EI = \frac{PL^3}{3\Delta y}$$

Phase 3: The Flight Test

1. The plane will be thrown indoors especially to minimize all wind and other external factors.
2. The glider will be released by hand at a constant height and position.
3. Distance and time will be measured for each material.

4. It will be conducted 10 times per material [45-46].

5. Any observation will be recorded. Ex. Aerolastic Flutter

Phase 4: Data Analysis

1. Sink Rate will be calculated. Sinkrate = h/t [47-48].

2. Glide Ratio will be calculated. Glide Ratio =
distance/height [47-48].

3. Any other variable we decide will be calculated.

4. Comparing the flex ratio on the x-axis and the glide
distance on the y-axis to find the best spot.

5. The sink rate will also be plotted on the graph (secondary
y-axis).

6. The weight penalty will be plotted on the graph on each
data point on the axis (overlay).

7. A separate graph will be created using all these variables,
however we will replace our formula, with the more known
and engineer use formula [49-50].

26/01/2026:

Ok, we actually need to find a feasible and working design. I think we did.



The glider here is very thin, with long wings in the center. It has a raindrop inspired main body [51-52]. I think we can reference this.

We found and have developed a final design we actually believe is perfect. The center of mass, wing placement, and overall

design are all components we took into consideration.



We now need to get this 3D printed.

05/02/2026:

Our design studies and art teacher, Ms. Inkster, helped with the scaling and 3D printing process of this design. We now actually have it printed



Now the trials and testing will begin soon. We also have to find a way to make a universal size for the wings, so that the size and surface area is a constant variable. As per the dimensions and specifications, here they are:

- The 3D model weighs 16 g
- 15 cm long

- 2 cm wide (excluding elevators)
- 6 cm wide including elevators
- 5 cm tall
- 3 cm slot

10/02/2026:

After much trial and error, we can not figure out a solution to this problem; the glider does not glide. We have tried counter weights and everything but still no solution. But we do think there is a way to fix it. First we should drill holes to maybe shift the center of mass and reduce weight:



That didn't work as well as we wanted to work, so maybe making a massive hole might:



Again, no solution. If we actually remove the excess weight between the hole and the elevators, we can reduce the weight by at least 5-8 grams:



Unfortunately, even after all this the glider doesn't fly. It is probably a matter of aerodynamics in play now, not weight. Extending the size of the horizontal stabilizer and elevators might work [53-54]:



It actually worked, now we have to do tests tomorrow. These are our new adjusted glider specifications:

- The 3D model weighs 16 g (glue adds weight)

- 13 cm long
- 2 cm wide (excluding elevators)
- 12 cm wide including elevators
- 8 cm tall
- 3 cm slot

11/02/2026:

Phase 2 recordings:

Phase 2: Bench Test

$EI = \frac{PL^3}{3\Delta y}$

Material	$F = \Delta y$	
Paper 1	1.06	7246 m/N
Paper 2	1.06	7246 m/N
Paper 3	0.93	6330 m/N
Cardstock 1	1.00	6803 m/N
Cardstock 2	0.86	5882 m/N
Cardstock 3	0.8	5435 m/N
Poster Board 1	0.6	4525 m/N
Poster Board 2	0.3	2267 m/N
Poster Board 3	0.2	1360 m/N
Paper, Card, Post	0.2	1360 m/N
Card, Post, Paper	0.06	453 m/N
Post, Paper, Card	0.2	1360 m/N

Phase 3 recordings:

Phase 3 Flight Test		
A1 Paper	Distance	Time
1 layer:	247cm	0.66s
	261cm	0.66s
Avg Distance: 272cm	267cm	0.71s
	264cm	0.60s
Avg Time: 0.70s	297cm	1.00s
	248cm	0.69s
	257cm	0.74s
	246cm	1.00s
	264cm	0.58s
2 layers:	244cm	0.41s
	266cm	0.66s
	239cm	0.76s
Avg Distance: 245.2cm	251cm	0.51s
	302cm	0.43s
Avg Time: 0.55s	318cm	0.46s
	242cm	0.79s
	321cm	0.53s
	336cm	0.51s
	322cm	0.57s
	301cm	0.81s
3 layers:	324cm	0.74s
	366cm	0.60s
Avg Distance: 306.3cm	306cm	0.63s
	349cm	0.76s
Avg Time: 0.694s	286cm	1.00s
	291cm	0.49s
	349cm	0.71s
	345cm	0.51s
	323cm	0.54cm
	390cm	0.62cm

