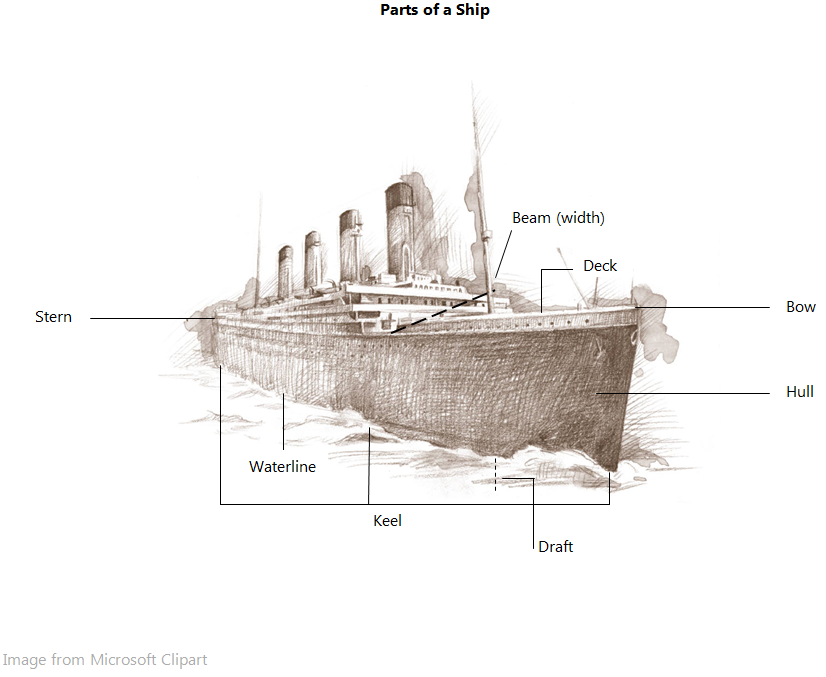
**Background Reading: What’s Happening to a Boat in the Water***Modified from:* [*http://oceanservice.noaa.gov/education/for\_fun/BoatBuildingChallenge.pdf*](http://oceanservice.noaa.gov/education/for_fun/BoatBuildingChallenge.pdf)

Water tends to maintain a level surface. When you put an object into water, gravity pulls the object down which displaces some of the water, meaning that some of the water is pushed aside. Now the surface of the water is no longer level. Gravity pulls the displaced water down, and causes an upward force on the object. [*Note: This upward force is due to pressure, which is higher at the bottom of the boat compared to that at the top.*] This upward force is equal to the weight of the water that the object displaces, and is called buoyancy. Buoyancy depends upon the volume of liquid displaced as well as the density of the liquid. Density is the ratio of mass to volume. It is easier to float in the ocean than in fresh water, because seawater is denser than fresh water, thus your buoyancy is greater in the ocean.

The amount of fluid that an object displaces depends upon the weight of the object: more weight means more fluid displaced, which means more buoyancy. Increasing the amount of surface area in contact with fluid increases the effect of friction as the object moves through the fluid. Boat designers have to consider buoyancy as well as friction when deciding on the shape of a boat’s hull. A boat designed for speed must have enough displacement to stay afloat, but surface area has to be minimized to decrease the effects of friction. Note that it is only the surface area that is in contact with the water that creates friction. On the other hand, an object designed to carry a heavy weight, such as a cargo boat, must be designed with greater power to overcome the effects of increased friction. However, drag caused by the shape of the boat is likely more important than simple friction.

Displacement occurs when an object is immersed in a fluid, pushing it out of the way and taking its place. The volume of the fluid displaced can then be measured, and from this the volume of the immersed object can be deduced (the volume of the immersed object will be exactly equal to the volume of the displaced fluid).

Boat hulls are designed to have a maximum displacement greater than the weight of the boat (and its intended cargo). As mentioned, increasing boat volume increases the maximum possible boat buoyancy (while affecting mass and density as well), but not necessarily the buoyant force for a given cargo load. Should the force of gravity pushing down on the boat exceed the boats maximum displacement (which is equal to the force pushing up on the boat or buoyancy) the boat will sink. If there is no longer sufficient water displacement to counteract the force of gravity on the pieces of the hull, the boat will sink.

**Seago Shipping Services**  
3953 Canal Road  
Tampa, FL 33603  
(555) 354-8394   
  
**Introduction**

Seago Shipping Services is soliciting proposals from engineering teams for a shipping vessel to transport our cargo across the sea. We are an international shipping company that depends on our boats to transport heavy loads of cargo as fast and cost effectively as possible.

**Purpose of this Request for Proposals**

Our company’s current vessels are becoming older and more prone to costly repairs. It is time to update our fleet, and thus we are requesting proposals for a new vessel so we can build the best design to refurnish our fleet. We would like to begin replacing our fleet as soon as possible.

