CCSS.MATH.CONTENT.HSF.IF.B.4
For a function that models a relationship between two quantities, interpret key features of graphs and tables in terms of the quantities, and sketch graphs showing key features given a verbal description of the relationship.

CCSS.MATH.CONTENT.HSF.IF.B.6
Calculate and interpret the average rate of change of a function (presented symbolically or as a table) over a specified interval. Estimate the rate of change from a graph.

ITEEA Standards for Technological Literacy

- **ITEA/STL 8** *Students will develop an understanding of the attributes of design.*

  -*ITEA/ STL 8E* Design is a creative planning process that leads to useful products and systems.

- **ITEA/STL 9** *Students will develop an understanding of engineering design.*

  - *ITEA/STL 9G* Brainstorming is a group problem-solving design process in which each person in the group presents his or her ideas in an open forum.

  - *ITEA/STL 9H* Modeling, testing, evaluating and modifying are used to transform ideas into practical solutions.

- **ITEA/STL 11** *Students will develop the abilities to apply the design process.*

  - *ITEA/STL11I* Specify criteria and constraints for the design.

  - *ITEA/STL11K* Test and evaluate the design in relation to pre-established requirements, such as criteria and constraints and refine as needed.)

- **ITEA/STL 12** *Students will develop the abilities to use and maintain technological products and systems.*
  - *ITEA/STL 12J* Use computers and calculators in various applications.

Through this project, students learned about different parts of an airplane and various forces that act on it during the flight. The major topics that this activity focuses on belong to Mathematics, like data analysis, reading and plotting scatter-plot graphs, conversion of measurement units, finding area, rate of change.

The ED process helped teach the science and mathematics concepts. During *brainstorming* the students chose what kind of papers are available to us at school and chose 3 of them. They watched a video on aerodynamics of a plane on NASA website and played with the FOILSIM, a NASA-generated interactive simulator that teaches you how different values affect a flight. During *research* the students learned about 4 forces that act on a flight, that is the role of air and gravity on flight, how do we get thrust and lift and second law of motion. Then the students build airplanes with different paper and different designs. They *tested and evaluated* their designs through *iterative process* of building more paper airplanes while recording their data and analyzing it.

I feel I chose an appropriate engineering design process and helped students understand it by giving them a list of question for every step. I will not make it complex as most of my students are low-level learners and struggle behaviorally. I still have to do this project with my entire class so don't know yet, what changes should I make. I may add some additional Math concepts to go with this project.

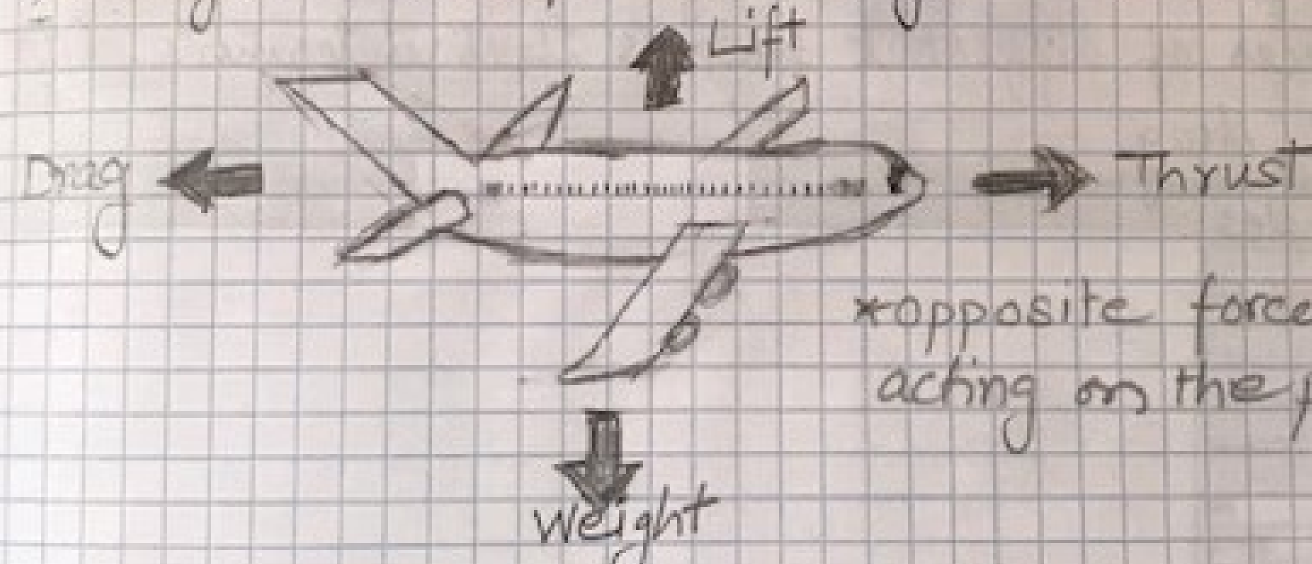
Design Challenge: Optimizing a flight

Define: What is the problem or design challange?

Design a paper airplane that flies the farthest and stays aloft for longest time.

The 4 forces that allow a paper plane to fly are the same ones that help a real plane fly, which are

1. Weight 2. Lift 3. Drag 4. Thrust



*opposite forces acting on the plane

1. Thrust is a force that pushes a paper plane forward when thrown in the air.

2. Lift is a force that is provided by air under the wings that helps the plane rise up while moving forward.

3. Drag is the force opposite to thrust, by air pushing back against the plane slowing it down.

4. Weight / Gravity - The weight of the paper plane also affects its flight, as gravity pulls it down toward Earth.

AERODYNAMICS is the study of these forces and the resulting motion of objects through the air.

We investigated the aerodynamics on a plane using NASA's FoilSim Elementary JS Version1, which is an interactive program. We changed the values of different factors that determine lift and drag.

Examples:

Fig.1 Original values

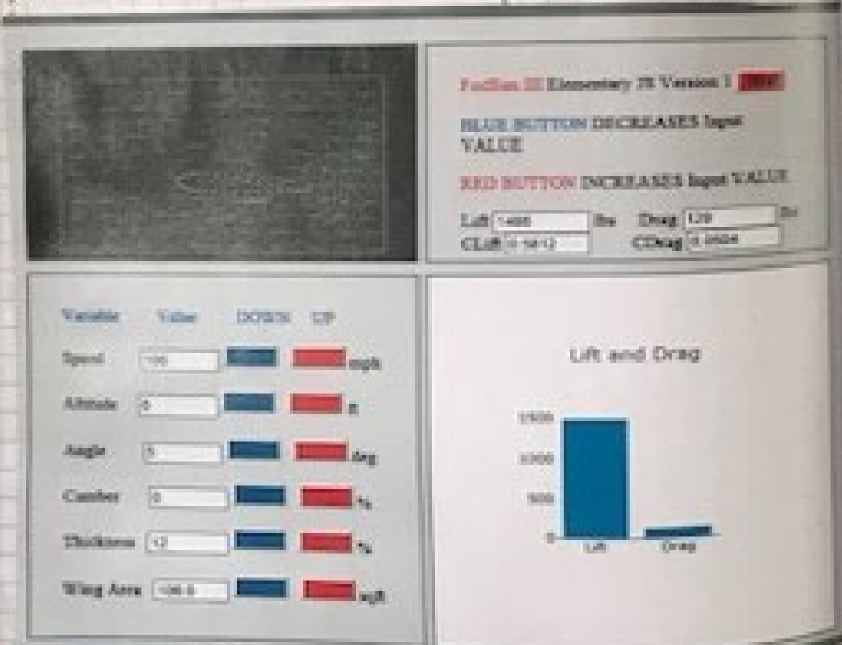


Fig.2 Change in Angle

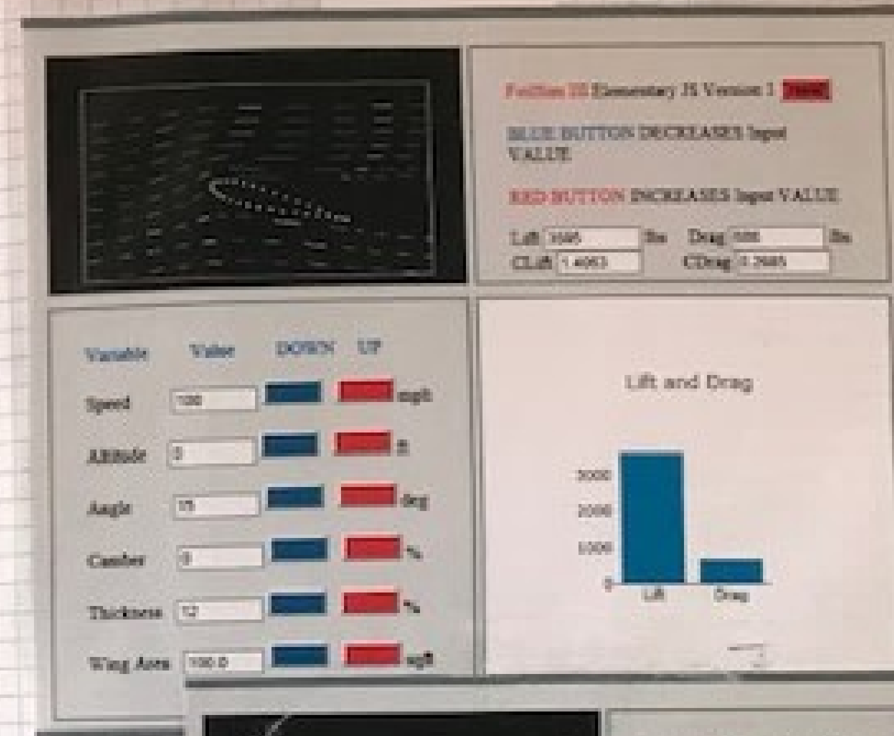
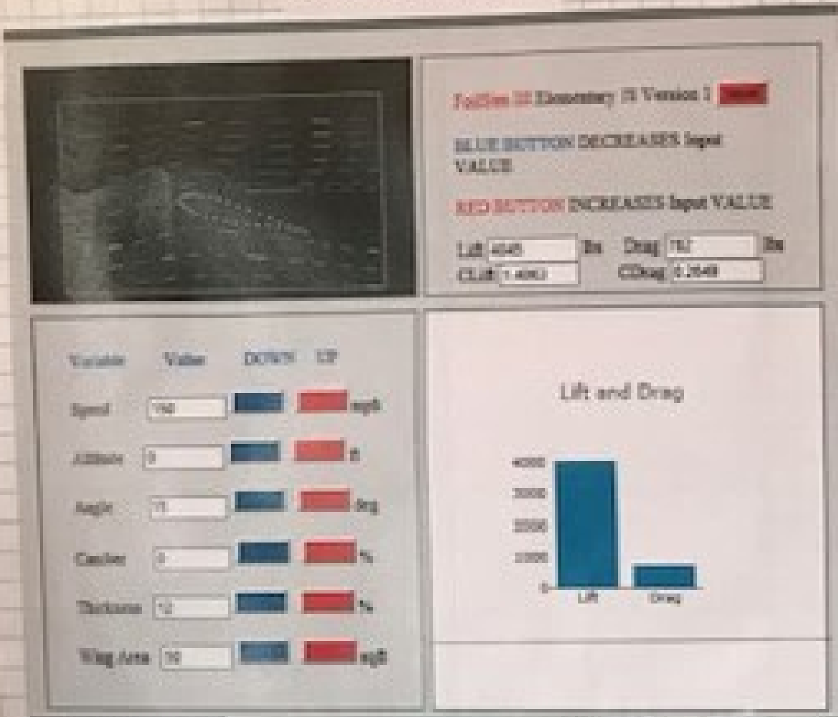
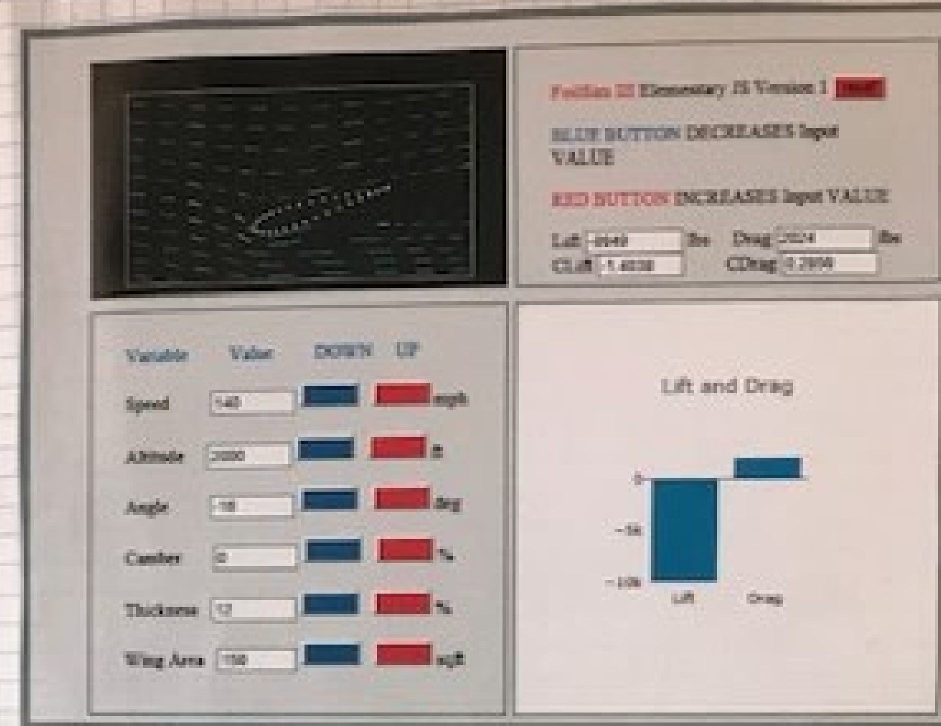