Cardstock	Distance	Time
1 layer:	332cm	0.74s
	348cm	0.73s
Avg Distance: 371.1cm	369cm	0.59s
Avg Time: 0.70s	410cm	0.78s
	374cm	0.66s
	380cm	0.73s
	422cm	0.71s
	357cm	0.95s
	342cm	0.68s
	340cm	0.65s
2 layers:	447cm	1.09s
	364cm	0.71s
Avg Distance: 365.8cm	401cm	0.71s
Avg Time: 0.74s	349cm	0.77s
	396cm	0.75s
	397cm	0.55s
	320cm	0.96s
	248cm	0.53s
	416cm	0.94s
3 layers:	301cm	0.61s
	317cm	0.63s
	449cm	0.76s
Avg Distance: 361.2cm	324cm	1.12s
Avg Time: 0.762cm	391cm	1.06s
	363cm	0.98s
	407cm	0.81s
	287cm	0.66s
	398cm	0.68s
	364cm	1.11s
	421cm	0.94s

Hybrid	Distance	Time
	525cm	1.0s
	475cm	0.7s
	452cm	0.88s
Avg Distance: 478.2cm	417cm	0.68s
Avg Time: 0.852s	367cm	0.76s
	502cm	0.95s
	495cm	0.63s
	428cm	0.75s
	510cm	0.95s
	501cm	1.1s
# Always go down #	379cm	0.66s
	367cm	0.49s
	488cm	0.66s
Avg Distance: 461.8cm	327cm	0.46s
Avg Time: 0.715s	584cm	0.94s
	496cm	0.73s
	511cm	0.98s
	400cm	0.83s
	424cm	0.60s
	617cm	1.05s
	457cm	0.73s
	427cm	0.85s
	490cm	0.76s
	488cm	0.63s
	451cm	0.61s
	467cm	0.91s
	561cm	0.93s
	486cm	0.81s
	485cm	0.76s
	402cm	0.79s

Poster Board	Distance	Time
1 layer:	306cm	0.59s
Avg Distance: 378.2cm	371cm	0.71s
Avg Time: 0.681s	436cm	0.81s
	393cm	0.66s
	462cm	0.70s
	362cm	0.66s
	342cm	0.91s
	322cm	0.55s
	320cm	0.58s
	407cm	0.64s
2 layers:	397cm	0.43s
Avg Distance: 440.5cm	470cm	0.80s
Avg Time: 0.71s	367cm	0.83s
	387cm	0.53s
	394cm	0.55s
	453cm	0.71s
	442cm	0.82s
	502cm	0.88s
	372cm	0.70s
	542cm	0.93s
3 layers:	490cm	0.71s
Avg Distance: 421cm	366cm	0.48s
Avg Time: 0.711s	440cm	0.79s
	422cm	0.73s
	386cm	0.58s
	441cm	0.86s
	371cm	0.75s
	450cm	0.68s
	450cm	0.80s
	422cm	0.73s

