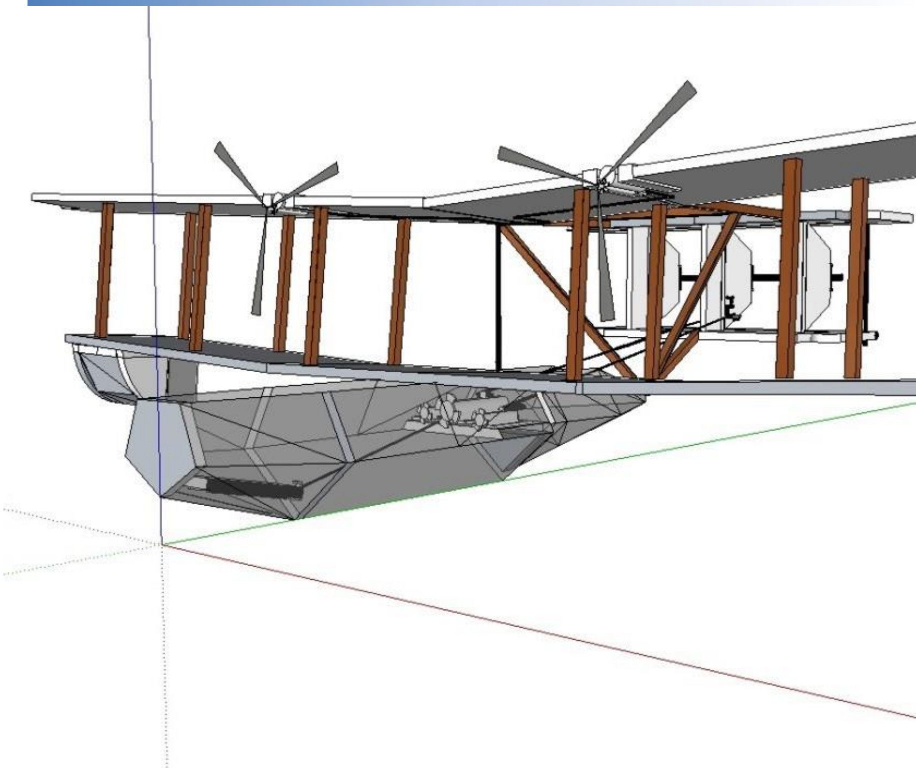
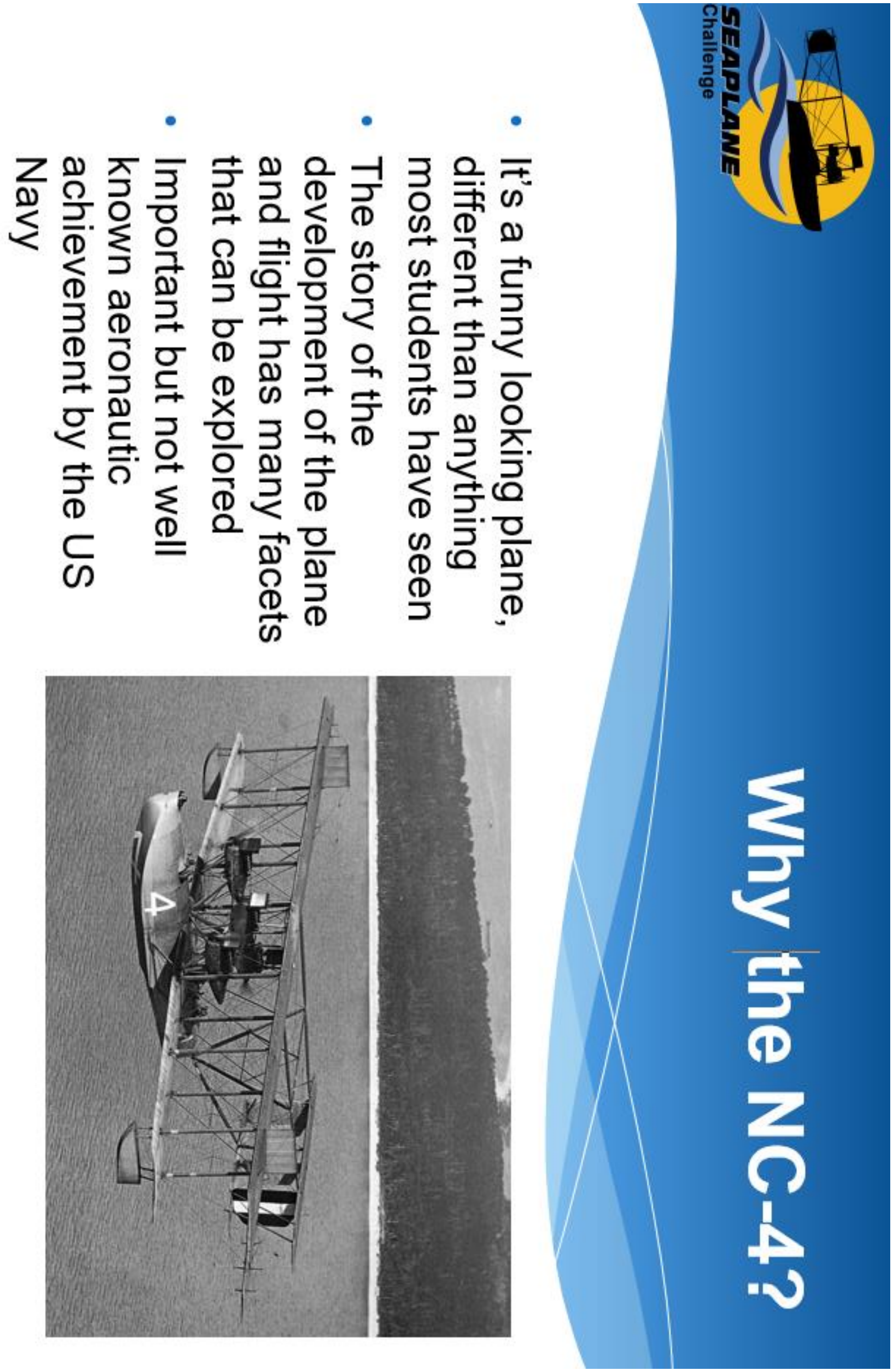
SEAPLANE CHALLENGE
BUILD INSTRUCTIONS



WHY THE NC-4?


SEAPLANE Challenge
Why the NC-4?
It's a funny looking plane, different than anything most students have seen
The story of the development of the plane and flight has many facets that can be explored
Important but not well known aeronautic achievement by the US Navy
4

BACKGROUND FOR EDUCATORS

The **Seaplane Challenge** is a STEM outreach program for students that was created at Naval Surface Warfare Center-Carderock Division. This program is designed to teach and excite students about aviation, aerodynamics, hydrodynamics, engineering, history, and design. The program draws inspiration from the Navy's NC flying boats, one of which was the first aircraft to cross the Atlantic Ocean. It is an exciting study in both exploration and engineering, and provides a great story from which to build. Additional content and material has been added to this guide in order to create a truly interdisciplinary learning experience for students across multiple disciplines.