Fig.3 Change in Speed

Fig.4 Change in Wing Area





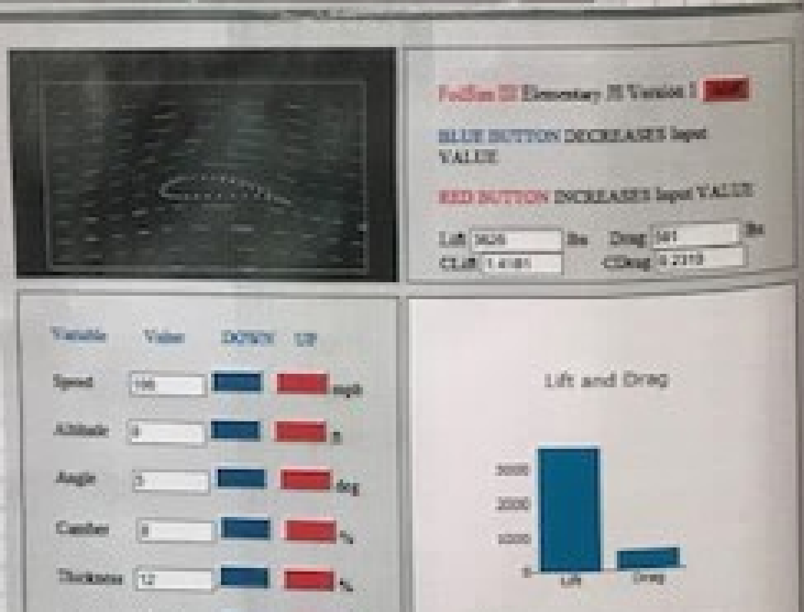
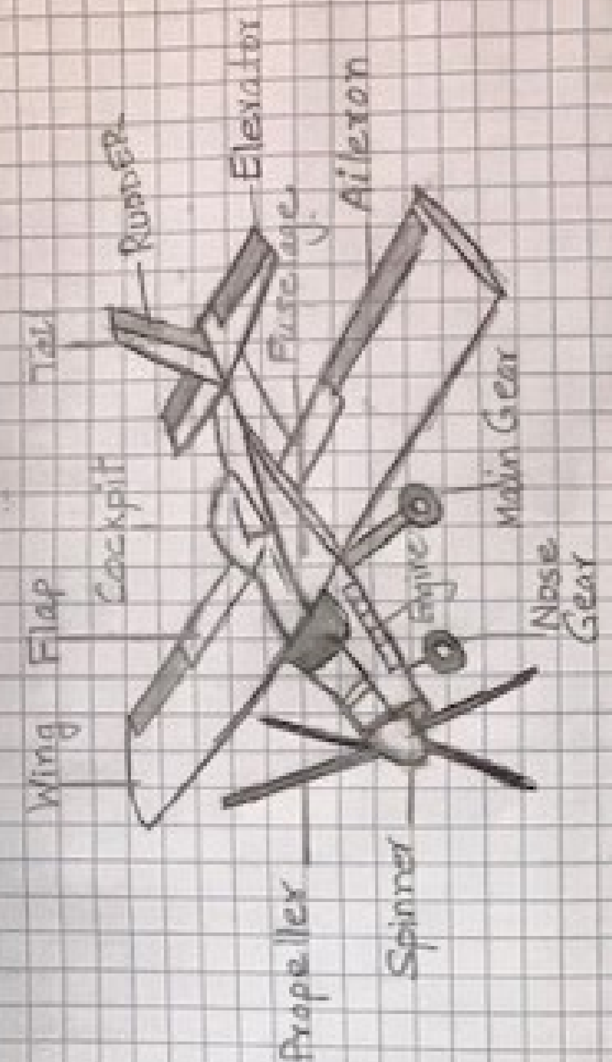


Fig.5 Change in Camber

Parts of an airplane



* How does airplane stay in the air?

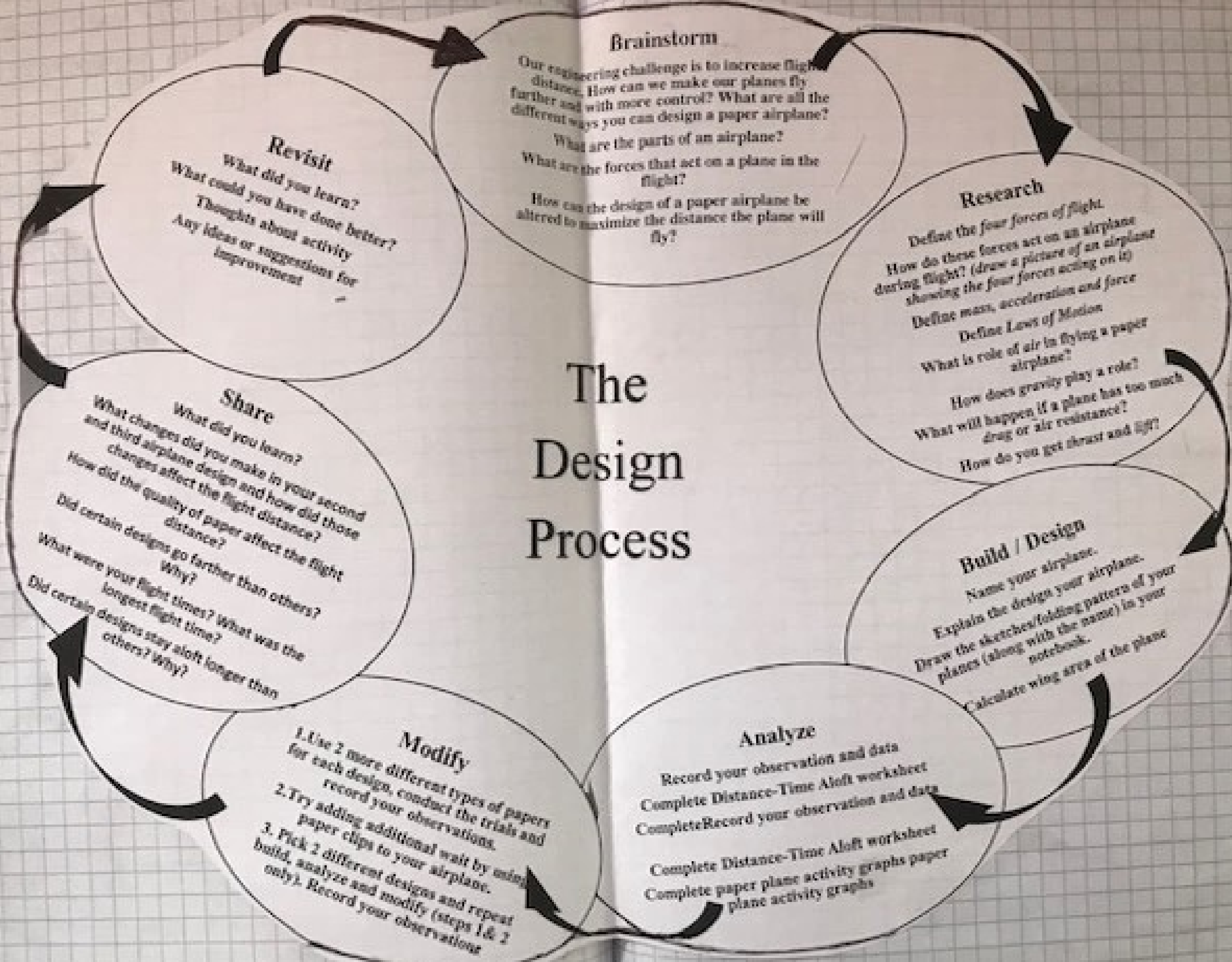
A plane stays in the air because of the forc "lift" which is mostly generated by the wings.

* How do we calculate force?

Newton's Second Law of Motion says that a force F is produced when a body of m 'm' is accelarated 'a'. In notation,

$$\boxed{F = m \cdot a}$$

Acceleration is change in velocity (speed) al a constant rate.


The Design Process
Brainstorm
Our engineering challenge is to increase flight distance. How can we make our planes fly further and with more control? What are all the different ways you can design a paper airplane?
What are the parts of an airplane?
What are the forces that act on a plane in the flight?
How can the design of a paper airplane be altered to maximize the distance the plane will fly?
Research
Define the four forces of flight.
How do these forces act on an airplane during flight? (draw a picture of an airplane showing the four forces acting on it)
Define mass, acceleration and force
Define Laws of Motion
What is role of air in flying a paper airplane?
How does gravity play a role?
What will happen if a plane has too much drag or air resistance?
How do you get thrust and lift?
Build / Design
Name your airplane.
Explain the design your airplane.
Draw the sketches/folding pattern of your planes (along with the name) in your notebook.
Calculate wing area of the plane
Analyze
Record your observation and data
Complete Distance-Time Aloft worksheet
CompleteRecord your observation and data
Complete Distance-Time Aloft worksheet
Complete paper plane activity graphs paper plane activity graphs
Modify
1.Use 2 more different types of papers for each design, conduct the trials and record your observations.
2.Try adding additional wait by using paper clips to your airplane.
3. Pick 2 different designs and repeat build, analyze and modify (steps 1& 2 only). Record your observations
Share
What did you learn?
What changes did you make in your second and third airplane design and how did those changes affect the flight distance?
How did the quality of paper affect the flight distance?
Did certain designs go farther than others? Why?
What were your flight times? What was the longest flight time?
Did certain designs stay aloft longer than others? Why?
Revisit
What did you learn?
What could you have done better?
Thoughts about activity
Any ideas or suggestions for improvement