Phase 4: Data Analysis

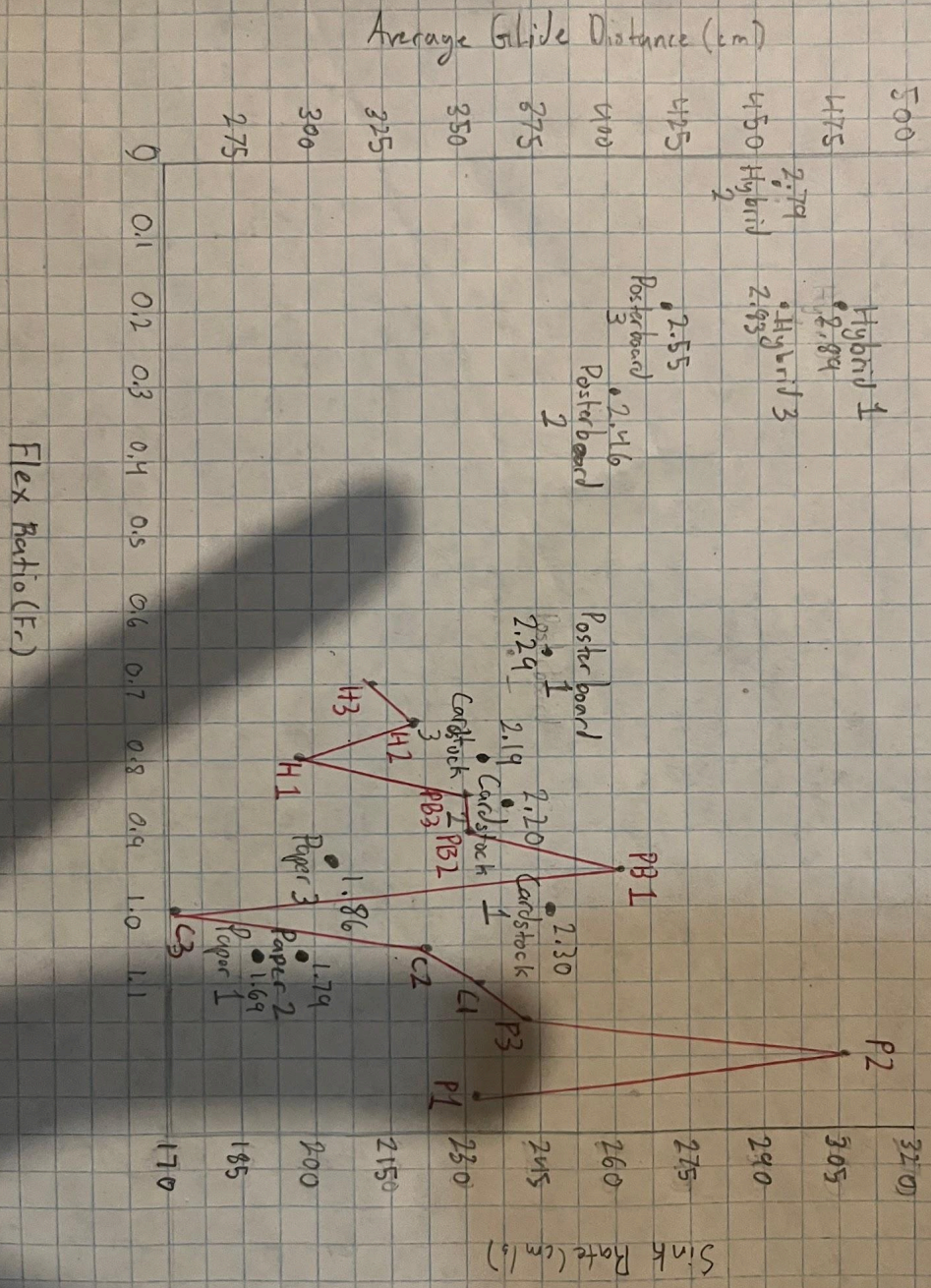
Lunch Height = 165cm

Phase 4: Data Analysis

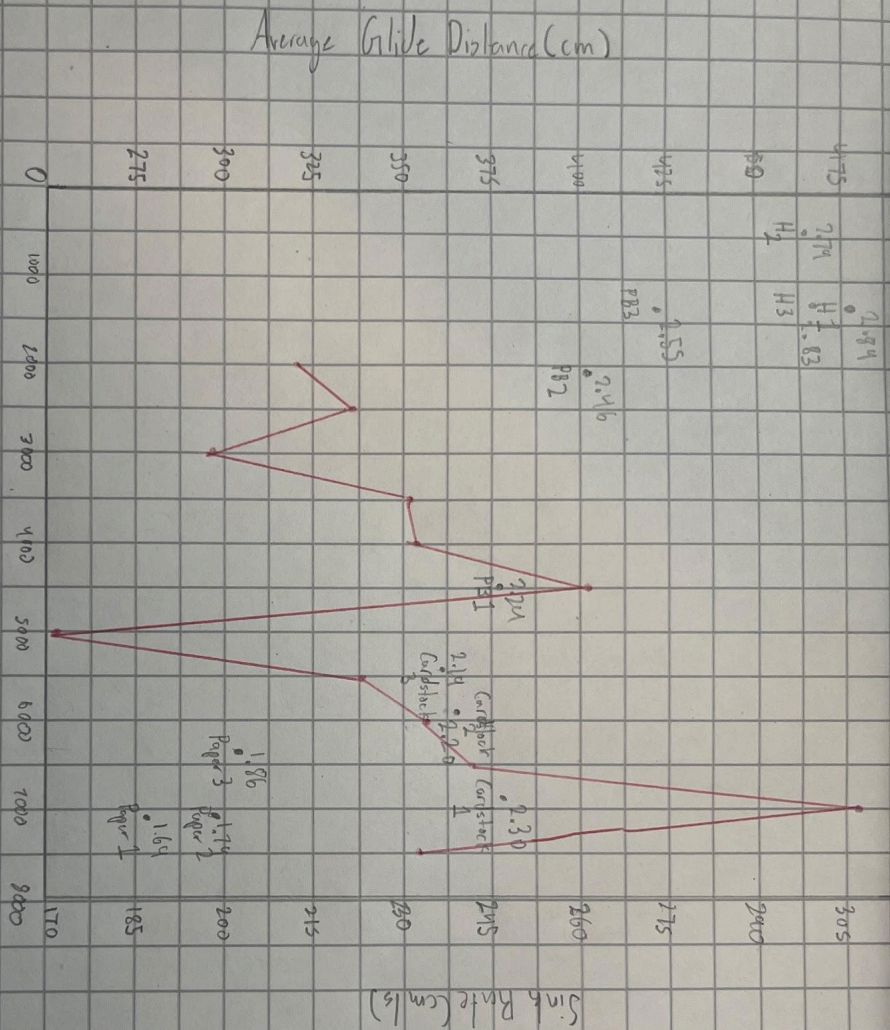
Glide Ratio = $\frac{\text{Avg Flight Distance}}{\text{Launch Height}}$ or $\frac{\text{Launch Height}}{\text{Avg Flight Time}}$

Material	Layer	Avg Distance	Avg Time	Glide Ratio	Sink Rate
Paper	1	278.4cm	0.708s	1.64:1	233.05cm/s
Paper	2	295.7cm	0.535s	1.79:1	308.41cm/s
Paper	3	306.2cm	0.644s	1.96:1	237.75cm/s
Cardstock	1	379.9cm	0.709s	2.30:1	232.72cm/s
Cardstock	2	363.9cm	0.744s	2.20:1	220.29cm/s
Cardstock	3	361.2cm	0.968s	2.19:1	170.15cm/s
PB	1	378.5cm	0.631s	2.29:1	261.49cm/s
PB	2	405.1cm	0.71s	2.46:1	232.39cm/s
PB	3	421.5cm	0.714s	2.55:1	231.09cm/s
Hybrid	1	479.2cm	0.952s	2.99:1	193.66cm/s
Hybrid	2	461.9cm	0.745s	2.79:1	221.48cm/s
Hybrid	3	467.2cm	0.778s	2.93:1	212.08cm/s

Flex Ratio vs Glide Distance



Flexural Rigidity vs Glide Distance



Phase 3 & 4 Observations:

1. Performance Leaders

- The best performer based on the chart can be seen as hybrid 1.
- It achieved the best distance and glide ratio.
- Hybrid 1 was able to achieve the highest average distance of 478.2 cm and the highest glide ratio of 2.89:1.
- Standard paper performed the worst in distance averaging 278.4cm.

2. Material Behavior & Weight Thresholds

- An important observation is that when more layers were added to paper and poster board it would generally improve the Glide ratio.
- However for cardstock, when 1 layer was used it gave the best results.
- This could translate back to the fact that sometimes more materials or added weight is not always the best.
- The observation of sometimes added layers or weight is not the best can be supported by the results in trials of cardstock.
- For adding more layers to cardstock wings, specifically from 1 layer to 2 layers, the average distance dropped from 379.9cm to 363.8 cm.
- This also confirms the observation and theory that added weight was almost a drawback and the stiffness was just not able to overcome the added weight.

3. Stiffness vs. Stability

- The wings made of 3 layers of cardstock had the lowest sink rate of 170.45 cm/s.
- This means that the wing was able to stay in the air the longest relative to the drop, which is most likely due to the fact that it had just the right amount of stiffness as the poster board was much stiffer.
- In theory since more layers of cardstock layers would make the wings stiffer and fly smoother you would expect cardstock 2 and 3 to perform the best.

