



THE APPRENTICE SCHOOL STUDENT SECTION OF
THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS



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2027 Guidelines

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THE APPRENTICE SCHOOL STUDENT SECTION OF
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REVISIONS

A list of select, important changes to the Guidelines from year to year.

Revision	Page	Description
2027	13	Eliminated prescribed paint colors
	43	Changed 1 st and 2 nd stage races awarded point values to score on a curve



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COMPETITION OVERVIEW

[The Apprentice School](#), of [Newport News Shipbuilding](#), Society of Naval Architects and Marine Engineers (SNAME) student section sponsors a boat design competition for high school students to increase awareness of the naval architecture profession and the shipbuilding industry. The competition engages students' math, science, and creative abilities and introduces them to engineering, drafting, project planning, and leadership principles.

Participating high schools will form one or more student teams and work independently to design a boat. The designs will be judged for thorough documentation decisions, proper drafting practices, and calculation accuracy.

Four designs will be selected as finalists and will be constructed by Newport News Shipbuilding. A head-to-head competition between the four constructed boats will take place at a local body of water. A winner will be selected from the boat's hydrostatic characteristics, speed, and maneuverability.

<u>Key Dates</u>	
<u>Phase I. Registration Phase</u> Form a team and register.	Registration Opens: September 1, 2026 Last Day to Register: October 31, 2026
<u>Phase II. Design Phase</u> Teams design their boat in accordance with competition Guidelines.	Final Design Due: January 6, 2027
<u>Phase III. Construction & Test Phase</u> Teams' designs are constructed and raced.	Race Day: Spring, 2027 Rain Date: Race Day + 1 Day/Week (depending on site availability)



PHASE I: REGISTRATION PHASE

Form a Team

A team may be formed for a class project, extra credit assignment, after school program, etc. Teams are limited to a minimum of two members and a maximum of six members. No student can be a part of two teams. There is no limit to the number of teams per school; however, only two teams per sponsor are eligible for finalist judging and only one team per school may place as a finalist. All registered teams are eligible for superlative awards.

Boat Design Competition Website

The Boat Design Competition website contains a variety of resources and additional information:

<https://communities.sname.org/designcompetition>

Questions and Answers

During the Design Phase, questions and answers will be uploaded to the competition website. The questions and answers are compiled from teams' questions that may not be answered by these Guidelines. Questions judged as proprietary to a team's design will not be included.

Register

The registration form is available on the competition website.

Surveys

Students will complete surveys upon registration and Final Design Package submittal. The surveys are designed to gauge the knowledge of each student before and after the project and help shape the competition for future participants.

Competition Email

Teams are encouraged to ask questions throughout the design phase. Questions must be specific so that competition officials can elaborate. Officials shall not influence designs nor directly participate in completing any portion of the Final Design Package. Submitted questions and answers will be posted online for viewing by all teams (in accordance with Q&A).

sname@as.edu

Withdrawal

If a team decides to withdraw from the competition, please notify us.



PHASE II: DESIGN PHASE

Design Phase Parameters

Before beginning a design, review the [Design Phase Judging Rubric](#) and use the following list (downloadable from the competition website as a checklist) to avoid major point deductions:

- ☐ Boats shall be designed to be easily produced. No single plate can be curved in two planes (i.e. no complex curvature). Consider the distance between plates, the angles where plates meet, access to points where plates intersect, etc. when designing the boat since fabricators and welders need to overcome jobsite conditions. Note that there is no limit on the angle between plates (e.g. at a knife bow) because welds may be applied on the exterior of the hull instead.
- ☐ Maximum length (LOA) of twelve feet and maximum beam of fifty inches.
- ☐ Any hull shape is acceptable as long as it can be produced with only the materials provided and it does not violate these design parameters.
- ☐ Boats shall be designed with open hull(s) (i.e. no plating should render a portion of the hull inaccessible and no part of the hull should be enclosed/sealed).
- ☐ Catamarans/trimarans shall be designed with adequate structure supporting the hulls. Since there is usually minimal material between the hulls, the boats tend to flex in construction and transportation.
- ☐ Boats shall be able to adequately and reliably accommodate and secure the Steering Assembly and removable propulsion equipment. The Steering Assembly shall be located at least six inches above the load waterline.
- ☐ Boats shall have a minimum of six inches of freeboard along their entire length, even after being loaded with optional ballast. Though the absolute minimum requirement is six inches, teams should consider designing for a larger freeboard due to calculation rounding, approximations (inherent in Simpson's Rule), and error.
- ☐ Boats shall be able to carry the arranged payload and remain within these design parameters.
- ☐ Boats shall be unique and cannot be copies of past submittals.
- ☐ Final Design Package shall be submitted before end-of-day on [date specified](#).

