Europa Rover Landing System Project

Submitted by: Anthony Canestaro, Physics and Engineering
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Target Grade: 11^{th}-12^{th} Physics

Time Required: Seven 40-minute classes

Standards:

NGSS

- **HS-PS2-3**. Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.
- **HS-ETS1-2**. 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-ETS1-3**. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

Lesson Objectives:

Students will:

- use the engineering design process to design the best possible solution to a problem which meets numerous constraints.
- design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.
- evaluate trade-offs in a decision, and use an informed process to come to the best possible decision in a problem.

Central Focus:

NASA is looking to send a rover to Europa to examine below the layer of ice for evidence of life! In this engaging physics lesson, students will construct a scaled model of a landing system and demonstrate its effectiveness. This new take on the classic egg drop challenge will require students to understand force, the engineering design process, and real-world problems. Students will minimize force on a macroscopic object during collision, which will maximize student engagement during instruction!

Key words: engineer, create, evaluate, redesign, solution, criteria, problem solving, team work, group, groups, physical science

Background Information:

Impulse-Momentum Theorem

The impulse momentum theorem states that forces exerted over time change the momentum of objects. In trigonometry-based introductory physics, the impulse-momentum theorem is given by the equation:

$$F_{net} \cdot t = \Delta p$$

Where F_{net} is the net force acting on an object, t is the time in which the force is acting on an object, and

Δp is the change in momentum of an object. In calculus-based mechanics, the impulse-momentum theorem is given by:

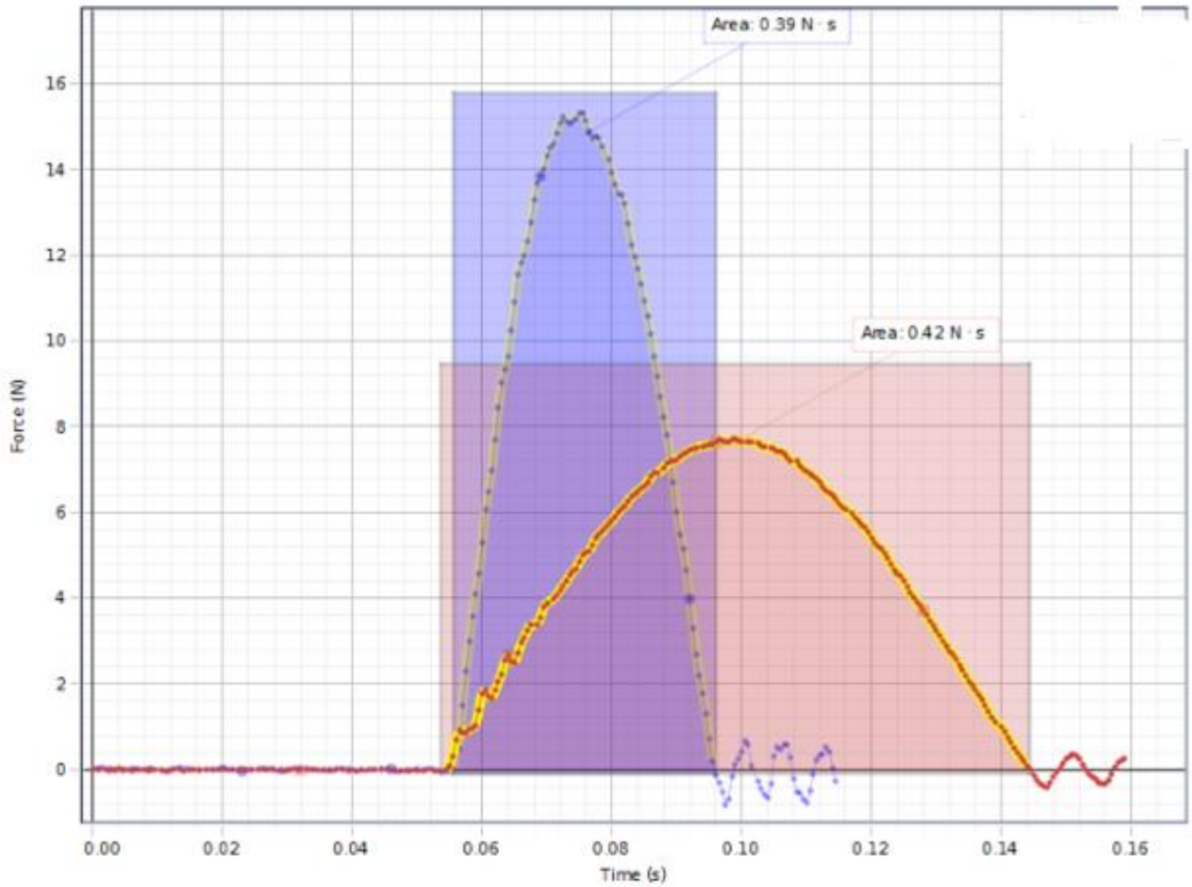
$$\int F \cdot dt = \Delta p$$

This theorem is useful when a force is non-constant. This equation also tells us that the change in momentum of an object, also known as the impulse, can be found by taking the area under a graph of force vs. time.

This equation has numerous applications in physics and everyday life. For example, the function of a bumper in a car or the squishy foam in a bicycle helmet can be explained by this equation. Both objects increase the impact time with which the object has with whatever it is colliding against. No matter if the impact time is large or small, the object will have the same change in momentum. Therefore, a large impact time equals a small average force exerted on the object, and a small impact time equals a very large force exerted on the object.

Another way to think about this equation is in terms of Newton's 2^{nd} Law, force=mass x acceleration (F=ma). If an object comes to a rest in a very small amount of time, it has to have a large acceleration, thus a large force must be exerted on it to make it come to a stop in a short time. Similarly, if it takes a large amount of time to come to a stop, it would not require as large of a force.

Using the calculus version of the impulse-momentum theorem, we can understand and interpret graphs of force versus time. The data below was obtained through a Vernier force plate and illustrates two collisions. The blue line is a golf ball dropped onto the plate (hard material=short impact time=large forces) and the red line is a tennis ball (softer material=longer impact time=smaller forces). Both have approximately the same mass (50g vs 58g respectively) and were dropped at the same height, accounting for equivalent impulse exerted on the plate.