Next Generation Science Standards: Grades 3-5

Engineering Design

- **3-5-ETS1-1** Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
- **3-5-ETS1-2** Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- **3-5-ETS1-3** Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

Common Core State Standards

ELA/Literacy

- **RI.5.1** Quote accurately from a text when explaining what the text says explicitly and when drawing inferences from the text. (3-5-ETS1-2)
- **RI.5.1** Draw on information from multiple print or digital sources, demonstrating the ability to locate an answer to a question quickly or to solve a problem efficiently. (3-5-ETS1-2)
- **RI.5.9** Integrate information from several texts on the same topic in order to write or speak about the subject knowledgeably. (3-5-ETS1-2)
- **W.5.7** Conduct short research projects that use several sources to build knowledge through investigation of different aspects of a topic. (3-5-ETS1-1),(3-5-ETS1-3)
- **W.5.8** Recall relevant information from experiences or gather relevant information from print and digital sources; summarize or paraphrase information in notes and finished work, and provide a list of sources. (3-5-ETS1-1),(3-5-ETS1-3)
- **W.5.9** Draw evidence from literary or informational texts to support analysis, reflection, and research. (3-5-ETS1-1),(3-5-ETS1-3)

Mathematics

- **MP.2** Reason abstractly and quantitatively. *(3-5-ETS1-1),(3-5-ETS1-2),(3-5-ETS1-3)*
- **MP.4** Model with mathematics. (3-5-ETS1-1),(3-5-ETS1-2),(3-5-ETS1-3)
- **MP.5** Use appropriate tools strategically. (3-5-ETS1-1),(3-5-ETS1-2),(3-5-ETS1-3)

Next Generation Science Standards: Grades 6-8

Engineering Design

- **MS-ETS1-1**. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- **MS-ETS1-2**. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
- **MS-ETS1-3**. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for

success.
- **MS-ETS1-4**. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Common Core State Standards Connections:
ELA/Literacy
- **RST.6-8.1** Cite specific textual evidence to support analysis of science and technical texts. (MS-ETS1-1),(MS-ETS1-2),(MS-ETS1-3)
- **RST.6-8.7** Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). (MS-ETS1-3)
- **RST.6-8.9** Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic. (MS-ETS1-2),(MS-ETS1-3)
- **WHST.6-8.7** Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration. (MS-ETS1-2)
- **WHST.6-8.8** Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation.(MS-ETS1-1)
- **WHST.6-8.9** Draw evidence from informational texts to support analysis, reflection, and research. (MS-ETS1-2)

Mathematics -
- **MP.2** Reason abstractly and quantitatively. (*MS-ETS1-1),(MS-ETS1-2),(MS-ETS1-3)(MS-ETS1-4)*
- **7.EE.3** Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form (whole numbers, fractions, and decimals), using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using

EDUCATIONAL LINKS
History of the Navy-Curtiss NC-4 Flying Boat
http://www.aviation-history.com/navy/nc4.html
https://www.navalaviationmuseum.org/aircraft/nc-4/
https://www.historynet.com/aviation-history-three-us-flying-boats-were-the-first-to-fly-across-the-atlantic-in-1919.htm
https://airandspace.si.edu/collection-objects/curtiss-nc-4

INTERDISCIPLINARY CONTENT
ELA or Social Studies
Students can research Primary Sources through the Library of Congress. Using the Primary Source Reflection Tool (included) or http://www.loc.gov/teachers/primary-source-analysis-tool/, students can make observations, reflections and create additional questions or points of research as they analyze historic documents, articles and pictures relevant to the NC-4. Students can further research aviation history, or how the development of the NC Curtiss changed the shape of World War I
https://www.loc.gov/search/?in=&q=Navy+Curtiss+NC-4&new=true&st=

Science, STEM or Engineering Classes
https://www.faa.gov/education/educators/curriculum/k12/
https://www.nasa.gov/sites/default/files/files/Living-in-the-age-of-airplanes-resource-guide.pdf

https://www.faa.gov/education/educators/curriculum/k12/media/K-12_One_Hundred_Years_of_Sustained_Flight.pdf
https://www.aiaa.org/get-involved/students-educators/k-12-teacher-resources

Engineering Class-
Build a model from balsa wood and blocks
https://outerzone.co.uk/plan_details.asp?ID=8099

TIPS FOR TEACHERS

- Unit measurements – There are different units used throughout the build to encourage students to practice conversions and think critically.
- 3D printed parts are different shapes for different wings.
- Pay attention to the LEADING EDGE. Both leading edges should be facing to the front during assembly.
- The heavier the paper, the better it looks, but the worse it will fly. Midweight cardstock seems to work best but you could even use that as a challenge and have students calculate which paper which best. Additionally, you can combine mediums to get a better plane – lighter weight cardstock for wings and heavier cardstock for hull.
- Part of the idea of the SeaPlane build is to have students "figure things out" or discover the best approach by using trial and error with the Engineering Design Process. Some of the directions are intentionally left vague so that students will work together to solve the problem.
- *In lieu of 3D printed parts use 24 - ¼ inch diameter x ½ inch length brad fasteners or standard sized paper clips and tape. Glue or hot glue also works well.*
- YouTube video showing how to build SeaPlane: https://youtu.be/4NioQwn6cF4

PREPARATION

Teachers should prepare all materials ahead of time. This activity and build will take several hours, so it should be completed over several class periods. Students can work in pairs or groups of threes to cut out and assemble the different parts of the plane.

Materials

- Templates (6 pages) – printed on medium weight cardstock
- 3D printed parts, regular size paper clips, or ¼ inch diameter x ½ inch length brad fasteners
- 13-15 Clear, regular drinking straws
- Pencil
- Scissors
- Ruler
- Hole punch
- Tape (clear, preferred)
- (Optional) Hot glue gun or white glue for use with brads or paper clips

Key

- Solid Line: Cut here
- Dotted Line: Fold here
- (2x): two time

VOCABULARY: Can assign as part of the lesson or use when reviewing directions.
Can also be used to label the NC-4

Aft – Back part of a hull

Boom – A stiff rod or bar that acts like both a spar and a strut.

Bow – Front part of a hull

Dihedral – The angle between the left wing and the right wing. Dihedral can help to make an airplane stable. On this model, the lower wing has dihedral.

Elevators - The hinged part of the horizontal stabilizer; it is used to deflect the tail up and down.

Hull – Part of a boat that sits in the water. On this seaplane, it is the “body” of the airplane. On other kinds of airplanes, the body is called a *fuselage*.

Leading Edge – Front edge of a wing

Rudder - The hinged part of the vertical stabilizer; it is used to deflect the tail to the left and right as viewed from the front of the hull.

Spar – A stiff rod or bar that keeps parts from bending. This models uses drinking straws to make spars.

Strut – A stiff rod or bar that holds other parts together. This model uses drinking straws to make struts.