Material needed:

Papers - 3 of each (construction, printer, notebook)

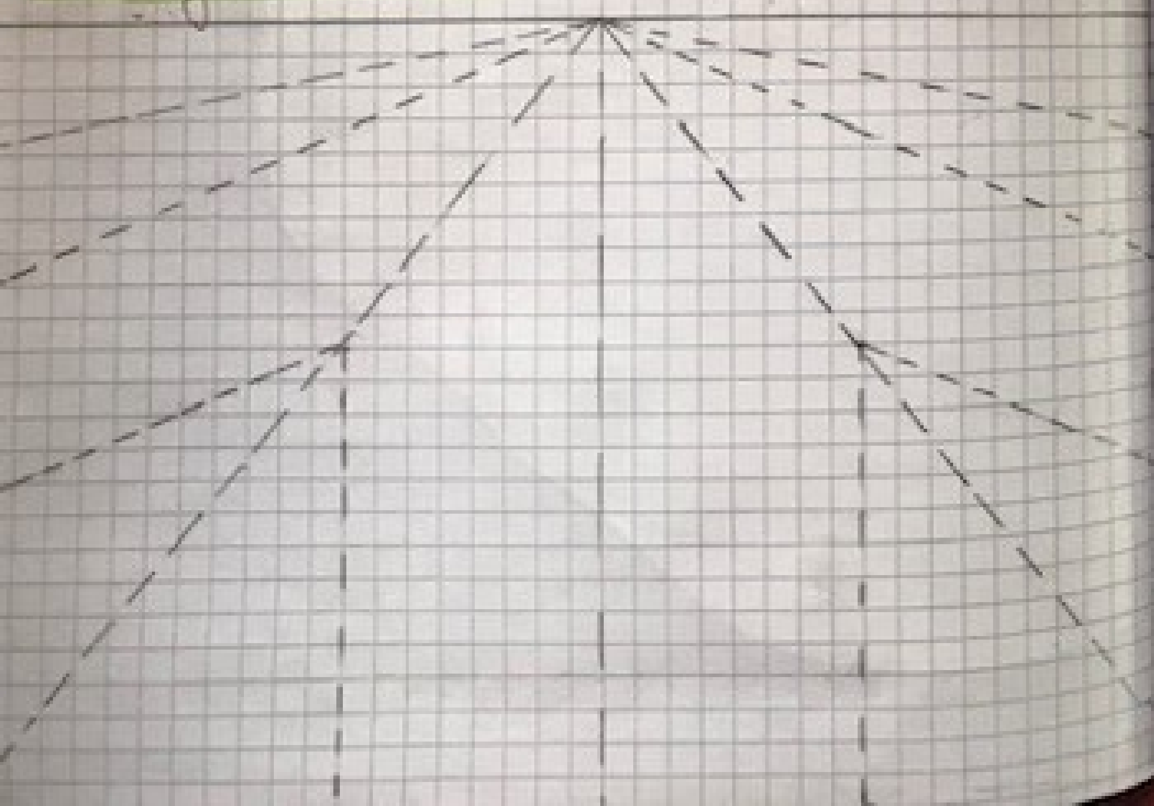
Tape Measure

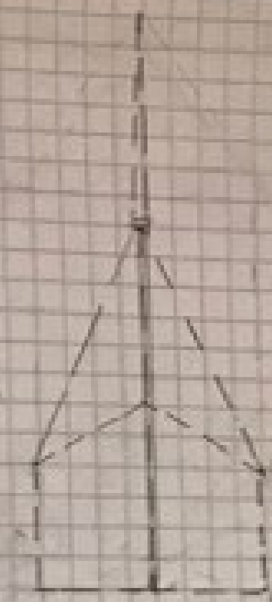
Computer, Calculator, Pencil, Notebook

Design:

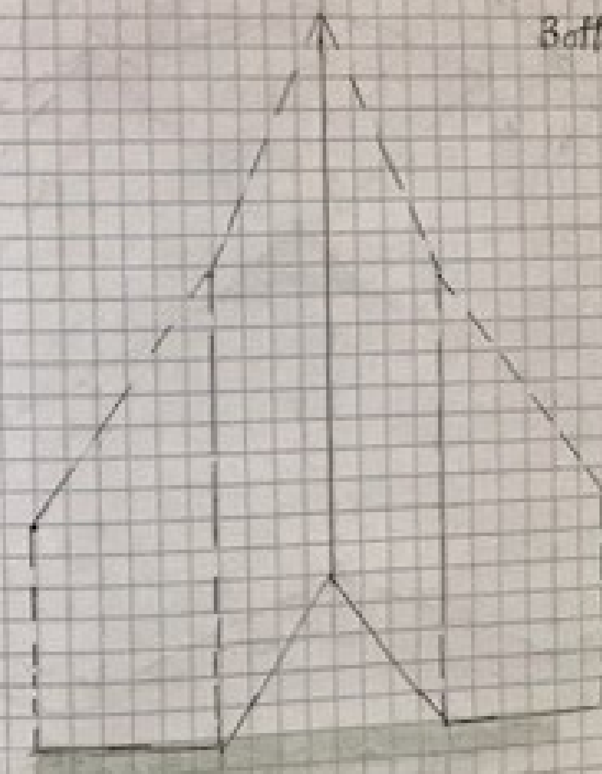
We choose 3 different designs of airplanes and build each design using construction paper, printer paper & notebook paper. So, we have 9 paper airplanes that we will test for distance travelled.