Note that the golf ball clearly has a smaller impact time and experiences a larger peak force (~15N vs. ~7.5N) then the tennis ball. For an ideal bumper or helmet design, the ideal impulse curve is "fattened" by having a very large time of impact and small peak force exerted.

Materials

- Vernier Force Plate (1-2).
  - The force plate should be able to produce a graph of force versus time to determine impulse (area). Logger pro software must be installed on a useable computer.
- Materials for egg drop project.
  - Straws
  - Duct tape
  - Scotch tape
  - Electrical tape
  - Eggs
  - Boxes (ranging in size)
  - Printer paper
  - Construction paper
  - Thin string
  - Firm string
  - Rubber bands
  - Cups
  - Plastic bags (ranging in size)
  - Paperclips
  - Toothpicks
  - Hot glue gun
  - Hot glue

- Fake money (~$15k in large bills and $2-3k in small bills)
    - Teacher suggestion: Pokémon™ monopoly game money minimizes the chance of forgery
- Student Handout (1 per student)
- Engineering Notebook (1 per student)
- Large tarp (for the demonstration)

Instruction

Introduction of Challenge

The challenge should start with teacher and students reading the premise and challenge on the front page of the engineering design challenge worksheet. The big piece to note is that there are two acceptable forms of this egg drop project:

[1] Traditional egg drop. Students build a device to surround the egg and drop it from the top floor.

[2] Naked egg. Students build a device to drop a raw egg into. An example of this is a box with foam and paper that students will drop eggs into.

Students are not limited to these two designs. They **can** combine the two if desired and if money and time allow. If that is the case, they will need to make drawings and designs for both parts.

Explain the budget and requisition sheet. Students will have to carefully plan their use of materials so that they do not go over budget. Emphasize that planning and communication is key for this activity. There are no additional ways to get money, so if they run out, they run out.

Next, explain briefly the steps of the engineering design process (front cover of student notebook) and that all engineers go through this exact process when trying to find the optimal solution to a complex problem.

Finally, give time to allow students to look through the rubric and engineering design notebook to become familiar with the project expectations. Make sure students are aware of exactly how they will be graded for the project (notebook rubric, not just egg survival) and the day-to-day homework and objectives.

Define the Problem (Day 1, 5 minutes)

After grouping students, give the groups approximately 5 minutes to redefine the problems in their own words. They should not be trying to brainstorm solutions here. The key is that they simply take the complex problem, divide it into smaller pieces, and rewrite the problem to demonstrate understanding of the expectations and objectives.

Brainstorm (Day 1, 20 minutes)

During the brainstorm phase, students should spend time working individually and as a group (teacher discretion on use of time). Remind students that this is a time for ideas only. No decisions or comments on ideas should be made at this point. Encourage the use of pictures to help students convey ideas.

Identify Constraints (Day 1, 10 minutes)

After the brainstorming phase, have students think about the constraints on their problem, that is, the essential items they have to consider to be successful. Some example constraints include:

- Budget. They only have $3,000 to work with.
  - Eggs cost a lot, but they can buy multiple eggs and perform multiple tests
  - Rental fees are expensive, but allow students to test their device multiple times
- Time. They have 5 class periods to complete this project.
- Size. There is no size constraint, but larger objects will require more materials and will be more expensive
- Materials. They will only have access to common school materials listed. No specialized materials should be provided, as they will most likely be successful enough that students will be discouraged from going through the revision/redesign process.
- Egg. The egg has to survive no matter what.

Initial Discussion of Options (Day 1, 15 minutes, finish on Day 2)

Students should now be given time to consider their problem and constraints to identify which ideas might be a solution to the problem. The teacher should recommend students combine one or more ideas. Encourage the students to narrow the options down to a smaller list by crossing off ideas which either [1] will not solve the problem or [2] are outside the scope of this project. By the end of class students should have a rough idea of 3-4 solutions to explore in detail. Make sure to discourage any students/groups that get set on only one idea.

Tradeoff Matrix (Day 2, 10 minutes)

With the list of solutions narrowed to 3-4, students will complete the tradeoff matrix to determine the best solution for their group. Students should estimate the cost of each device here (they will need to figure out all materials required). In addition to the criteria provided, students should be encouraged to add their own categories to help identify the best solution. After ranking, students should select the solution with the highest score. A great discussion point is to ask students if the highest ranking option was the one they were leaning towards or not.

Scale Model (Day 2, 30 minutes)

With the option selected, students should begin thinking in detail about the materials required for this project. They will then make an orthographic projection of their device, showing the details from all angles. While most students want to immediately starting building, explain the importance of the drawing: it allows them to further plan and think about their device. Encourage students to think of potential problems and develop a plan to mitigate them. Once completed, students should work on the materials sheet and make an initial requisition of materials to build their prototype.

Construction/Testing/Redesign of Prototype (Days 3-5)

The teacher should make sure to hand out monopoly money and collect from students as they purchase supplies. Students should use the force scale and then use the data to drive the changes they make in their device. If it breaks during testing, have students carefully consider the location of where it broke and how to specifically address the issue.

Students may decide their device isn't perfect and/or that they want to go back to square one at this point. Remind them in the real world, doing this costs a lot of money and often is not possible. The objective isn't to have a perfect device, but the best possible device that **they** can make given the time, money, and problem constraints.

Preparation of Pitch (Day 6)

The day before the presentation of devices, groups will create a short pitch of their device. They should highlight:

- The landing system chosen and why
- The main features of the device that make it stand out
- Initial problems that were encountered and how they were fixed
- Problems they foresee as the project is scaled up to real life and how they will be addressed

Demonstration of Devices (Day 7)

Place tarp on floor and invite classes around to come watch! Students will take turns by first giving their pitch and then demonstrating their devices. The teacher should make sure to drop the eggs from the same height (50 feet) for each test.

Project Debrief (Day 7)

Have students complete the project debrief in their notebook. The questions should serve as discussions for the class to have about the engineering design process. For question [5], share answers with the class so everyone can hear some words of encouragement.

An additional question to consider at the end is "How is this project similar/different to what engineers do in real life?" This will allow students to reflect on the process as well as think about the life/work of an engineer.

Differentiation

Differentiation is worked into this lesson by allowing students to draw, write, and construct. If students find it difficult to develop a useable model, consider providing groups with the opportunity to research models that have worked in the past.