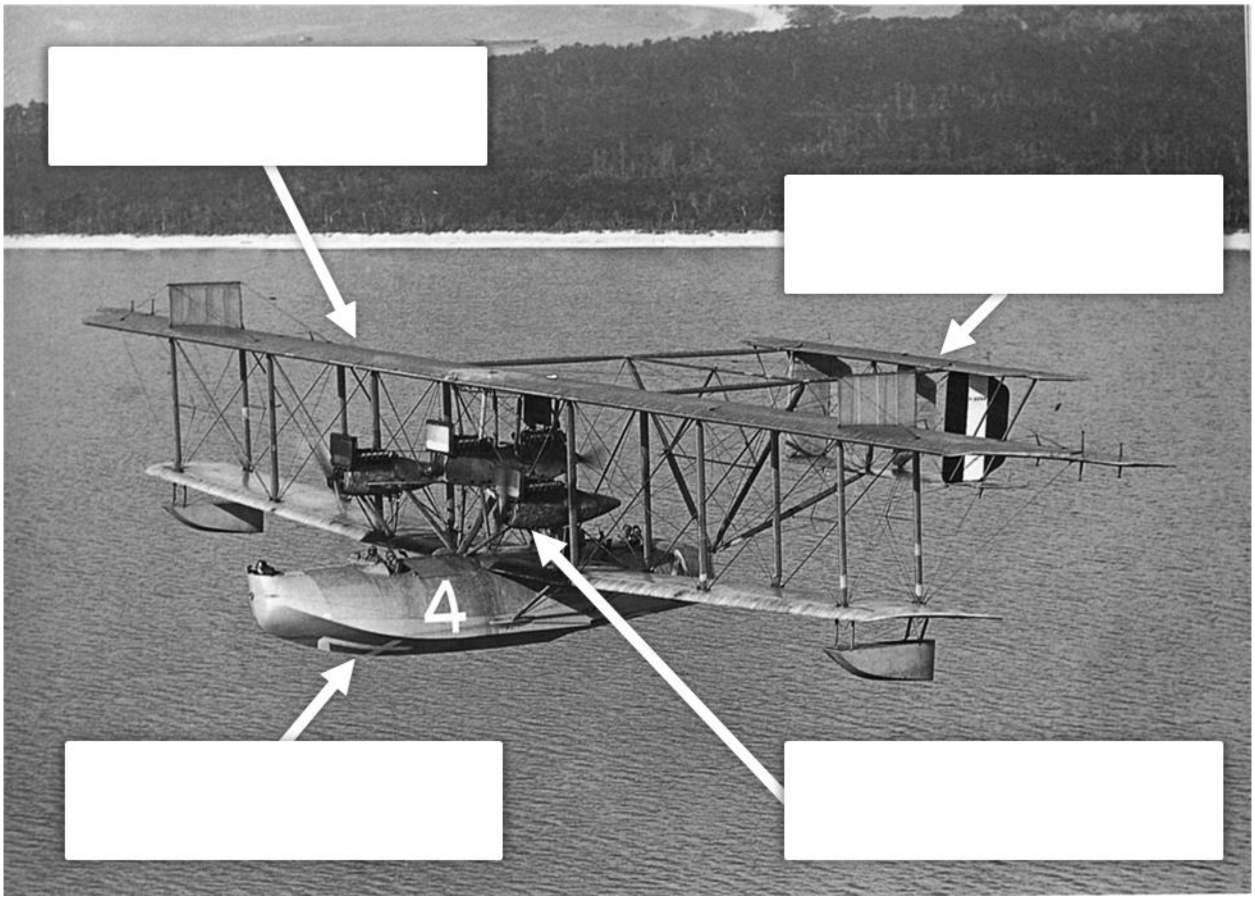
Rivet – A kind of fastener, like a screw or a nail.

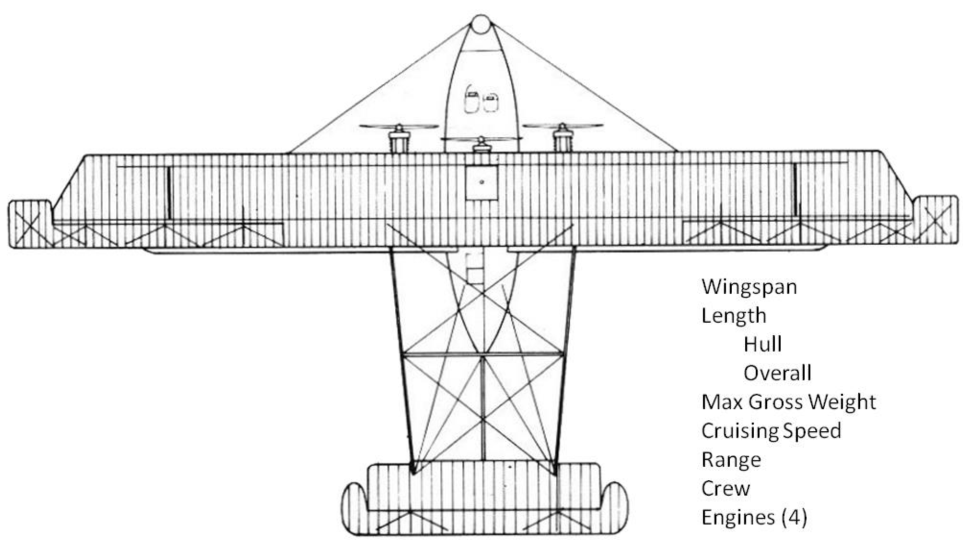
Trailing Edge – Back edge of a wing

Truss – A bunch of struts connected together.

THE NAVY-CURTISS NC-4 FLYING BOAT

Name the Parts of the Real NC-4!





Wingspan	126 ft.
Length	
Hull	45 ft.
Overall	68 ft.
Max Gross Weight	28,000 lb
Cruising Speed	84 kts
Range	1,278 nm
Crew	6
Engines (4)	400 hp Liberty L-12

PRIMARY SOURCE ANALYSIS TOOL

OBSERVE — REFLECT — QUESTION

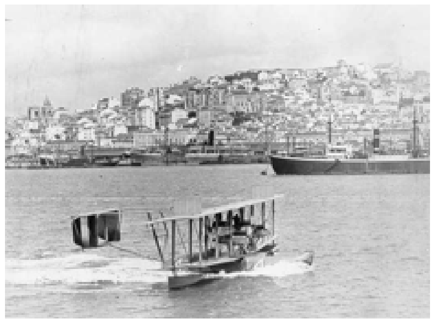
OBSERVE	REFLECT	QUESTION

FURTHER INVESTIGATION

NC-4 HISTORY

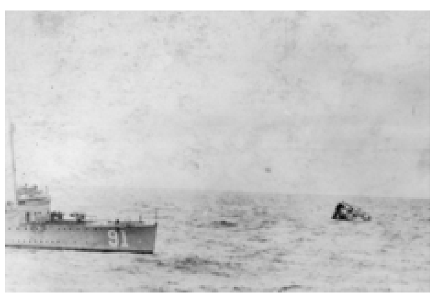
Story of Adventure, Achievement, and Failure

NC-4 arrives in Portugal to a hero's welcome



NC-3 survived high winds and large waves, "sailing" to port safely, if not bruised and battered

NC-1 was lost at sea after sustaining damage landing



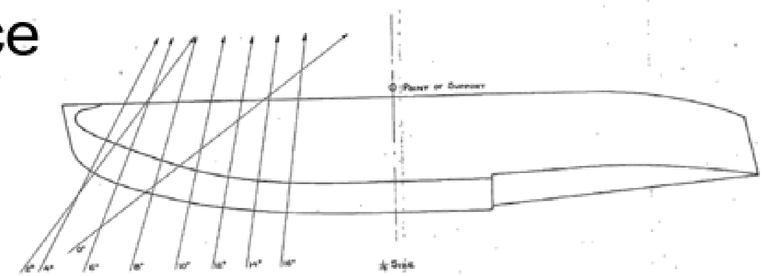
- The crews of the transatlantic mission were explorers in the same vein as the Apollo 11 astronauts
- They accomplished what many believed to be impossible
- 2 of the 3 aircraft on the transatlantic mission failed to complete the journey, but succeeded in other ways (no crew member was lost on the mission)