**General Background Information**

Our routes take us across the Gulf of Mexico to several countries in South America. Occasionally we will also ship our cargo to several countries on the west coast of Africa. Therefore, the vessels that we use will be required to operate across long distances.

**Proposal Requirements – Instructions to Bidders**

Technical requirements and information:

* An efficient, hydrodynamically sound vessel is ideal (or low friction and able to realistically travel through the water)
* Cargo needs to sit inside the hull of the vessel (below the deck, rather than on it)
* Maximize carrying capacity (hold as much cargo as possible)

Boat models and a data table have been provided for your consideration. Please test the models to finish filling out the data table. Use this data to decide which boat would best meet our needs. Engineering teams should respond to this RFP by providing written documentation which details the step-by-step procedure used to choose your vessel. We will need to be able to follow your thought process if we select your boat to build.

*\*Note: Scale is 1cm = 10 meters*

**Testing**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Boat | Carrying Capacity  1  (g) | Carrying Capacity  2  (g) | Carrying Capacity  Average  (g) | Boat Mass  1  (g) | Boat Mass  2  (g) | Boat Mass  Average  (g) | Stability - Side Peg | Stability - End Peg | Stability Average  (g) | Steering | Steering | Steering Average |
| A |  |  |  |  |  |  |  |  |  |  |  |  |
| B |  |  |  |  |  |  |  |  |  |  |  |  |
| C |  |  |  |  |  |  |  |  |  |  |  |  |
| D |  |  |  |  |  |  |  |  |  |  |  |  |

**Calculations**

|  |  |  |  |
| --- | --- | --- | --- |
| Boat | Efficiency  (%) | Boat Volume  (cm3) | Boat Density  (g/cm3) |
| A |  | 13.5 |  |
| B |  | 13.5 |  |
| C |  | 13.5 |  |
| D |  | 13.5 |  |

**Data Table**

**(Values in this table should be used to develop your step-by-step procedure.)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Boat | Cost  () | Build Time  (Months) | Stability | Steering | Carrying  Capacity  (g) | Efficiency  (%) |
| A | 146.33 | 29-34 |  |  |  |  |
| B | 125.54 | 21-25 |  |  |  |  |
| C | 128.48 | 17-20 |  |  |  |  |
| D | 119.55 | 22-26 |  |  |  |  |

**Terminology:  
*Stability***: Weights (e.g., paperclips) are hung from the side peg (either side) and the end peg (not at the same time). The resulting mass will represent the mass/weight the boat can withstand before capsizing. The location of the weight is crucial; in particular, it’s position relative to the boat’s center of mass.  
***Steering***: A rank (e.g., best to worst) of each boat according to how straight the boat glides when launched.  
***Carrying capacity (cargo mass)***: The mass of the maximum amount of cargo (e.g., paperclips) that can fit in the boat without sinking.   
***Efficiency***: The ratio of maximum cargo to boat mass.

****  
**Seago Shipping Services**  
3953 Canal Road  
Tampa, FL 33603  
(555) 354-8394

**Addendum**

We would like to thank each engineering team who sent us a proposal. All of the proposals were well-received and it will be a difficult decision to select which team’s boat to build.

Before that, however, we need to amend our Request for Proposals. We recently added a new shipping route that will take us beneath several bridges. We are concerned current designs will not accomplish this task safely. Therefore, we have revised one of our technical specifications that you must now consider.

**Revised Technical Requirements and Information**

Technical requirements and information:

* An efficient, hydrodynamically sound vessel is ideal (or low friction and able to realistically travel through the water)
* Cargo needs to sit inside the hull of the vessel (below the deck, rather than on it)
* Maximize carrying capacity (hold as much cargo as possible)
* **Boat will be traveling beneath bridges, so the height of the boat must be 60 meters or less.**

Please design a boat that satisfies all requirements listed above. Please respond with an updated response to this RFP. Bidders should respond to this RFP by providing written documentation which details your engineering team’s step-by-step procedure of how to select the best boat, keeping in mind this new requirement. We will need to be able to follow your procedure and thought process if we select your boat to build. Include your rationale for your new boat design. Your team must also submit a scaled drawing of your prototype, and an approximation of your boat’s cargo hold volume, stability, carrying capacity, and steering based on your knowledge of the boats that were tested in Part 1.

Finally, keeping in mind the shape of your boat’s cargo hold, design a different shaped cargo hold that will hold the same amount of cargo as the boat you designed. Thank you for providing us with this additional option.