Assessment

Summative Assessment:

The submission of the engineering notebook at the conclusion of the project will serve as the summative assessment. The rubric is provided to students in the handout titled "Engineering Design Challenge: Europa Landing System."

Formative Assessment:

At each major milestone along the process (e.g. problem definition, brainstorming, selection, drawing, initial creation of prototype, testing, etc.) the teacher should formatively assess student progress through anecdotal notes and conversations to ensure that students understand the problem and are taking the necessary steps required to come to a solution.

Engineering Design Challenge

Europa Rover Landing System

Name: ____

Partners' Names: ____________________________________

Premise:

NASA is looking to send a rover to Europa to examine below the layer of ice for evidence of life. Due to an extremely thin atmosphere which is composed primarily of molecular oxygen, O_2, along with the hard layer of solid ice, designing a landing system has demonstrated to be an issue (traditional thrusters= bad news ☹) . You are being hired to design a landing system to protect the sensitive equipment that will be dropped into Europa from a shallowly orbiting shuttle.

Challenge:

Your job is to secure the bid for the job by providing a "proof of concept" of your design system. You will design a scale model of your landing system and demonstrate its effectiveness. NASA is requiring all competing firms to meet next week to demonstrate their designs so that they can choose the design they would like to go with. To accurately represent the scale of impact velocity and maximum forces the rover will be capable of handling, you will be dropping your device from a height of approximately 50 feet. The force sensor inside the device will be a raw egg, which will break when a peak force of approximately 35 N is achieved (http://www.mayfieldha.com/stephen/kevlar-and-blunt-trauma/determining-the-force-requi.html).

NASA is currently considering two separate design options for the rover landing system.

[1] Encapsulation Ground Gear (E.G.G.). The rover would be surrounded by the landing gear so that the landing system is able to protect the rover from the collision with the ground. This design has been used in the past, for example, the Spirit Rover (https://www.youtube.com/watch?v=kSbAUtyO7xo). When considering this design option, consider that the rover must be capable of exiting the landing system easily as NASA will not consider any options in which the rover is permanently stuck inside the landing system. In addition, consider the atmosphere of Europa, which is quite thin, if considering a parachute-like design.

[2] Surface Hitting Extraneous Landing Location (S.H.E.L.L.). A landing system separate from the rover would first be deployed to the surface of the planet. The rover would then be dropped onto the landing system.

Budget:

You will be provided $3,000 to use to purchase materials and facilities use time. Please see the requisition sheet on the following page to see what is available for purchase and the cost of the item.

Requisition Sheet

Materials

- Straws: $100/straw
- Tape (duct): $175/linear foot
- Tape (scotch): $75/linear foot
- Tape (electric): $100/linear foot
- Eggs: $300/egg
- Box (Small): $200
- Box (Medium): $400
- Box (Large): $600
- Paper (plain): $25/sheet
- Paper (construction): $40/sheet
- String (thin): $30/linear foot
- String (Firm): $50/linear foot
- Rubber Bands: $20/band
- Cups: $50/cup
- Plastic Bags (small): $100
- Plastic Bags (large): $200
- Paperclips: $10/clip
- Toothpicks: $10/pick
- Cleaning supplies: free of charge (when used for clean-up purposes)
- Note: No outside resources will be allowed as the design must remain proprietary to our firm

Rentals:

- Force Scale Rental: $200/20 minutes
- Hot Glue Rental (glue provided): $100/20 minutes
- Facility Use Rental (Staircase): $100/10 minutes
- Hire custodial Staff: $200/visit

Weight Limit

It costs a lot of money to send things into space. If the weight of your device exceeds 400 grams, you will be charged $400. If your device exceeds 800 grams, you will be charged $600. Finally, if your device exceeds 1200 grams, you will be charged $750.

<u>ALL REQUISITIONS MUST BE GIVEN IN WRITING AND WILL REQUIRE AT LEAST 12 HOURS PRIOR NOTICE IN ORDER TO BE FULLFILLED!</u>

Timeline of Project: (Note that mandatory items are in bold and suggested items are plain)

Note: All days are considered 40 minutes, so double periods will count as 2 days!

Day 1

- **Define Problem (5 minutes)**
- **Brainstorm (20 minutes)**
- **Identify Constraints (10 minutes)**
- **Begin Discussion of Options (5 minutes)**

Day 2

- **Narrow list of possible choices to 3 (10 minutes)**
- **Complete Tradeoff Matrix to determine best option (10 minutes)**
- Each person makes an accurate (scaled) drawing of the design model
- Group selects best option
- **Group creates a scaled model of their design on paper (10 minutes)**
- **Group submits initial requisition order to be fulfilled by next day (10 minutes)**

Day 3

- **Construction of Initial Prototype**

Day 4

- **Construction/Testing of Prototype**
- Improvement/Redesign of Prototype

Day 5

- **Construction/Testing of Prototype**
- Improvement/Redesign of Prototype

Day 6

- **Final Preparations of prototype**
- **Creation of short (1-2 minute) speech to present to NASA before presenting prototype**

Day 7

- **Demonstration of Landing Systems**
- **Project De-Briefing**
- **Complete and prepare Engineering Notebook for Submission**

Rubric

Category	0 Points	1 Point	2 Points	3 Points
Problem Definition	Problem not defined	Problem restated or unclearly redefined	Problem has been redefined in group's own words	Problem has been redefined in group's own words; clear understanding of problem shown
Identification of Constraints	No constraints identified	1-2 constraints identified	Some (more than 2) constraints identified	Numerous (at least 4) constraints identified and decisions have been made because of them
Background Research	Project was done using solely group's individual knowledge	Some research done, but unclear if it relates to problem at hand	A good deal of outside research done, including impulse-momentum theorem	Extensive research done, including reference to impulse momentum theorem and analysis of Force vs. Time graphs
Brainstorming	Brainstorming session was not followed correctly	Both types of designs are initially considered during brainstorming. No decisions initially made	Each member contributes 2-3 unique ideas. Both types of designs are initially considered during brainstorming. Diagrams drawn. No decisions initially made	Each member contributes 3-4 unique ideas. Both types of designs are initially considered during brainstorming. Diagrams drawn. No decisions initially made
Tradeoff Matrix	Decision was biased and/or matrix not used	Matrix used, but bias was apparent	Matrix used, no additional decision choices were added to template	Tradeoff Matrix was solely used to make an unbiased decision; additional criteria added which helped improve decision
Scale Model	No model made	1 or two sides shown; drawing is made, but incomplete	Orthographic Projection drawn	Orthographic Projection drawn, drawing is done to scale (or shows measurements)