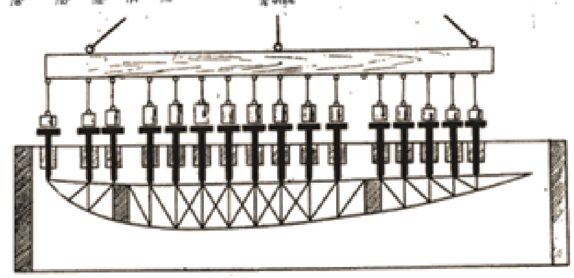
Great Innovators

Leaders in aeronautics for the Navy and industry

Focus on the Engineering Process

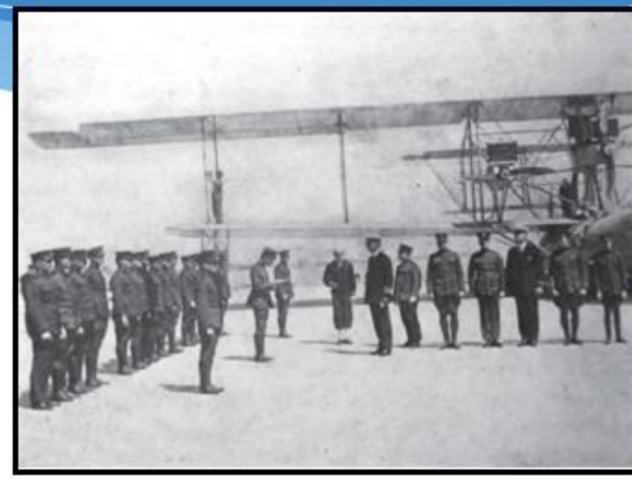
- The NC flying boats were designed and built using modern engineering practice
  - Model testing and experimentation
  - Component engineering
  - Advanced materials
  - Design for manufacture
- Advanced technology used where needed
- Proven concepts used where possible



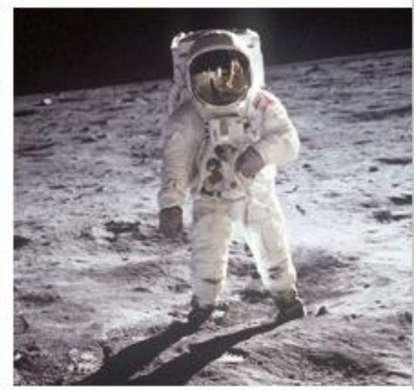


Connection to the Navy

- World's first transatlantic flight was a US Navy mission
- Compared to Columbus' voyage to America
- Well planned and executed – not a daredevil stunt
- Original NC-4 on display at the National Museum of Naval Aviation at NAS Pensacola, Florida



Connection to Today and the Future



"...anyone in the present age of new and startling inventions who says positively that we will never attain an altitude of 60,000 feet, will never fly at 500 miles an hour, or will never be able to cross to Europe in the forenoon and return in the afternoon is a most courageous person"

Albert Read, 1919
Commanding Officer, NC-4

STUDENT BUILD DIRECTIONS:

We are going to build a model of the Navy-Curtiss NC-4 Flying Boat – the very first aircraft to fly across the Atlantic Ocean! Your model will be a glider, or an airplane without a motor. After you finish, you can decorate your model to look like the real NC-4, or any way you would like! Please read the directions carefully and be sure to ask your teacher if you do not understand a particular instruction. Each section will be built first and then the entire airplane assembled together. Like an engineer, you should try to be as precise as possible when building your plane.

Materials – make sure you have all materials prior to starting

- Templates (6 pages) – printed on medium weight cardstock
- 3D printed parts or ¼ inch diameter x ½ inch length brad fasteners
- 13-15 clear, regular-size 7 3/4 or 10 inch drinking straws
- Pencil
- Scissors
- Ruler
- Hole punch
- Tape (clear, non-removable preferred)
- (Optional) Hot glue gun or white glue for use with brads or paperclips

Key

- Solid Line: Cut here
- Dotted Line: Fold here
- (2x): two times

BUILDING THE TAIL

<u>Tail Components:</u>

T1: Lower Horizontal Tail → Elevators

T2: Upper Horizontal Tail → Elevators

T3: Vertical Tail (3x) → Rudders

<u>Instructions:</u>

1) Cut out all the pieces of the tail. Remember only cut on solid line.

2) Bend the tabs on the Vertical Tails (T3) as shown in Figure 1. Using the tabs, tape the Vertical Tails to the Lower Horizontal Tail on the marked lines. The Vertical Tails should be perpendicular to the elevator.

3) Tape the other side of the Vertical Tails to the Upper Horizontal Tail, making sure that they line up with the lines on the template.

Congratulations! You have completed the tail!

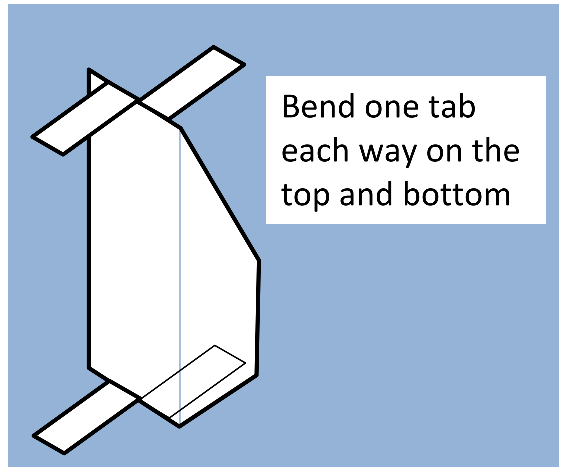
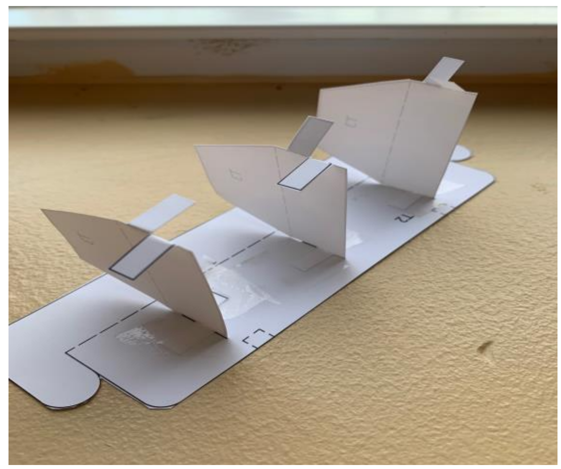
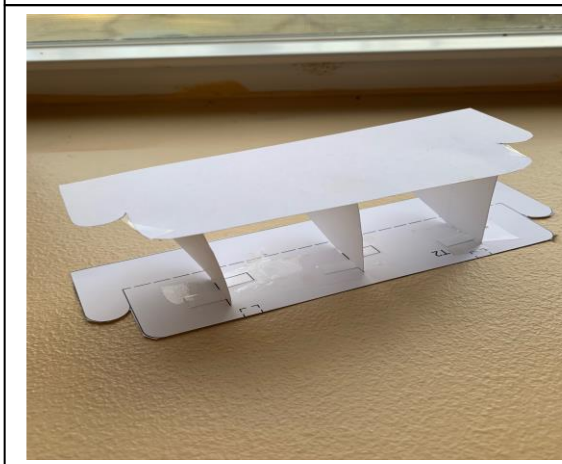


Figure 1.



Step 2: Tape the Vertical Tails to the Lower Horizontal Tail



Step 3: Tape the Vertical Tails to the Lower Horizontal Tail

BUILDING THE WINGS

<u>Wing Parts:</u>

W1: Middle Upper Wing Section

W2: Outer Upper Wing Section (2x)

W3: Lower Wing Section (2x)