Design 1: AIRNOVA

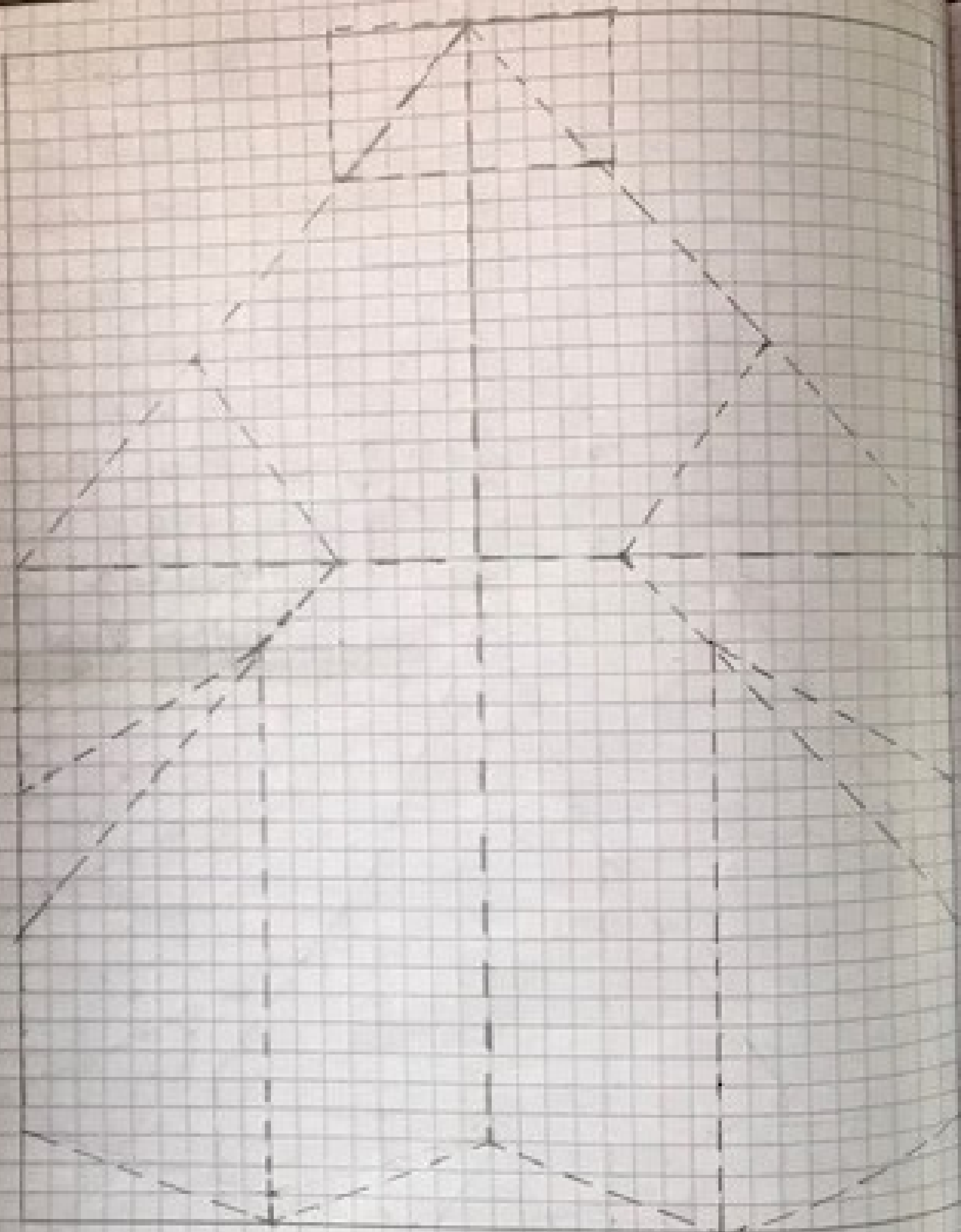




Top View

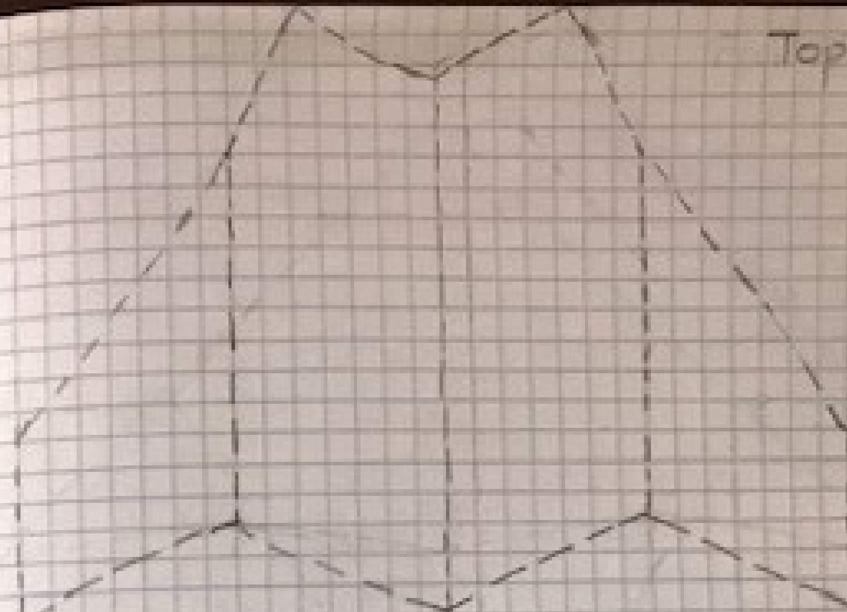


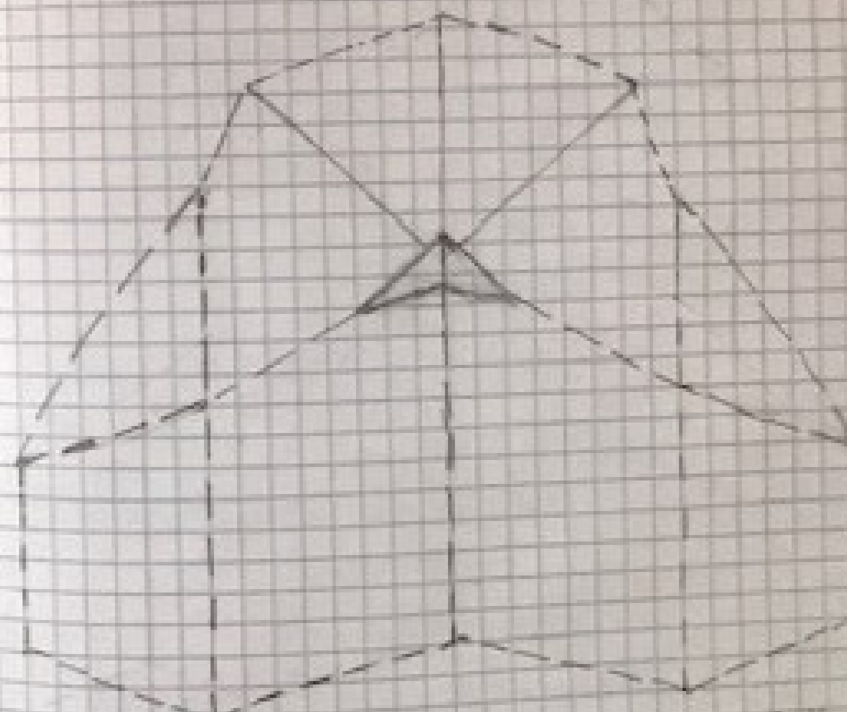
Bottom View



Design 2: BRASSRUSH

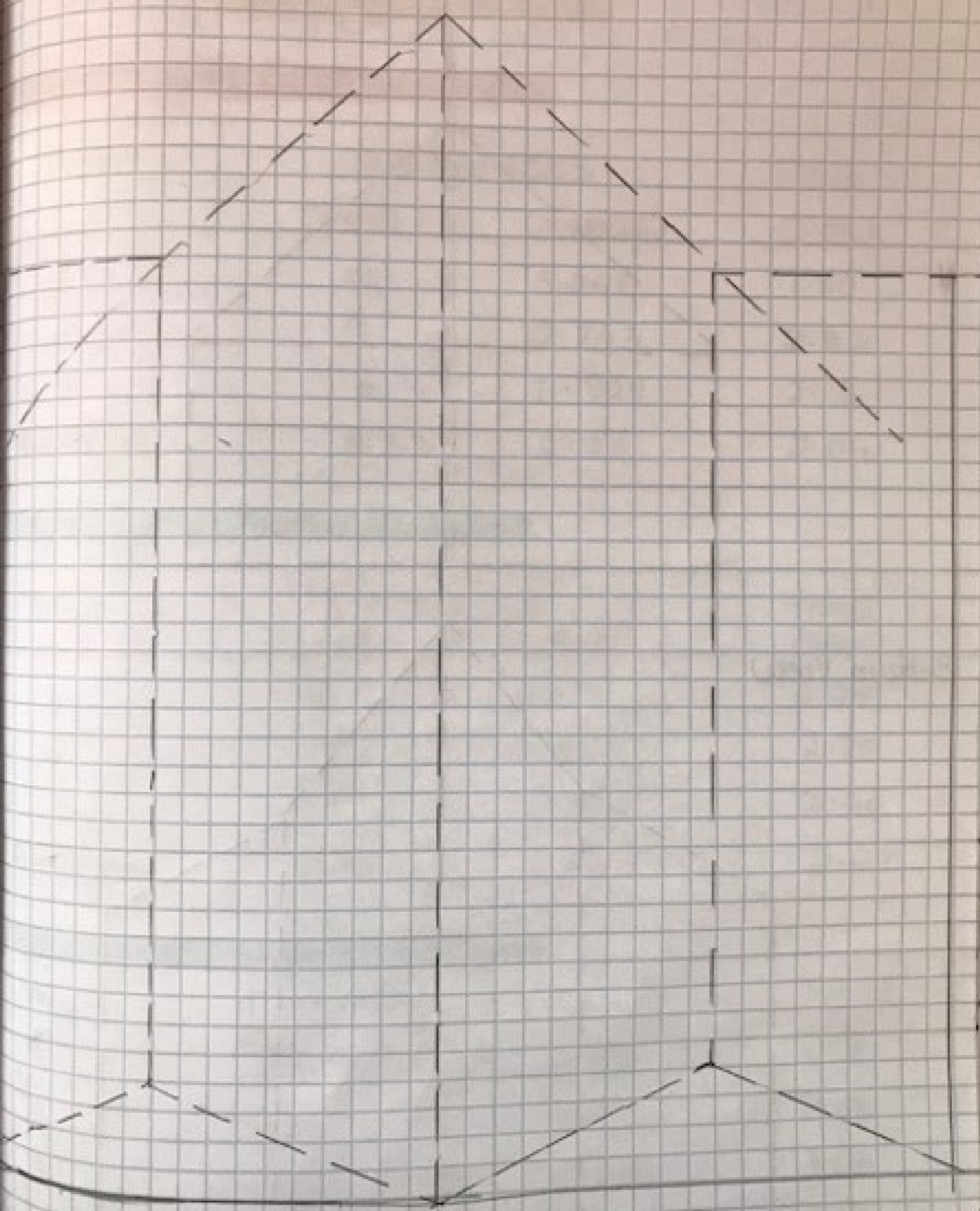
Top Vie



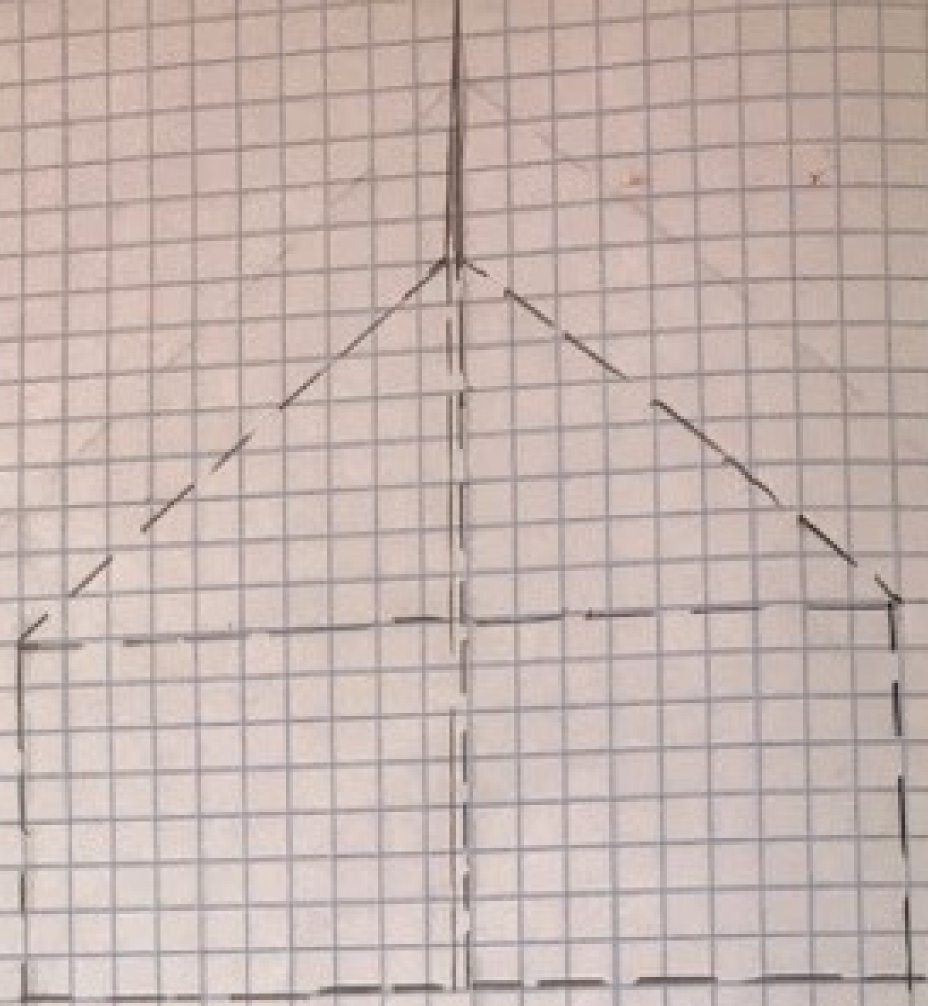


Bottom Vie