Prototype Construction	Prototype not made	Prototype does not follow design model	Prototype follows model, except for a few (2-3) small differences	Prototype follows design model exactly **or** design model is altered to address changes made due to testing
Daily Log	Not Completed	Some days missing and/or minimal work done	Completed for each day	Completed for each day; thorough notes with diagrams
Revision/ Redesign of Prototype	No changes/improvements made from initial design	Improvements/changes made, but were done solely from opinion	Some useful changes made to device	Significant changes/improvements made based upon evidence collected from testing
Testing Log	No data collected	Data collected, but it's use is not apparent	Data collected. Use is apparent but is not used to improve design	**Useful** data collected which is directly used to improve/redesign prototype
Budget	Over Budget	N/A	N/A	Under or at budget
Time	Went over allotted time	N/A	N/A	Met time constraint
Success of Device	Project was unsuccessful on final attempt	N/A	N/A	Project was successful on final attempt
Project De-Brief	Little to nothing written	Very modest reflection provided	Reflection written down	Detailed reflection illustrating that person learned both about physics as well as the engineering design process

Please note that there is **NO penalty** for breaking the egg while testing, other than the fact that you will have to buy a new egg.

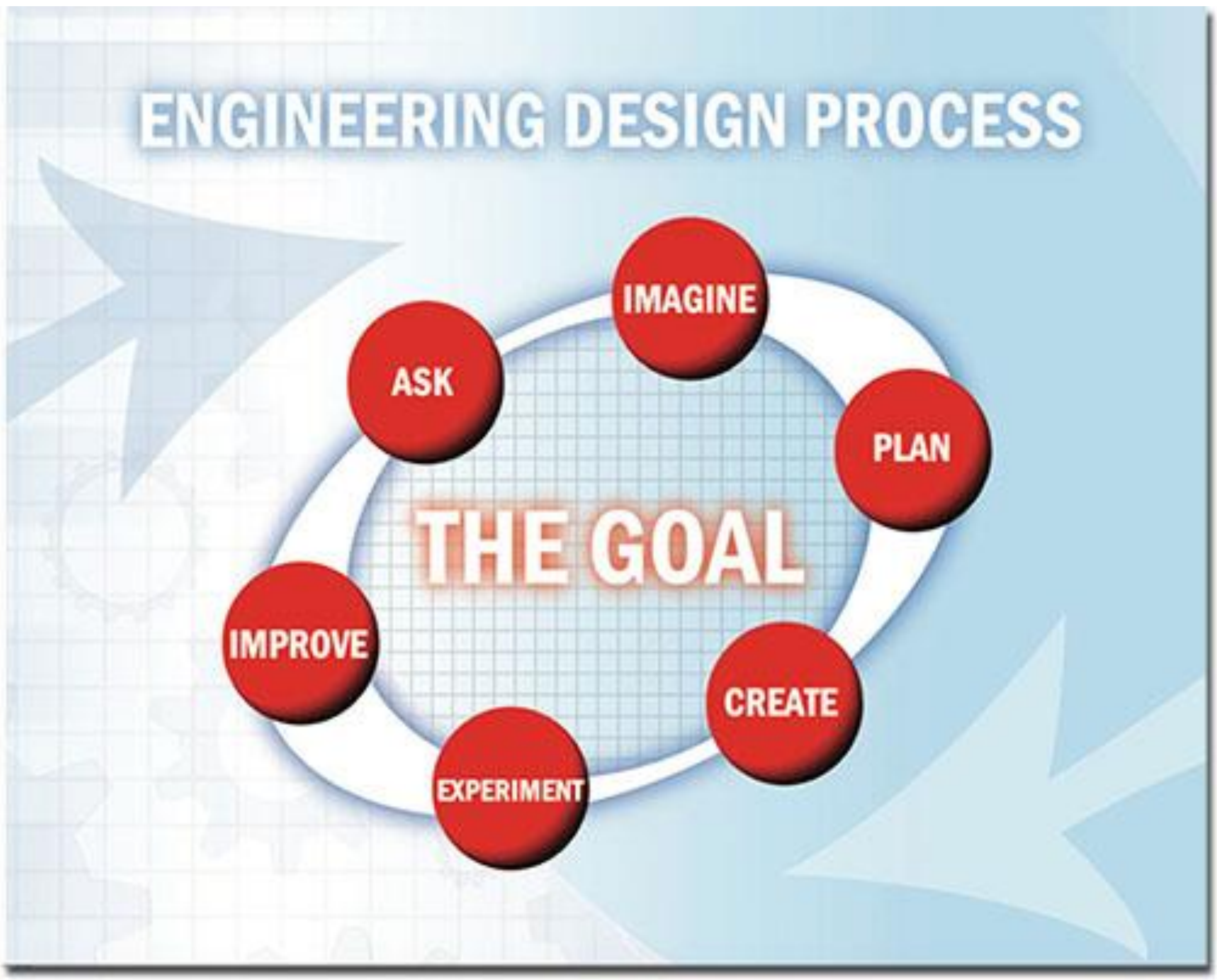
For the final test, an egg will be provided to you at no charge, unless your device requires that the egg be inserted into the device prior to the test day.

Name: ______________________________

Partners: ____________________________

Engineering Design Notebook

Europa Rover Landing System



https://www.nasa.gov/sites/default/files/thumbnails/image/best-edp-box2.jpg

Problem Identification

Use this space below to jot down notes about your problem. In box provided, write your FINAL DRAFT of your re-definition of the problem.

Background Research

Use this page as a hub for all research you do which pertains to the problem. Remember to write down sources so you can access the information in the future!

Brainstorming

Use this space to brainstorm ideas for your project.

E.G.G. Device Ideas

S.H.E.L.L. Device Ideas

Constraints:

Use this space to write down questions you still have to ask.

Use this space to identify constraints on the problem and how you plan to address them.