<u>Wing Spars:</u>

Upper Wing Spar – straw length to be measured in step 8

<u>Wing Struts:</u>

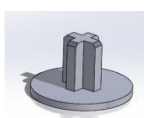
4x Inner Wing Struts—60 mm straw

4x Middle Wing Struts—5 cm straw

4x Outside Wing Struts—40 mm straw

<u>3D Printed Parts</u>

12x Upper Wing Rivets

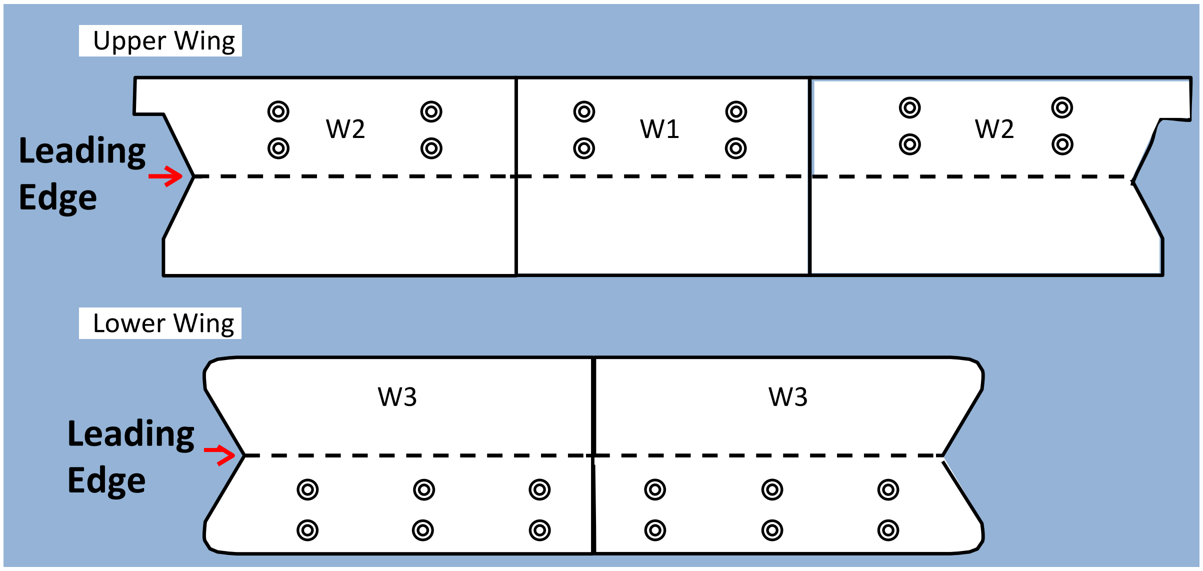


12x Lower Wing Rivets

In lieu of 3D printed parts use
24 - ¼ inch diameter x ½ inch length brad fasteners or standard sized paper clips and tape.
Glue or Hot glue also works well.

<u>Instructions:</u>

1) Cut wing parts from templates.
2) Fold along dotted lines to form creases. If a crease looks like it is going to tear, you can reinforce it with tape. This fold will be the ***<u>LEADING EDGE (front)</u>*** of the wing.



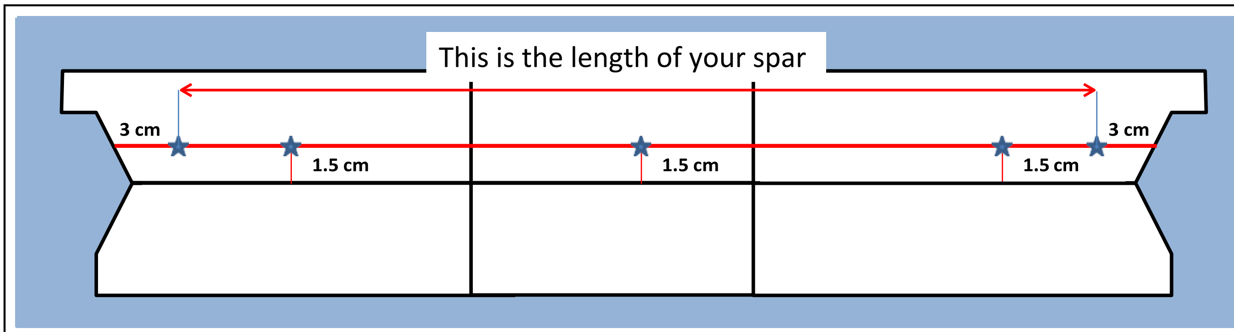
Steps 2 and 3: Fold and then tape wing pieces together

3) Tape all three upper wing pieces together, making sure that the circles are all on the same side.

4) Tape both lower wing pieces together, making sure that the circles are all on the same side.

5) Upper Wing: Flip the wing over to the side of the paper WITHOUT the printed marks, measure a point 1.5 cm above leading edge (the folded crease) in at least 3 places.

6) Using a ruler, draw a straight line connecting the marks and extending to the wingtips (ends of the wing).



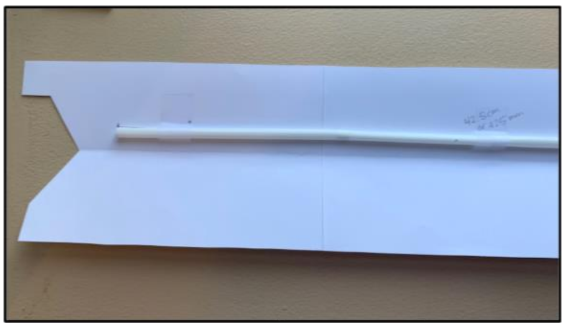
Steps 5 - 8: Measure for the Upper Wing Spar

7) Measure 3 cm in from the left and right ends of the wing and mark the line.

8) <u>Measure the length of the line between the marks</u> – this is how long your Upper Wing Spar needs to be. You can write the length near the line.

9) Cut out the Upper Wing Spar from straws using the length you measured in step 8. If you need more than one straw, tape or glue them together.

10) Tape the Upper Wing Spar over the line you drew in step 6, between the points you measured in step 7.



Steps 9-11: Finishing the Upper Wing Spar

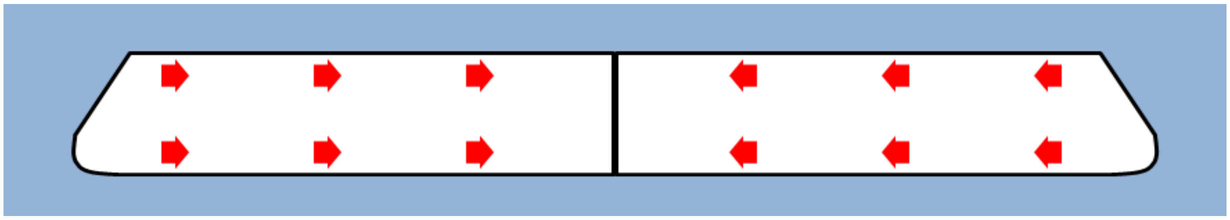
11) Bring up the bottom half to fold and tape the two surfaces of the wing together with the spar on the INSIDE. Try and keep the lower surface (the side with the marks) flat.

12) Fold Lower Wing at leading edge and tape upper and lower surfaces together (marks on the outside). There is no spar for the Lower Wing. Crease or bend the lower wing in the middle in anticipation of Step 17. The holes should be on the bottom and the fold should face upward.

13) Using a hole punch, make holes where marked on the Upper and Lower Wings.