- However the opposite happened, cardstock 1 achieved a flight distance of 430 the farthest for cardstock wings.
- Unlike cardstock, poster board had its best distance of 542cm and best average of 421.5cm when it was at its heaviest, which was 3 layers.
- This could suggest that unlike cardstock and other materials, poster board requires more mass and layers to stabilize itself.
- Something interesting to note is that poster board at 1 layer is already the stiffest material, but it needs all the 3 layers to become even stiffer so it can fly the best it can.

Even though the hybrid 1 gave the best results, just looking at the results individually tells another story of how reliable each design was. Cardstock 1 showed very close results between each trial with the trials being between 0.65s and 0.78s. This shows its reliability and its resistance to slight alterations that could happen between or during throws. Hybrid 3 had the widest range of results having a very high distance throw of 647 cm but also several throws in the 400 cm range. This showed how this wing design had the most potential, but the difficulty in achieving and replicating the same launch perfectly every single time can have big effects on it.

Basics of Aeroelasticity and Passive Shape Change 1b

Wings on planes usually stay stiff, built that way for steady flight. Now though, engineers are leaning into bend - watching how air pushes while materials push back. Elastic reactions mix with airflow in ways once avoided, now explored. Shape shifts mid-sky used to mean trouble, today it's part of the plan. Firmness gives control, but flexibility may offer gains. What resisted motion before now dances with wind pressure. Designs once locked in place now respond, twist, adapt.

When air pushes against it, the wing bends on its own - no motors needed. This shift happens quietly, shaped by airflow instead of gears. Flexibility lets the form follow force, changing mid-flight without commands. Movement comes from pressure, not parts. The structure gives way gently, adapting as conditions change.

Wings that bend tend to curve more along their shape - this added roundness helps them grab extra lift when flying slow. Because of this change, flexible wings might keep a glider up in the air longer compared to rigid ones stuck in place. How much they twist and swell matters - subtle shifts in form open room for staying aloft without rushing forward.

Material Science: Young's Modulus and Flex Ratio 1c

How stiff something is comes down to its Young's Modulus. Wings bend based on that stiffness level. What changes here depends directly on the wing material's value. When the number runs high - meaning very rigid - the example used is three layers of poster board. Even with stiffness from three layers, poster boards resist bending well. Still, their rigidity keeps them from adjusting to shifting air forces. One layer of paper bends easily, showing low resistance. A special test applies two grams on the wing tip to check how much it dips. This number gives the Flex Ratio, guiding choices. Finding balance matters - too stiff and it cracks, too soft and it folds. Just right means it moves without breaking.

Aerodynamic Risks From Flutter and Turbulence 1d

A sudden wobble can grow when a wing becomes too flexible. This motion steals power from the airflow around it, feeding itself into wild oscillations. Wings that bend more easily might start

to rock uncontrollably under certain conditions. Instead of calming down, the movement gets stronger as air pushes back unevenly.

Laminar flow keeps flights steady, air sliding in neat sheets along the surface. When wings bend too much, that smooth motion breaks apart. Instead of gliding, the airflow tumbles into chaos. Smooth layers give way to messy swirls. Stability fades once flexibility interferes. Turbulence takes over where order once ruled.

Because turbulence creates lots of extra resistance - often called parasite drag - gliders lose lift quickly, sometimes stopping altogether. That's why during testing, ultra-flexible materials tend to fail compared to those with stiffness near that of cardboard.

Design Iteration through Horizontal Stabilizers and Pitch Stability 1e

Not just the wings decide how well a glider performs - the whole frame must sit evenly in flight. Early trials revealed dives happened unless 3D-printed bodies had their mass placed just right. To fight unwanted nose drops from bendy wings, scientists enlarged the tail's flat parts instead. When everything lines up properly, shape shifts that happen on their own turn airflow into forward motion.

Biomimicry and Environmental Impact 1f

Wings that bend follow nature's lead - birds and bugs mastered them long before humans arrived. Look ahead. Big names such as Boeing, flying the 787 Dreamliner, along with NASA, now test these shifting wings to cut down on heavy parts and strain. Efficiency climbs when wings reshape themselves without added power. Planes then sip less fuel instead of guzzling it. Fewer emissions come out behind. That quiet shift could matter deeply in slowing global warming. Research into pliant wings won't shout - but its role may grow where it counts.