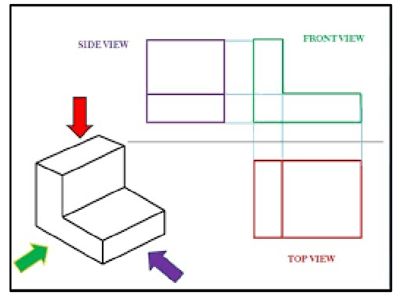
Tradeoff Matrix

Use the tradeoff matrix below to weigh the options and arrive at a decision for the best idea to model and prototype. Use a scale from 0-10 where 0 means the idea is terrible or will not work and 10 means the idea is perfect and will work wonderfully. Thus, high score presents the optimal choice. Space is purposefully left for additional options and criteria, if desired.

Design Choices	Feasibility	Likelihood for Success	Time Required to Make	Durability	Cost	Risk			**Total Score**
#1-									
#2-									
#3-									
#4-									

Scale Model

Use this page to draw a scale model of your prototype. Make an orthographic projection, showing your prototype from all possible points of view. See image below for an example.



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Prototype Testing

Use this page to keep track of tests and data collected that you perform on your prototype. Make sure to label and date all data tables and information.

Prototype Redesign

This page should contain the following:

[1] Key places where the initial prototype failed/didn’t work as well as desired

[2] Specific Changes that will be made to the design

[3] Sketch of new design, illustrating key changes in a different color

Daily Log- Day 3

Use the space below to fill in your work from day 3.

Daily Log- Day 4

Use the space below to fill in your work from day 4.

Daily Log- Day 5

Use the space below to fill in your work from day 5.

Daily Log- Day 6

Use the space below to fill in your work from day 6.

Daily Log- Day 7

Use the space below to fill in your work from day 7.

Project Speech

Use this space to jot down notes about your major talking points for your pitch.

Project Debrief

[1] What was the greatest challenge to your team throughout the process?

[2] How did you use the Engineering Design Process to help you with the design?

[3] Specifically, what did the testing phases teach you about your device?

[4] What was one variable/constraint that was unaccounted for during your testing and with your knowledge now, how would you account for it?

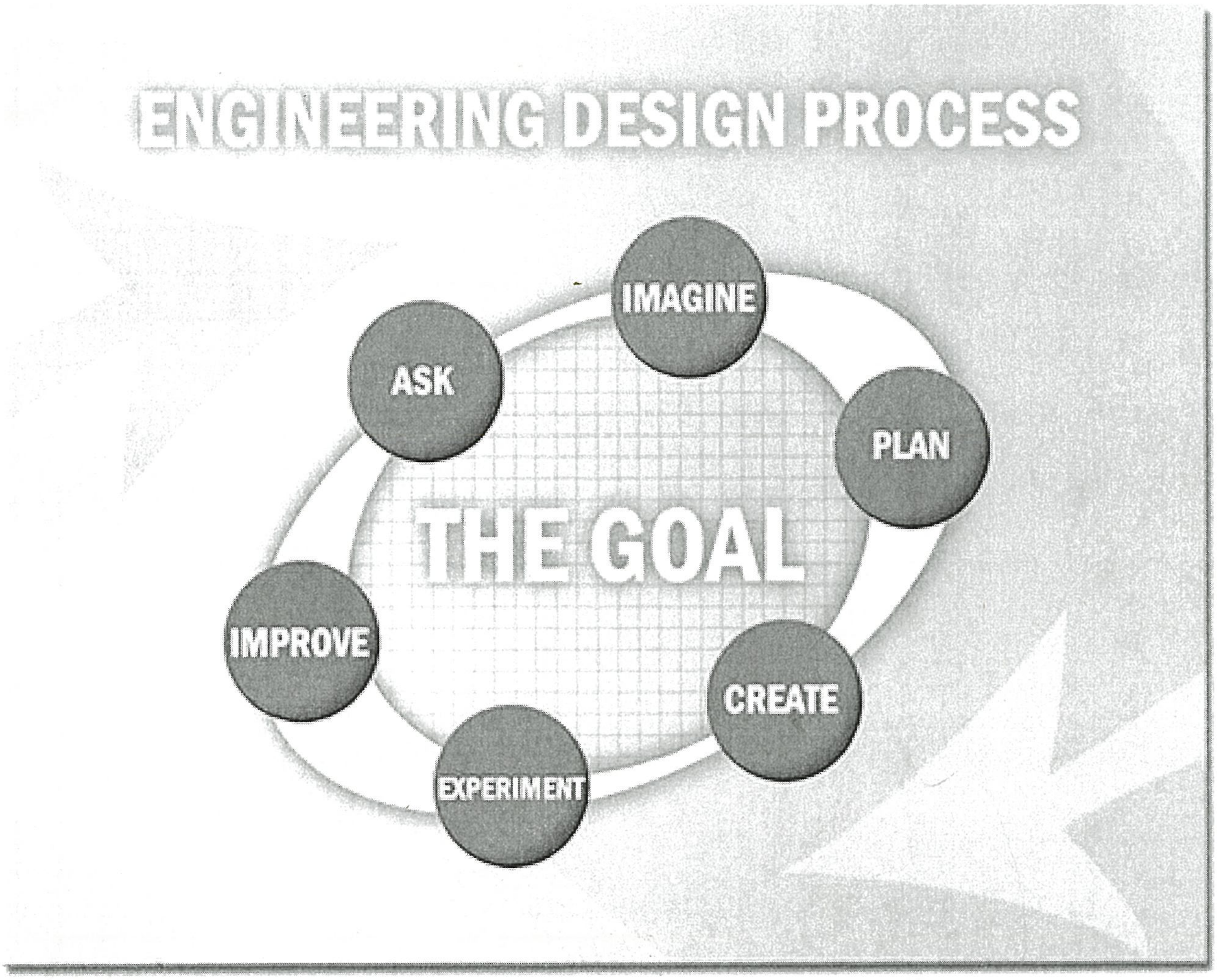
[5] Use this space to write a quick note for each group member describing one moment where they were either: [1] especially creative, [2] incredibly insightful, [3] responsible for keeping the group on track and/or focused, and/or [4] any other quality you'd like to point out.

Name: Charles Canestraro

Partners:____________________________

Engineering Design Notebook

Europa Rover Landing System



https://www.nasa.gov/sites/default/files/thumbnails/image/best-edp-box2.jpg

Problem Identification

Use this space below to jot down notes about your problem. In box provided, write your FINAL DRAFT of your re-definition of the problem

→ Egg Drop

egg in Box

or

Naked egg drop

Budget + time limit

Drop from ~50 feet

Allowed to test & revise

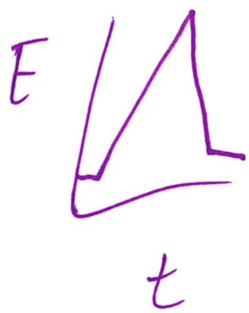
Don't Break the egg in the final Drop!