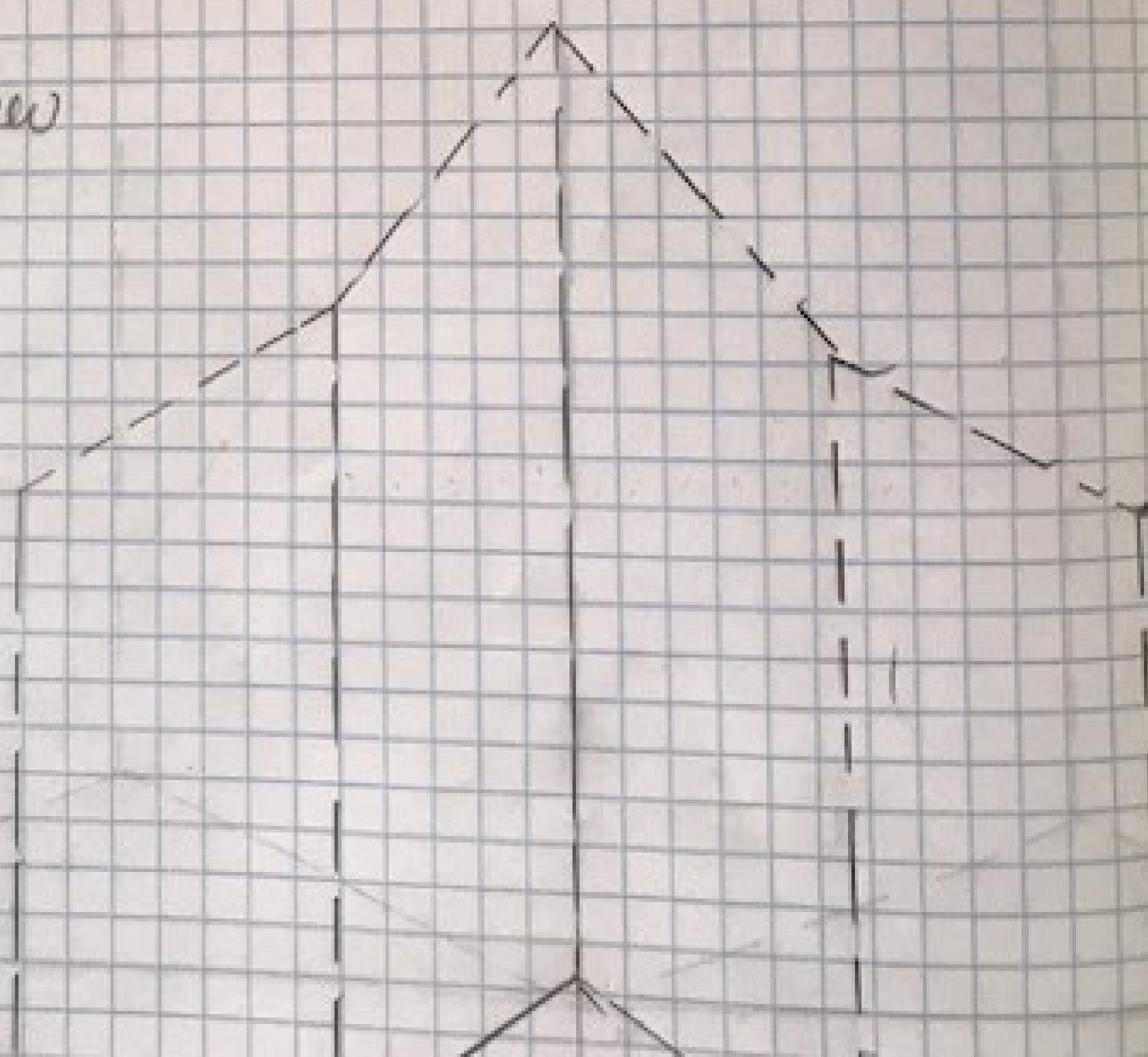
Design 3: CLOUDFLUX



Top View



Bottom View



FLIGHT: DISTANCE-TIME ALOFT

Design: AIRNOVA

Paper Type: Printer Paper

Trials	DISTANCES (feet)	DISTANCES (meters)	TIME (sec)
1.	10	3.048	1.65
2.	9	2.743	2.32
3.	6	1.829	2.16
Average	8.33	2.54	2.04