Bench Test Methodology Measuring 1g Flex

One way to make sense of how flexible something feels - like calling a wing "bendy" - is by using the Flex Ratio. Based on an old idea called Euler-Bernoulli Beam Theory, it shows what happens when force bends a structure. When testing stillness,

the wing acts like a beam clamped at one tip. At the open end, exactly 2 grams - a bit more than a dime - gets added. What matters most is how far that point moves down compared to the full span. That number comes from dividing deflection by length. So Fr equals Δy divided by L . This number lets you compare how different materials - like paper and cardstock - behave even when wing sizes aren't exactly the same. Bending resistance matters in design work, where stiffness defines performance under load.

Flight Dynamics and Efficiency Metrics 1h

Phase 3 testing measures how well potential energy turns into motion, along with how far something travels. Figuring out efficiency means finding two key numbers tied to air movement. One is Glide Ratio (D/L), which compares Lift (L) to Drag (D); during real tests, it shows up as Horizontal Distance divided by Launch Height. When this number climbs, it hints the wing uses "Passive Morphing" effectively - staying aloft while fighting minimal resistance. The second measure? Sink Rate - that's just how fast the glider drops straight down. A wing that resists bending too much might fall faster because it fails to generate enough upward force. When built too loosely, vibrations can take over, dragging the descent even steeper. What works best comes down to a middle ground - subtle give without wobbling apart - slowing the drop just enough to stay airborne longer.

The Raindrop Fuselage Design 1i

Starting mid-sentence, shape matters when air pushes back. A glider took its form from droplets falling through the sky. Because nature solves problems first, engineers copied how water tightens while dropping. Streamlined like that, less pressure builds up front. Built with plastic layers stacked by machine, the frame follows flow found in storms. When objects move fast, edges that taper beat flat fronts every time.

A smooth airflow sticks close to the shape thanks to the blunt front and narrow rear. When air stays attached, it avoids forming a dragging vacuum at the back. Sharp edges would trip the flow, but curves guide it along gently. Without early separation, pressure stays balanced across the surface. That quiet zone behind doesn't get pulled apart by turbulence.

One shape fits all wings - keeping the fuselage unchanged means differences in how far it flies come only from wing bend, not body shifts. What do you see flying farther? Blame the flex, not the frame. Same tube, different twist. Flight path tweaks trace back to one thing: how much the wings give. Not the shell. Never the nose cone. Just the way they curve midair.

Stability and Surface Controls 1j

When wings bend during flight, the spot where lift acts moves around. Studies found that floppy wings make this shift hard to predict. Because of how they flex, pressure location jumps instead of staying put.

A bigger horizontal stabilizer got added to fix that problem. Because of it, the tail section keeps things steady in flight. That setup stops the glider from tilting upward too much - something flimsy paper wings often do. Without this balance, it might just nosedive instead. Long-term wobbling gets canceled out by smarter shaping behind the main wing.

Wings bend under pressure, yet tails resist that motion - keeping things level demands careful adjustment. Flight stays smooth only when both parts respond just right, not too stiff, not too loose. One shifts, the other follows, each affecting how the plane holds its course. Balance emerges through subtle opposition, never perfect, always shifting.

Variable Control and Environmental Consistency 1k

Finding solid answers means noticing how outside factors can shape results.

Flying took place inside a closed space so gusts and rough air could not interfere. Flexible wings needed calm conditions to deliver clear results. Without walls around, shifting winds might twist the readings off track.

From one trial to the next, the drop point stays fixed. A steady toss angle means airflow effects stand out clearly. Only what the object is made of changes each time. That change shows how flexibility shapes flight. Watching how far or long each one goes reveals patterns. Each test checks just one thing at a time. Results link directly to how stiff or bendy the item happens to be. Measurements track distance and timing alike. The setup keeps everything else locked down. What flies best becomes obvious under these rules.

Application:

Innovations in Commercial Aviation Efficiency

Fuel Saving: New age models like the Boeing 787 Dreamliner have wings designed to bend/flex by 26 feet during flight. This natural bending allows for the wings to change their shape during flight reducing the need for heavy mechanical systems to achieve the same purpose. This change directly results in the use of reduced amounts of fuel.