- thin Atmosphere

We are being tasked to create a device which protects an egg from a fall. The choice of device must optimize function, time, & $ constraints.

Background Research

Use this page as a hub for all research you do which pertains to the problem. Remember to write down sources so you can access the information in the future!

- 

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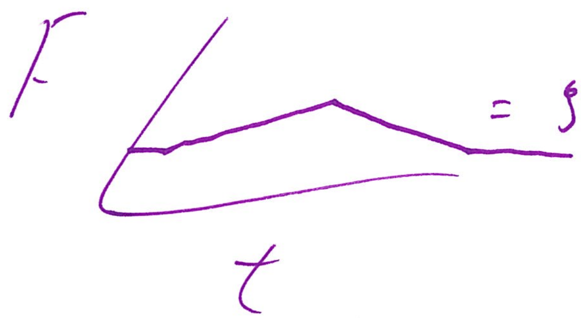

= good!

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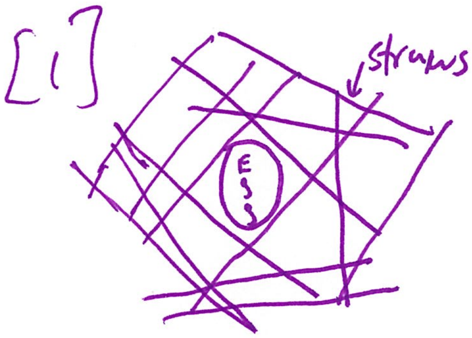
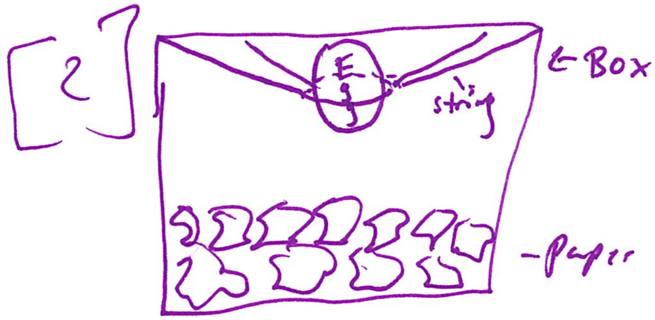
- Youtube
  - "1st Place egg drop project ideas - using SCIENCE"
  - "11 AWESOME 1st PLACE Egg drop Designs"
  - "Egg drop activity /// Home made Science with Bruce Yeany"

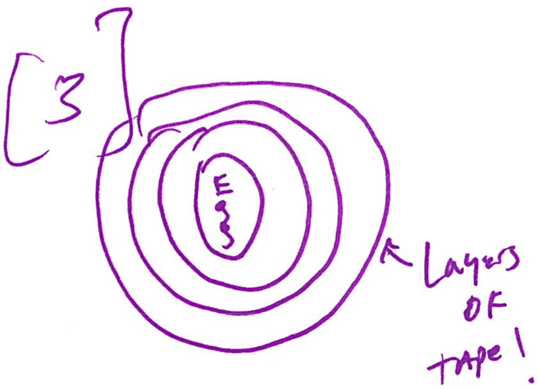
Brainstorming

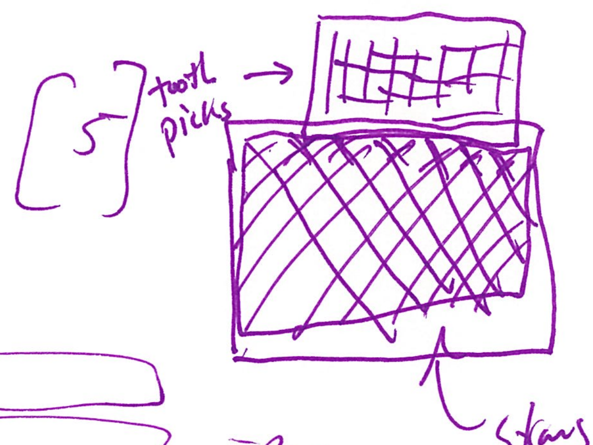
Use this space to brainstorm ideas for your project.

E.G.G. Device Ideas

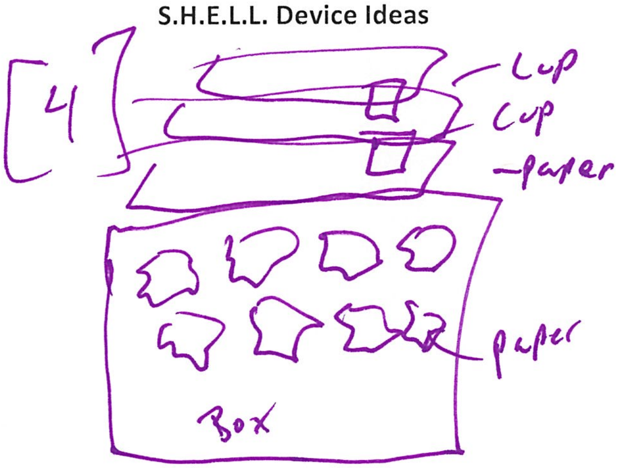


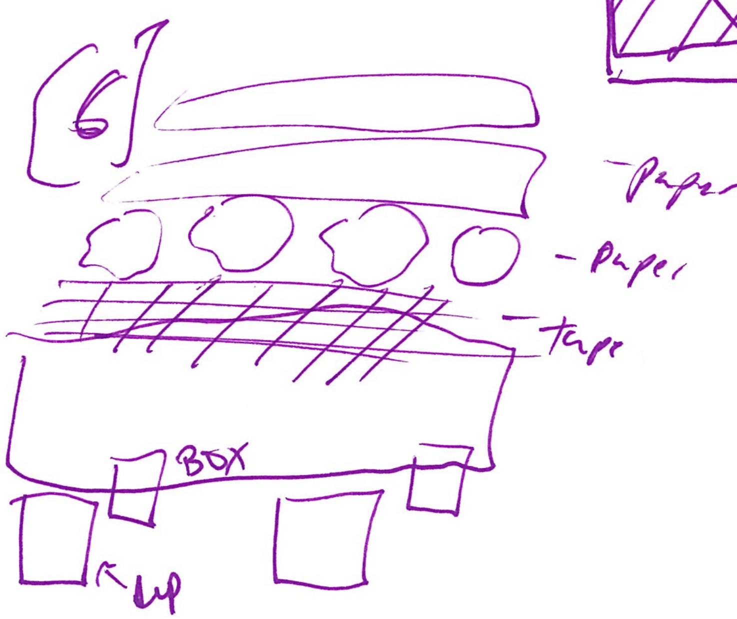






S.H.E.L.L. Device Ideas





Constraints:

Use this space to write down questions you still have to ask.