Paper Type: Notebook Paper

Trials	DISTANCES (feet)	DISTANCES (meters)	TIME (sec)
1.	4	1.219	2.24
2.	5	1.524	2.70
3.	7	2.134	2.46
Average	5.33	1.62	2.47

Paper Type: Construction Paper

Trials	DISTANCES (feet)	DISTANCES (meters)	TIME (sec)
1.	7	2.134	1.78
2.	11	3.353	2.68
3.	12	3.658	3.12
Average	10	3.04	2.52

FLIGHT: Distance - Time Aloft

Design: BRASSRUSH

Paper Type: Printer Paper

Trials	Distance (feet)	Distance (meter)	Time (sec)
1.	7	2.134	2.32
2.	5	1.524	1.55
3.	8	2.438	2.86
Average	6.66	2.032	2.24

Paper Type: Notebook Paper

Trials	DISTANCE (feet)	DISTANCE (meter)	TIME (sec)
1.	7	2.134	1.96
2.	6	1.829	2.66
3.	8	2.438	1.78
Average	7	2.13	2.13

Paper Type: Construction Paper

Trials	Distance (feet)	Distance (meter)	TIME (sec)
1.	9	2.743	1.65
2.	12	3.658	3.23
3.	12	3.658	3.60
Average	11	3.35	2.63

FLIGHT: Distance – Time Aloft

Design: CLOUDFLUX

Paper Type: Printer Paper

Trials	Distance (feet)	Distance (meters)	TIME (sec)
1.	10	3.018	1.62
2.	9	2.743	1.33
3.	14	4.267	2.50
Average	11	3.35	1.82

Paper Type: Notebook Paper

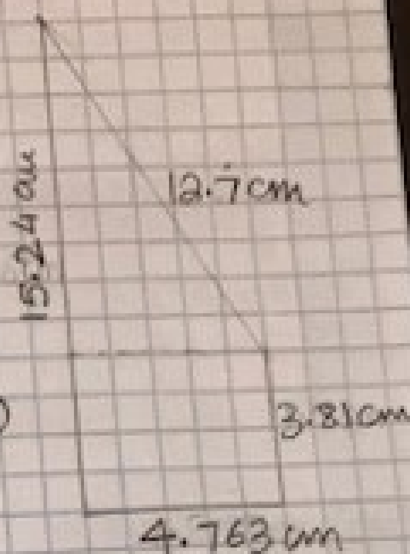
Trials	DISTANCE (feet)	DISTANCE (meters)	TIME (sec)
1.	8	2.438	1.56
2.	6	1.829	1.36
3.	10	3.048	2.10
Average	8	2.442	1.67

Paper Type: Construction Paper

Trials	DISTANCE (feet)	DISTANCE (meters)	TIME (sec)
1.	7	2.134	1.96
2.	6	1.829	2.66
3.	8	2.438	1.78
Average	7	2.13	2.05

WING AREA by Design

1. AIRNOVA



Shape of wing → Trapezoid

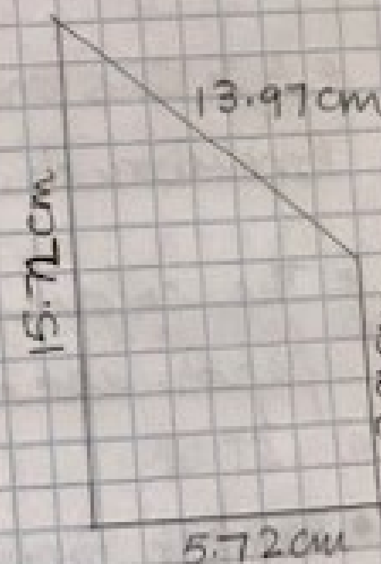
Formula to calculate area of trapezoid : $\frac{1}{2}$ (base 1 + base 2)·height