Emission Reduction: The wings of the Boeing 787 Dreamliner help in reducing the carbon footprint of the aircraft as the wings help in the aircraft "sipping" the fuel.

Biomimicry and Cutting Edge Design

Passive morphing of wings: As merger and acquisition activities in the airline industry continue, financial analysts predict that the triad of high volume traffic, low operational costs, and quality airline service will be achieved by the newly formed airline. This "passive morphing" will help a wing be pushed into an optimal curve that will be needed during flight to create a higher degree of lift without the use of complex mechanical systems that are present.

Aircraft Structures and Management of Stress Safety and Stress

As aircraft wings are designed to be flexed, the structure of the aircraft will be able to absorb the stress and turbulence instead of merely breaking it which will significantly increase the life of the aircraft and the overall safety. The process of "aeroelastic tailoring" helps to achieve the perfect balance in wing construction.

Future Aerospace Technology

NASA research: NASA and other large aerospace companies are now testing such bending, flexible wings to reduce the burden of heavy mechanical components.

Unmanned Aerial Vehicles (UAV): The principles you apply in your small-scale models—including discovery of the optimal Flex Ratio—apply to design of high-efficiency gliders and drones who need to maximize airtime at low energy usage.

Conclusion:

The objective of our experiment was to learn and analyze how wing flexibility affects glider efficiency by using sink rate and glide ratio. Our research was able to lead us to the best flexibility for wings in aeroelastic tailoring; which is about how a material is flexible to change shape under air pressure but stiff enough to maintain structural integrity.

Our hypothesis was right that wings with moderate flexibility performed the best beating very stiff and very flexible wings. The Hybrid 1 wing was able to achieve the highest efficiency with an average of 478.2 cm and a glide ratio of 2.89:1. It successfully utilized passive morphing to maximize lift. Materials that were too flexible did not perform good due to aeroelastic flutter, where the wing became unstable

In conclusion, this investigation into the Effect of Wing Flexibility on Glider Efficiency successfully demonstrated that a glider's performance is not solely dependent on rigid structural integrity, but rather on a calculated balance of flexibility a concept known as Aeroelasticity.

To sum up, this study on the Effect of Wing Flexibility on Glider Efficiency showed that a glider's performance doesn't just rely on having a stiff structure. Instead, it depends on finding the right balance of flexibility, which is called Aeroelasticity. Our research went through four different testing phases, and here are the main results we found: 1. Our Phase 2 bench tests showed a clear link between the material makeup and the Flex Ratio. Regular paper with one to three layers was quite flexible, but it couldn't hold its shape well enough to keep a steady airfoil form. On the other hand, three layers of poster board turned out to be too stiff and didn't bend well with the airflow. The "sweet spot" was found in the Hybrid 1 (H1) design, which mixed a stiff front edge with a flexible back surface, letting it change shape on its own. The flight data from Phase 3

and 4 showed that the Hybrid 1 wing had the best Glide Ratio (D/L) and the lowest Sink Rate. When the wing bends a bit under the wind's pressure, the glider boosts its lift-to-drag ratio. Wings that were too stiff ended up with more parasite drag, and on the other hand, wings that were too flexible ran into Aeroelastic Flutter, making them wobble uncontrollably and lose altitude fast. The Raindrop Fuselage design and a bigger Horizontal Stabilizer turned out to be really important for the plane's stability. We found out that when wings bend, the center of pressure moves. If the stabilized tail wasn't there to balance things out, the flexible wings would have made the craft pitch all over the place without control. This shows that for flexible wing technology to work, the whole shape of the aircraft needs to be matched to how the wing moves. Our results reflect where the aerospace industry is heading right now. Companies like Boeing and NASA are looking at how nature works through Biomimicry to develop "morphing wings." Our project shows, even on a small scale, that these designs can make flights more efficient. If airlines started using flexible wings on a larger scale, it could cut down fuel use and carbon emissions quite a bit in commercial flights. In the end, our idea was partly right: some flexibility does help with efficiency, but if there's too much, it causes problems like turbulence and flutter that can make the structure fail. The best glider is one that's stiff enough to keep its shape but still flexible enough to move with the wind. Finding the right balance is what will drive the future of aerospace engineering.

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