Use this space to identify constraints on the problem and how you plan to address them

- Allowed a parachute?
- How many test runs?

- $ (make budget sheet)
- time (make schedule)
- size (Bigger = more expensive)

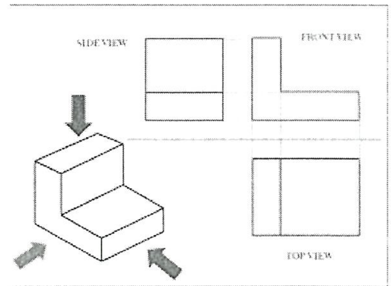
Tradeoff Matrix

Use the tradeoff matrix below to weigh the options and arrive at a decision for the best idea to model and prototype. Use a scale from 0-10 where 0 means the idea is terrible or will not work and 10 means the idea is perfect and will work wonderfully. Thus, high score presents the optimal choice. Space is purposefully left for additional options and criteria, if desired.

Design Choices	Feasibility	Likelihood for Success	Time Required to Make	Durability	Cost	Risk	Ease of Construction	Would work on Europa	Total Score
#1- [1]	10	8	5	8	9	3	7	6	56
#2- [2]	8	6	8	5	8	4	7	6	52
#3- [4]	6	7	7	3	7	4	8	8	50
#4- [5]	6	8	3	2	6	8	4	8	45

Scale Model

Use this page to draw a scale model of your prototype. Make an orthographic projection, showing your prototype from all possible points of view. See image below for an example.



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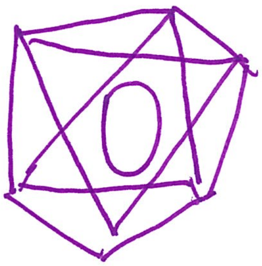
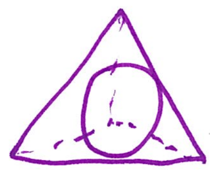
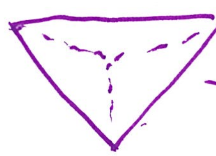


Layer 1



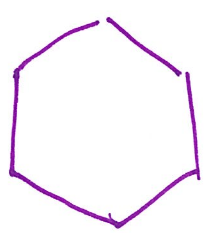
- eggs in pyramid

LAYER 2

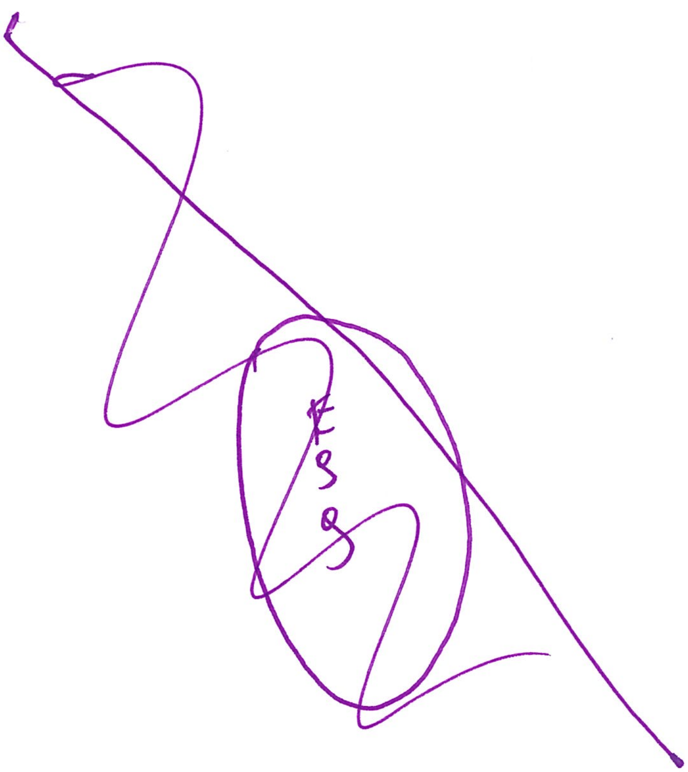


- opposite pyramid

LAYER 3



← hexagon shell



Prototype Redesign

This page should contain the following:

[1] Key places where the initial prototype failed/didn't work as well as desired

[2] Specific Changes that will be made to design

[3] Sketch of new design, illustrating key changes in color

[1] Landed on side

[2] tape came apart

[3] not protected on side

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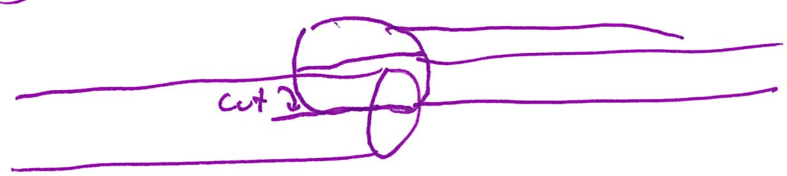
* Joints



← cut straws & tie together

* Ends

← cut at end & pull apart

Prototype Testing

Use this page to keep track of tests and data collected that you perform on your prototype. Make sure to label and date all data tables and information

1 ft , ✓, landed on side

2 ft , ✓, same side

5 ft , ✓, same side stop test 1

- add weight to opposite side
- add cuts to straws to break at ceratain points

10 ft, ✓, diff. side

10 ft , ✓. diff side

☆ Add tape Again

☆

Cost

20 straws	= $1,000
2' scotch tape	= $100
egg	: $300
2' scotch tape	: $100
Rental	= 100
Test 2	= 100
2' tape	= 100
total	= $1800

Daily Log- Day 7

Use the space below to fill in your work from day 7

N/A (finished in 5 days)

Project Speech

Use this space to jot down notes about your major talking points for your pitch

→ Chose E.G.G. over S.H.E.L.L. primarily b/c of Budget & Durability

→ Lots of Revision throughout process

- ↳ Joints
- ↳ outside straw cuts
- ↳ shape

→ use of straw wrapper (Awesome idea!)