Wing Area = $\frac{1}{2}(15.24+3.81)(4.763)$

= 45.36 sq. cm

Total Wing Area = 90.72 sq. cm

2. BRASSRUSH



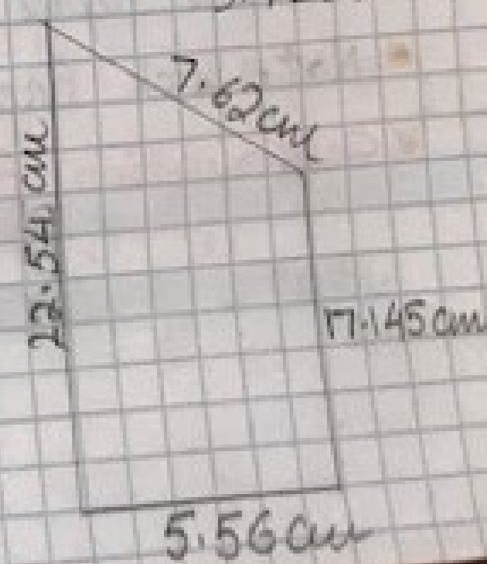
Shape of wing → Trapezoid

Wing Area = $\frac{1}{2}(15.72+3.81)(5.72)$

= 55.86 sq cm

Total Wing Area = 111.72 sq cm

3. CLOUDFLUX

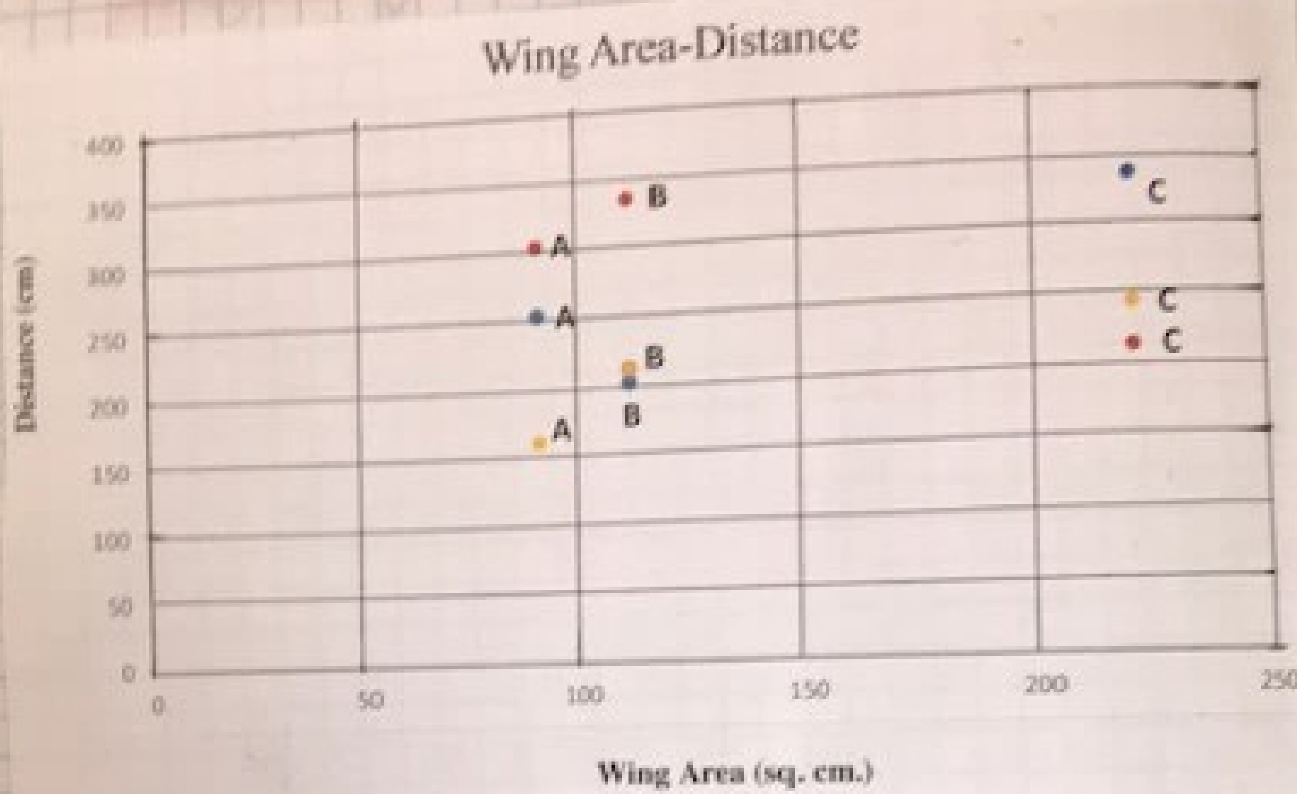


Shape of Wing → Trapezoid

Wing Area = $\frac{1}{2}(22.54+17.145)(5.56)$

= 110.32 sq cm

Total Wing Area = 220.64 sq cm



* A, B, C stand for airplane designs AIRNOVA, Brassbrush, and CLOUDFLUX

* The colour of bullets represents type of paper used to make airplanes.

- Printer Paper
- Notebook Paper
- Construction Paper

WING AREA – DISTANCE

Paper Type: Printer Paper

Design	Avg. Distance (cm)	Wing Area (cm^2)
1. AIRNOVA	254	90.72
2. BRASSBRUSH	203	111.72
3. CLOUDFLUX	335	220.64

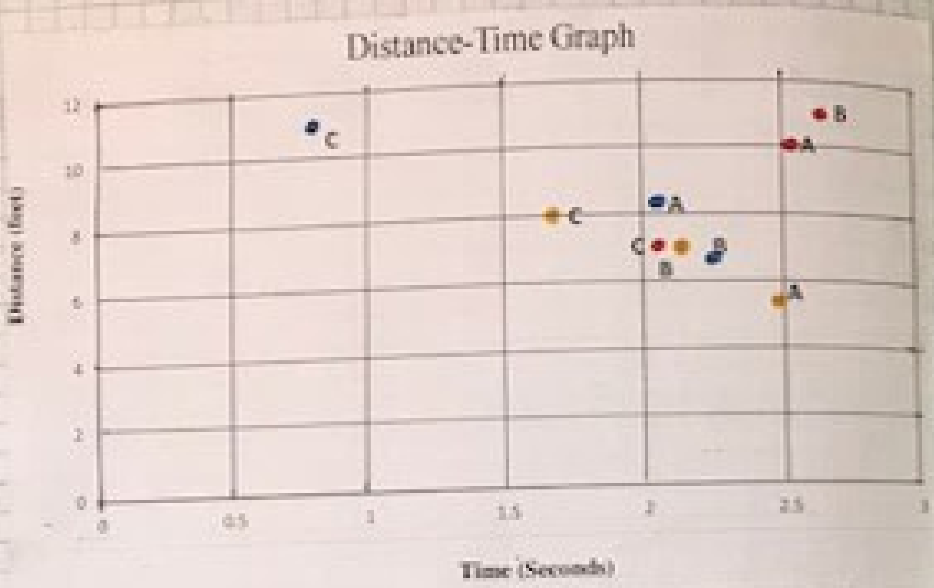
Paper Type: Notebook Paper

Design	Avg. Distance (cm)	Wing Area (cm^2)
1. AIRNOVA	162	90.72
2. BRASSBRUSH	213	111.72
3. CLOUDFLUX	244	220.64

Paper Type: Construction Paper

Design	Avg. Distance (cm)	Wing Area (cm^2)
1. AIRNOVA	304	90.72
2. BRASSBRUSH	335	111.72
3. CLOUDFLUX	213	220.64

Comparison of distace travelled by different designs, same paper and same wing area.



* A, B, C stand for airplane designs AIRNOV, Brassbrush and CLOUDFLUX.

* The colour of bullets represent type of paper used to make airplanes.

- Printer Paper
- Notebook paper
- Construction paper

Comparison of Distance and Time Based on Same Material and Different Designs

Paper → Printer Paper

Design	Avg Dist. (feet)	Time (sec)
1. AIRNOVA	8.33	2.04
2. BRASSBRUSH	6.66	2.24
3. CLOUDFLUX	11	0.8

Paper → Notebook Paper

Design	Avg. Dist. (feet)	Time (sec)
1. AIRNOVA	5.33	2.47
2. BRASSBRUSH	7	2.13
3. CLOUDFLUX	8	1.67

Paper → Construction Paper

Design	Avg. Dist. (feet)	Time (sec)
1. AIRNOVA	10	2.52
2. BRASSBRUSH	11	2.63
3. CLOUDFLUX	7	2.05

ANALYSIS

By paper used:

With printer paper the design brassbrush with second largest wing area (111.72 sq.cm) traveled the least distance (203 cm) but stays afloat of the longest (2.24 sec).

On the other hand the cloudflux with largest wing area (220.64) traveled the maximum distance (330 cm) but stays in air for the least amount of time (0.8 sec)

For notebook paper, when it comes to distance traveled, cloudflux is the winner again (244 cm) but again stays in the air for the least time. While airnova with least wing area (90.72 cm^2) travels the least distance but stays in the air for the longest time (2.47 sec).

For construction paper, brassbrush is the clear winner with average distance traveled 335 cm and staying afloat for 2.63 sec. Cloud flux travels the least, 213 cm, and stays in air for the least time, 2.05 sec.

Overall, all of the CLOUDFLUXES stayed in the air shorter than any other plane design, even though it had the largest wing area.
All planes made out of notebook paper also did not fly very far (due to the flimsy nature of the paper) as compared to the other planes of similar design but different material.

Conclusion: For best airplane, the material should not be too flimsy, like a notebook paper or too heavy as in construction paper. Also, the design of an airplane should not be too big or too small. The thrust with which an airplane is thrown in the air also decides how far it will go in what time.

Reflection

The design challenge "Optimizing a flight" was meant to create an interest in problem-solving using the concepts of paper airplanes, which almost every kid likes and has done it at some point of their childhood. This activity can be done in so many different ways using different engineering design processes. For students, I asked the to choose 3 designs and make each of them with construction paper, printer paper and notebook paper, one design at a time. They will then test the design and record the data for the 3 trials with the first set of airplane design. They had to continue the process with two more designs.

The one that I chose combined the steps build, evaluate and modify. This was a little complex. I created all the 9 planes with 3 different designs and 3 different papers and then tested them. I teamed up with a couple of my advanced students, for my engineering notebook, where they helped me collect the data.

It was an interesting project with plenty of data recording and analysis. This activity is aimed on students who struggle in basic math topics and can be made complex for advanced students by inserting topics like line of best-fit, rate of change.

I still have to do this project with my students, when I will really know what works and what doesn't, also, if I need to make any changes in the activity.

The following standards in Math, Science and Engineering were covered under this project.

Next Generation Science Standards (NGSS)

HS-ETS1-4 Engineering Design
Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

HS-ETS1-2 Engineering Design
Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

HS-PS2- Motion and Stability: Forces and Interaction
Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.

Common Core Math Standards (CCSS)

CCSS.MATH.CONTENT.HSG.MG.A.3
Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physical constraints or minimize cost; working with typographic grid systems based on ratios).

CCSS.MATH.CONTENT.HSN.Q.A.3
Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.