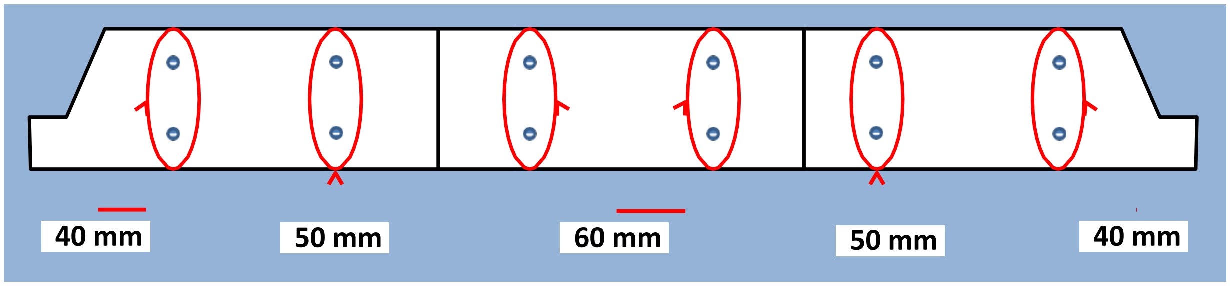
14) Insert the Upper Wing Rivets through the holes in the Upper Wing and tape or glue in place. *If using brads, place the legs of the brad through the hole from the top down. If using paper clips, bend at 90° angle, and place one in end in straw and glue or tape other end to wing. The legs will be glued inside the straw struts in Step 16.*

15) Insert the Lower Wing Rivets through the holes in the Lower Wing with the arrow of each facing towards the center of the wing. Tape or glue in place. *If using brads, place the legs of the brad through the holes from the bottom up. If using paper clips, bend at 90° angle, and place one in end in straw and glue or tape other end to wing. The legs will be glued inside the straw struts in Step 17.*



Steps 15: Lower Wing Rivets face the center of the wing

16) Place Wing Struts onto Upper Wing Rivets – shortest on the outside, longest on the inside. Tape or glue in place. If using brads or paper clips, place a drop of hot glue (or regular glue) inside the strut before inserting the legs of the brad into the straw.



Steps 16: Place Wing Struts on Wing Rivets into Upper Wing

Step 17: Attach Lower Wing

17) Place Lower Wing onto Wing Struts. If using brads or paper clips, place a drop of hot glue (or regular glue) inside the strut before inserting the legs of the brad into the straw. Note that you will need to bend the Lower Wing upward in the middle to connect. **This is called *dihedral.***

18) Once everything fits, tape or glue the struts to the wings.

Congratulations! You have completed the wings!

BUILDING THE SEAPLANE HULL

<u>Hull Parts:</u>

H1: Main hull body

H2: Bulkheads (2x)

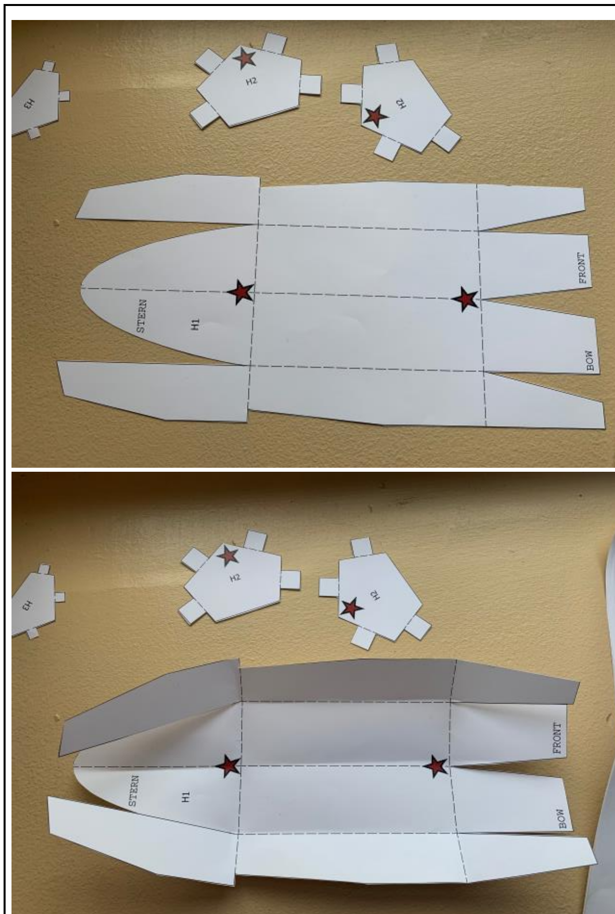
H3: Nose Cover

H4: Back Hull Cover H5: Front

Hull Cover

<u>Instructions:</u>

1) Cut out all the hull parts H1 – H5 from the templates. Fold H1 along the dotted lines to make creases.

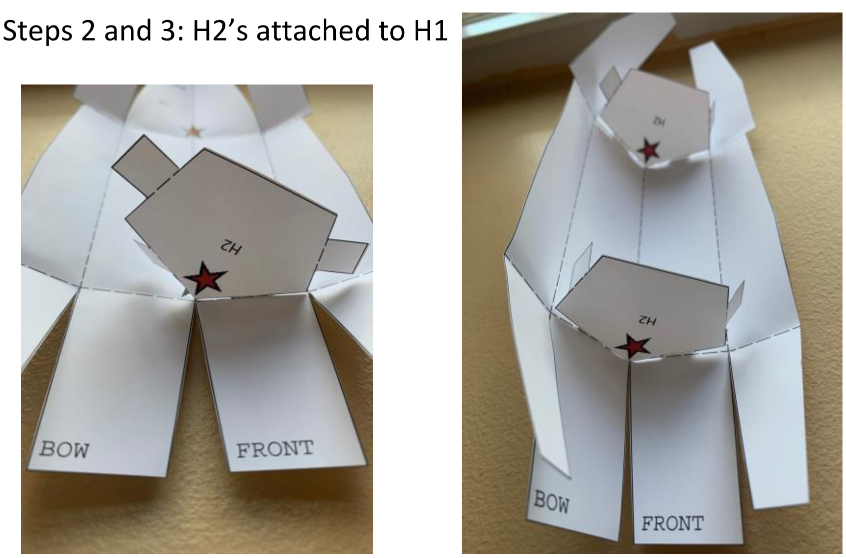


Step 1: H1 and 2x H2 shown (Front or ***bow*** on the right)

2) Place an H2 Bulkhead on the dotted line closest to the ***bow (front)*** of H1. Stars on H2 should match stars on H1. Bend the tabs on H2 to tape the piece onto H1.

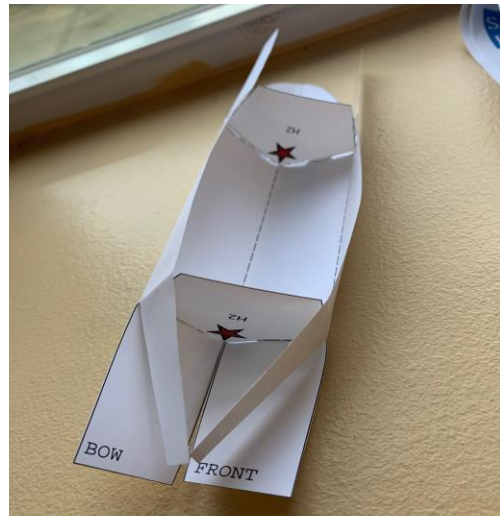
3) Repeat with the second (aft) H2 Bulkhead towards the hull's tail.

Steps 2 and 3: H2's attached to H1



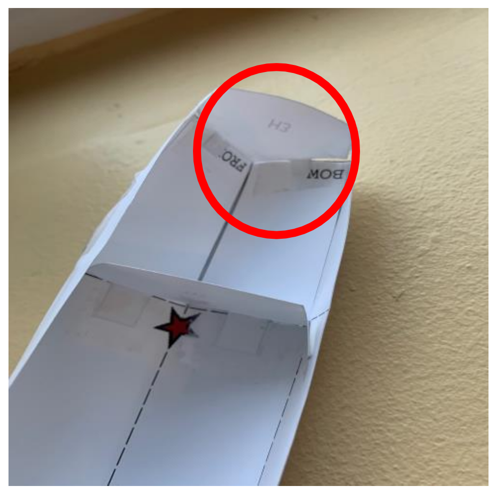
4) Fold the sides of the hull so that the 4 sides touch both H2 Bulkheads. Tape in place. *(It will look like a canoe.)*

5) Tape bow (front) of hull together.