→ Cheap & efficient design!

Project Debrief

[1] What was the greatest challenge to your team throughout the process?

- Actual construction of prototype
  - tough to get idea on paper made!

[2] How did you use the Engineering Design Process to help you with the design?

→ testing was crucial for coming up with ideas for revision
→ writing out the problem helped me understand it
→ I took pieces from different ideas I Brainstormed

[3] Specifically, what did the testing phases teach you about your device?

→ construction was not symmetric. Center of mass was ≠ geometric center
→ welds (tape) were inconsistant

[4] What was one variable/constraint that was unaccounted for during your testing and with your knowledge now, how would you account for it?

· Durability of straws / welds
  ↳ Keep tally of how many straws I had to re-tape

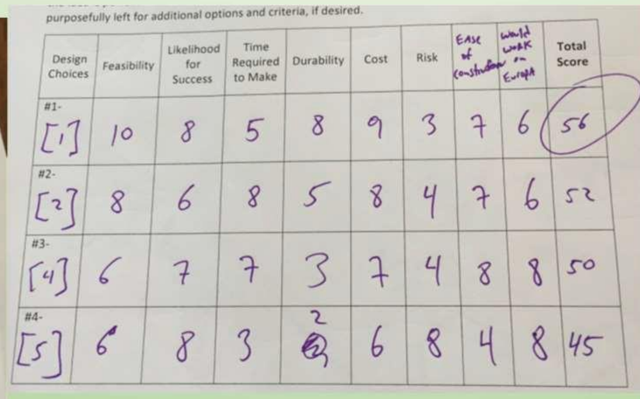
[5] Use this space to write a quick note for each group member describing one moment where they were either: [1] especially creative, [2] incredibly insightful, [3] responsible for keeping the group on track and/or focused, and/or [4] any other quality you'd like to point out

· I felt super creative using the wrappers that the straws came in for cushioning around the interior straws to keep the egg in place

Engineering Design Project
Europa Landing System

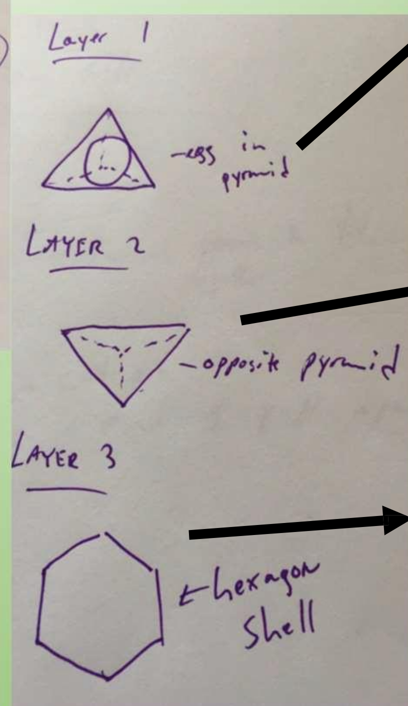
Charles Canestaro

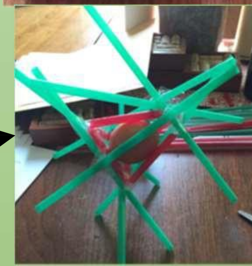
HS-PS2-3. Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.* [Clarification Statement: Examples of evaluation and refinement could include determining the succes the device at protecting an object from damage and modifying the design to improve it. Examples of a device could include a football helmet or a parachute.]

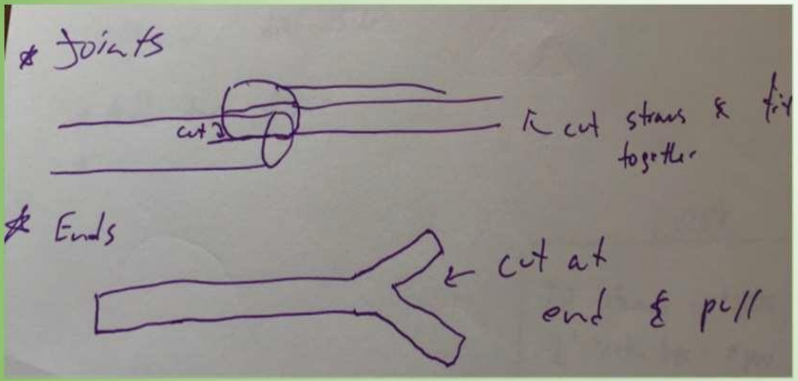


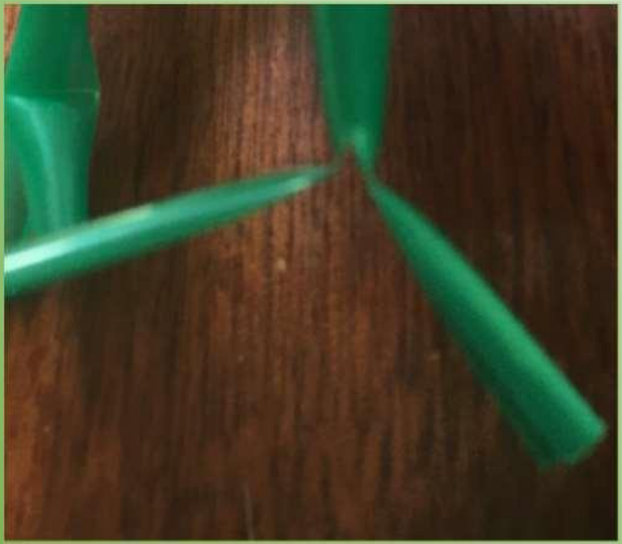
purposefully left for additional options and criteria, if desired.

Design Choices	Feasibility	Likelihood for Success	Time Required to Make	Durability	Cost	Risk	Ease of Construction	Would work on Europa	Total Score
#1- [1]	10	8	5	8	9	3	7	6	56
#2- [2]	8	6	8	5	8	4	7	6	52
#3- [4]	6	7	7	3	7	4	8	8	50
#4- [5]	6	8	3	2	6	8	4	8	45









Testing,
Revision,
Final Test, &
Results!