In summary, please submit the following:

* Written documentation which details your engineering team’s step-by-step procedure of how to select the best boat
* Scaled drawing of your boat design
* Rationale for your new boat design
* Approximation of your boat’s cargo hold volume, stability, carrying capacity
* Design a different shaped cargo hold that will hold the same amount of cargo as your boat

*\*Note: Scale is 1 cm = 10 meters*

1.) Fill out the chart based on your new boat design with your estimates based on your previous tests.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Boat  Name | Carrying Capacity  Average  (g) | Boat Mass  Average  (g) | Stability Average  (g) | Steering Average | Cargo Hold Volume |
|  |  |  |  |  |  |

2.) What are the shape and dimensions of your new boat’s cargo hold?

3.) What is your procedure and rationale for your new boat design? Did your procedure change now that you developed your own boat? Please explain.

4.) What is your design for a different shaped cargo hold that will hold the same amount of cargo as your boat? Be sure to show your work and specify the geometric shape of your boat’s cargo hold as well as the new shape.

**0.5 cm. Graph Paper**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

**Instructions for Testing the 3D Models**

**Boat Mass Testing instructions:**

* Obtain and turn on a digital scale
* Place the boat on the scale and record its mass/weight.
  + A distinction should be made between weight (mass\*gravity) and mass. You'll have the mass or weight of the water displaced depending upon the scale used.
    - If your scale measures mass you already have the desired value.
    - If you only have access to scales that measure weight (lbs.), divide the measured value by gravity (9.8 m/s2) to attain mass.
* If a scale is not available the following procedure should be used. Students should submerge the boat (the entire boat should be below water with no air pockets trapped) in a graduated cylinder partially filled with water, measuring the increase in volume. Students would then multiply the volume of displaced water by the density of water (1g/cm3) to find the boat's mass. (1 mL = 1 cm3)
  + Ex. Displaced water volume = 5 mL (measured value)
  + Density = (1g/cm3) = (1g/mL)
  + Displaced water mass = Boat mass = (water density)\*(displaced water volume) = (1g/mL)\*(5 mL) = 5 g
* To test the cargo-carrying capacity of the design, students should gather their boat, some weights, a small aquarium or plastic tub, and water on which to float the boat.

**Cargo Testing instructions:**

* Place water in the tub/aquarium so it is approximately 10-15cm or more deep.
* Write down how much mass (g) you think each design will carry, given the mass of the boat itself.
* Place the boat on the water so it floats. If it does not float, stop here. Record the results.
* Place weights, one at a time, into the boat, being careful to evenly distribute the weights as they are placed. Continue placing weights (keep in mind any constraints) until just before the boat begins to take on water (or when the waterline is even with the upper edge of the boat's hull).
* Gather the weights from the tub/aquarium and weigh them. The resulting mass/weight is the maximum cargo load for the boat. Record this value. The teacher should make sure the students are measuring dry weights, in case any have gotten wet.
* Write in your notes whether this value was less than, equal to, or more than you expected. Also include any other testing notes of interest.
* Calculate the ratio of maximum cargo to boat mass (efficiency). Record this value in the table.

**Stability Testing instructions:**

* Place water in the tub/aquarium so it is approximately 10-15cm or more deep.
* Write down how much mass (g) you think each peg will carry, given the mass of the boat itself.
* Place the boat on the water so it floats. If it does not float, stop here. Record the results.
* Each model must be tested using: 1) one side peg (either will work) and 2) the end peg. Each should be tested independently (e.g. First test the side peg and record the value. Then test the end peg and record the value.) Values should be used in conjunction to determine total stability.
* To test, incrementally add mass to the selected peg. Continue increasing mass until the boat begins to take on water. (Paperclips or small hanging weights can be used to complete this step.)
* Remove the clips/weights from the peg and weigh them. The resulting mass/weight will represent the mass the boat can withstand before capsizing. Record this value. The teacher should make sure the students are measuring dry weights, in case any have gotten wet.
* Write in your notes whether this value was less than, equal to, or more than you expected. Also include any other testing notes of interest.

**Steering Testing instructions:**

* Place water in the tub/aquarium so it is approximately 10-15cm or more deep.
* Rank (write down, in order from best to worst) each boat according to how straight the boat would glide if launched.
* To give a better idea of how each boat will react when loaded, place 5g in hollowed centers before testing.
* The provided boat launcher (ramp) is intended to hook onto the edge of your tub/aquarium. Each boat will be placed at the top of the boat launcher and released. The boat should slide down the ramp and be "launched" into water. Each boat should be ranked according to how straight it progresses through the water.
  + (Water levels and/or tub/aquarium design may create issues with the launcher. In the event the launcher does not operate as desired, simply hold the launcher in an appropriate position. Use the same position for all subsequent launches. Each boat should be launched as "straight" into the water as possible. The launcher should be angled enough so that the boat will begin to slide due to its own mass only. No additional force is required.)
* Record rating. Write in your notes whether this value was worse than, equal to, or better than you expected. Also include any other testing notes of interest.