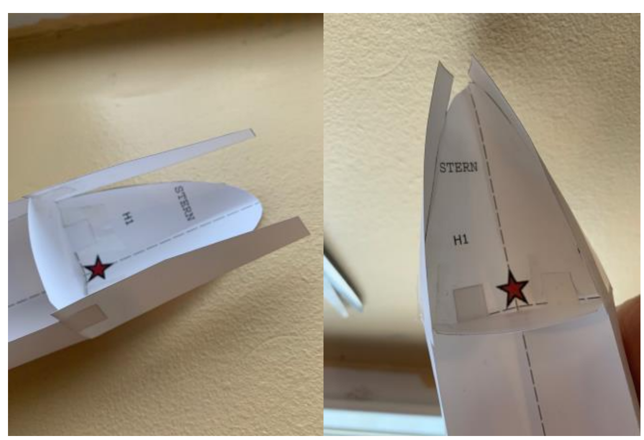
Steps 4 and 5: Fold up the sides of hull

6) Tape nose cover (H3) in place at the front (bow) and trim any parts that protrude.



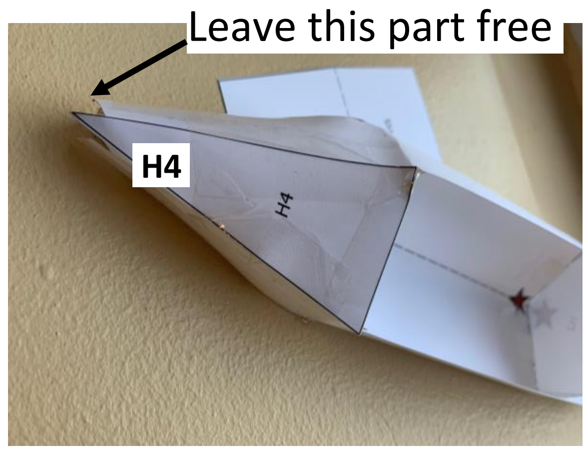
Step 6: Place the nose cover (H3) on the front of the hull

7) Tape the tail (stern) of the hull together, but leave the end open – you will need to put a piece in the back later.



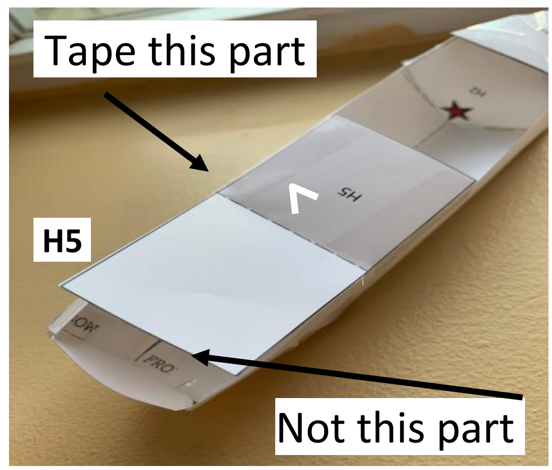
Step 7: Tape the tail together

8) Tape the Back Hull Cover (H4) in place. It should cover the stern from the tail to the rear H2. Leave the very back end free for now so you can get in later!



Step 8: Tape the Back Hull Cover (H4) in place

9) Attach the Front Hull Cover (H5) to the hull but tape ONLY THE BACK PART (towards the middle of the hull). You will need to get inside the front of the hull later to make the plane fly! (Don't worry if you taped the whole thing, you can open it up with scissors or by peeling the tape).



Congratulations! You have completed the hull!

ASSEMBLING THE PLANE

Plane Components:

Hull Wings Tail

Tail Truss Components:

Hull-to-Tail Boom—100 mm

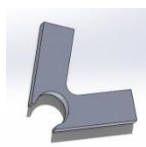
2x Truss Legs—90 mm

Crossbar—105 mm

2x Wing-to-Tail Booms—170 mm

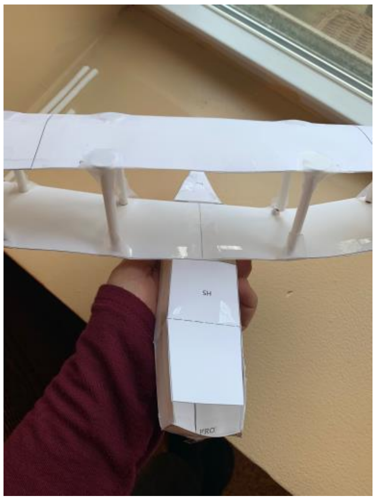
3D Printed Parts

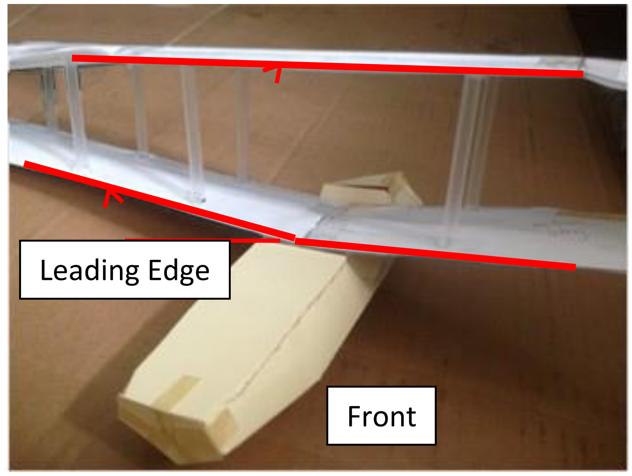
3x Truss Connectors



Instructions:

1) Attach the Wings to the Hull using tape or glue. The wing should cover the open space on the top of the hull and the Trailing Edge should rest against the aft bulkhead. **Remember: Leading Edge is forward!**

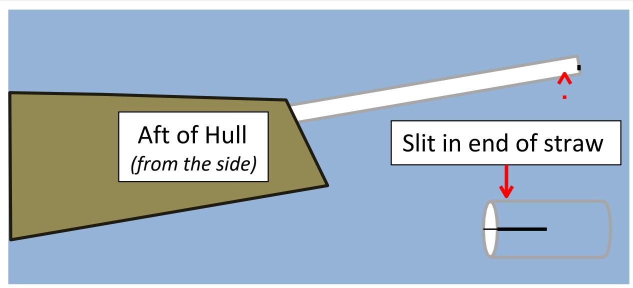




Step 1: Attach the Wings to the Hull

2) Cut straws to make Tail Truss components.

3) Measure 1 cm from the end of the Hull-to-Tail Boom and mark it. Insert this end of the Hull-to- Tail Boom into the ***aft (back)*** of the Hull and tape together so that the straw stays in place.



Steps 3-4: Attach the Wings to the Hull

4) Cut a short slit (about 10 mm) in THE OTHER END of the Hull-to-Tail Boom so that a sheet of paper can slide in between. This slit should be *horizontal*.

5) Cut short slits (about 10 mm) in both ends of the Wing-to-Tail Booms. These slits must be *horizontal* and *parallel* (=).

Steps 6 - 8: Place the Wing-to-Tail Booms and Hull-to-Tail Boom

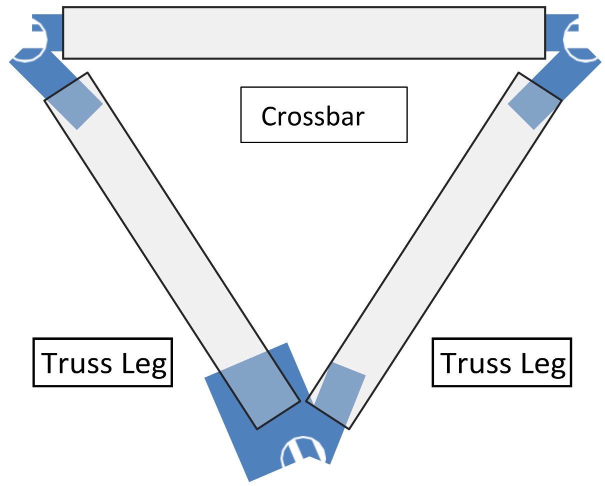
6) There are boxes marked by dotted lines on the *trailing edge* of the Upper Wing and the *leading edge* of the Upper Horizontal Tail. Insert these areas of the Upper Wing and Upper Horizontal Tail into the slits of the Hull-to-Tail Booms.

7) Insert Lower Horizontal Tail into slit cut in Hull-to-Tail Boom. Tape in place.

8) Align the Tail by sliding the Wing and Tail on the Booms:
   - Looking from the side, the Upper Horizontal Tail is even with the Upper Wing
   - Looking from the side, the tail is level with the hull
   - Looking from the top, the Tail is centered with hull
   - Looking from the top, the Tail is straight

9) When you are happy with the alignment of the tail, tape or glue all of the booms securely in place.

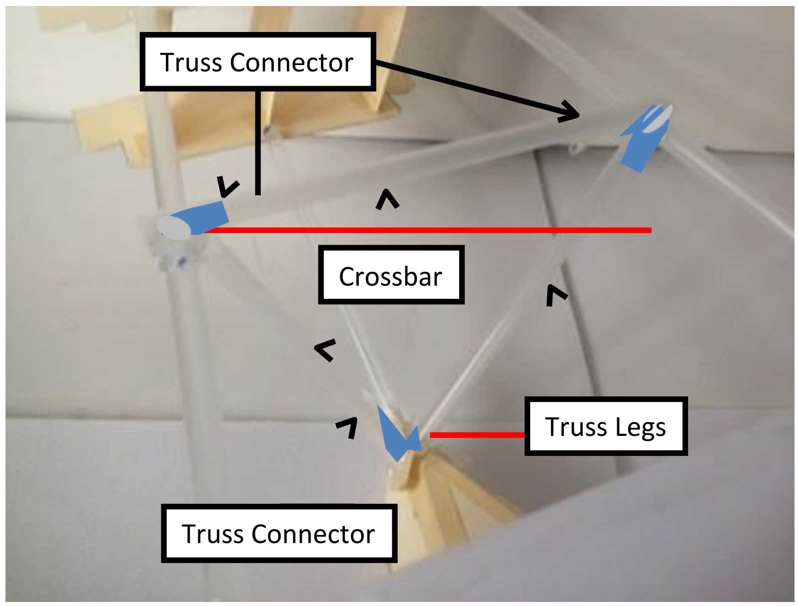
10) Using the Crossbar, 2x Truss Legs, and 3x Truss Connectors, make the Tail Support Triangle.



Steps 10: Tail Support Triangle

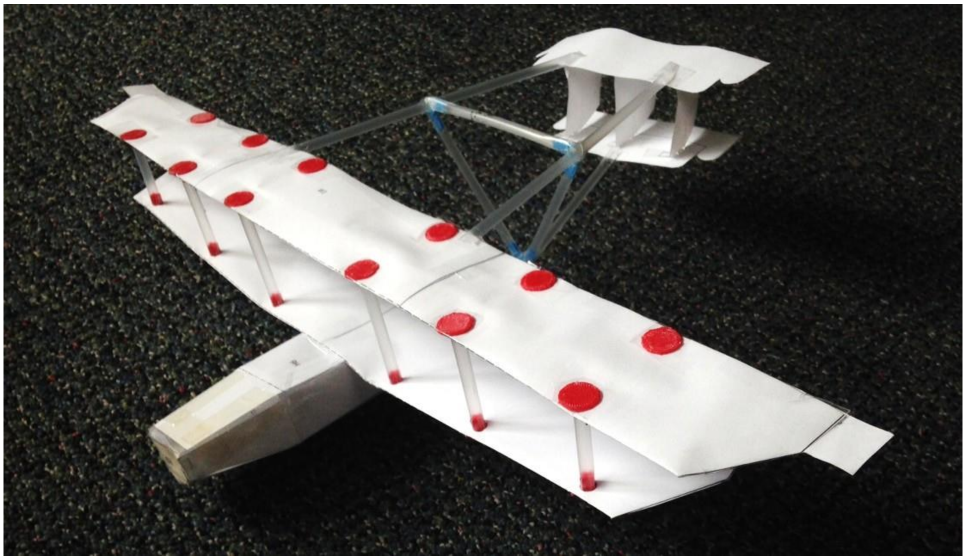
11) Attach Tail Support Triangle to the Wing- to-Tail Booms and Hull-to-Tail Boom.

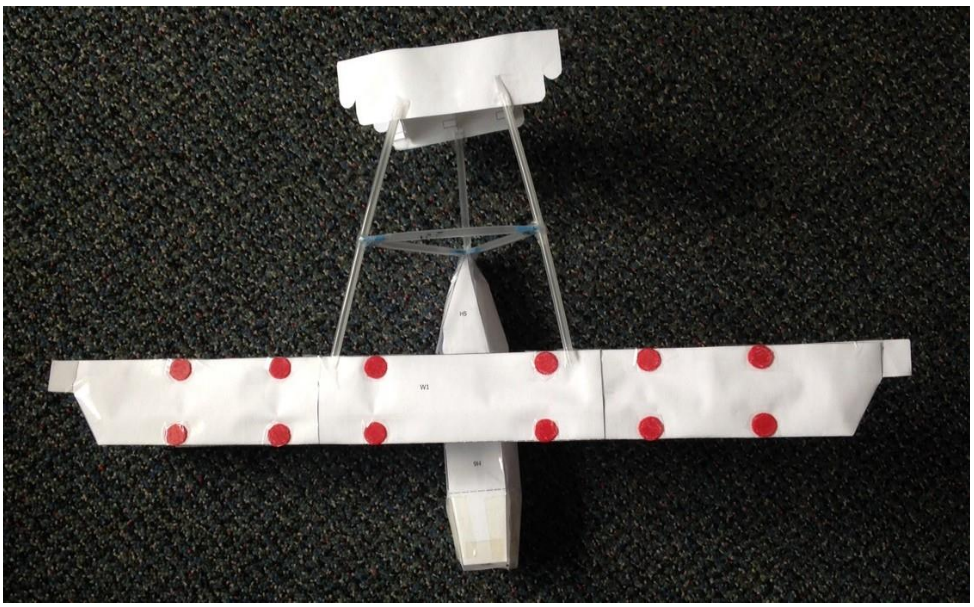
12) Move Tail Support Triangle as needed to make things fit. Once you are happy, tape or glue everything securely in place.



Steps 11 - 12: Attach Tail Support Triangle

Congratulations! You have completed the Seaplane! Now it's time to balance and trim it to make it fly.





BALANCING

The plane will not fly well, or at all, if you try and fly now. Go ahead and see what happens! Remember, you built it so you can fix anything that comes apart or breaks.

The plane probably pitched up (nose goes up) and then fell backwards. To fix this, we need to balance the plane.

Every plane is a little different, but we can start with the plane neutral and change things from there.

1) Place two fingers or pencil erasers on the bottom surface of the Upper Wing at the Wing Spar, near the Inner Wing Struts.

2) Add weight (modeling clay) to the front of the Hull (this is why we left the Front Hull Cover loose!) until the plane sits about level.

3) Test glide with a gentle toss straight ahead. You want to the plane to glide without pitching up or diving down

4) Adjust as needed.
    - If the plane pitches up, add more weight
    - If the place dives down, take some weight off

5) You can also adjust the angle of the Elevators (the back part of the Upper and Lower Horizontal Tails). Try bending them up or down and see what they do!