Final Design Package

A Final Design Package includes, but is not limited to, a Design History Notebook, a Drawing Set, and a Calculations Packet. An example Final Design Package is available at:

<https://communities.sname.org/designcompetition/downloads/fdp>

In addition to reviewing the [Design Phase Judging Rubric](#), the online Final Design Package Submittal Checklist should be downloaded to ensure submittal completeness and accuracy:

<https://communities.sname.org/designcompetition/downloads/checklists>



Design History Notebook

The Design History Notebook is an informal, yet professional and orderly, journal/website/blog/video diary that contains the highlights of each team's meeting, concepts explored, difficulties encountered during the design phase, methods to correct those difficulties, and the rationale that led to the final design. Recounting a team's development, both personally and in the design of the product, is more than just simply stating what was completed during any given day. How the team goes about completing these tasks is the real essence of the journal. The team's travel through the [Design Spiral](#) should be explicitly documented in the Design History Notebook.

Illustrations, pictures, screenshots, etc. should be used to enhance the journal, but should not simply be inserted without reference, explanation, captioning, resizing, and cropping.

Additional material can be provided in the Design History Notebook to highlight a team's accomplishments, capture the additional work, and justify the design decisions. Examples of additional material include 3D-printed designs, schedules, budgets, and speed/maneuverability calculations.

A recorded Design History Notebook is expected to be as thorough as a written one.

While the Design History Notebook might not be as inherently important as the drawings or calculations, the Design History Notebook is nevertheless easy points and should not be neglected.

Drawing Set

Designs should be developed using standard computer-aided drafting (CAD) software. Autodesk Inventor and AutoCAD are recommended since both are free to students, used by the shipyard, and have extensive online help. A combination of both programs may also be beneficial. All models shall use the reference point instructed. Teams are required to develop all the necessary views and details needed for design and construction. Dimension the drawings using *standard* fractions (or decimal equivalents) of an inch. Try constructing the boat out of paper from only the finished drawings to verify that there are no missing dimensions. See the [drafting appendix](#) for drawing requirements.

Templates and 3D models of commonly used components can be found at:

<https://communities.sname.org/designcompetition/downloads/cad>

Calculations Packet

Teams will submit hydrostatic calculations of their boat. The accuracy of the calculations are essential; they will be judged for finalist selection and again compared to the actual boat's measurements on Race Day. Each calculation should be completed in accordance with the procedure outlined in the [calculations appendix](#).



Design Phase Judging

A panel of judges will score each team's Final Design Package in the following areas:

- Design History Notebook
 - Explanation of Design
 - Format
 - Spelling & Grammar
- Drawing Set
 - Format
 - Efficient Construction
 - Effective Construction
- Calculations Packet
 - Completeness
 - Accuracy
- Design
 - Completeness
 - Payload (Pertinent to Specific Competition Year)

The rubric can be found in the [Design Phase Judging Rubric](#) appendix.

Superlatives

The superlative awards that may be available are:

- Best hull art/color scheme on the Luncheon Drawing inspired by scenario
- Best team name pun pertaining to scenario
- Best team logo (all logos must be original)
- Best Design History Notebook/Drawing Set/Calculations Packet
- Best Calculation Supplement Drawings
- Best Render on Luncheon Drawings
- Other exceptional qualities (e.g. lightest boat with largest payload or some variation thereof, best teamwork, etc.)

Luncheon

Pending funding, all teams may be invited to an announcement ceremony where the four winning designs will be announced as finalists. Superlative awards will also be announced. The luncheon is an opportunity for students to network with professional shipbuilders and their competitors. Location, directions, and date will be provided at a later time.



PHASE III: CONSTRUCTION & TEST PHASE

Construction

The four finalists' designs will be built at Newport News Shipbuilding by students of The Apprentice School and skilled trade workers.

Boat Trials

Prior to Race Day, the finalists will be given the opportunity to inspect their constructed boats and perform trials to become comfortable with their boat's performance. Teams shall instruct the outfitters on any special adjustment of their Propulsion Motor.

Race Day

The four finalists will: (1) validate their design predictions by comparing the predicted calculated values with the actual hydrostatic values, (2) compete for best boat performance by operating the boats remotely through designated courses. All teams are invited to witness Race Day.

Races

This event is the culmination of the Boat Design Competition. The final four teams will compete in a series of races that will test their boats' speed and maneuvering capabilities while carrying the required payload, optional ballast, and meeting freeboard requirements. The event will consist of two stages of competition:

1st Stage – High Speed Race ([See Figure 1](#))

- Determines the top speed of boat
- Course to be raced simultaneously by two teams
- Points awarded according to finishing order

2nd Stage – Scenario Race ([See Figure 2](#))

- Assesses handling, stability, and maneuverability of boat
- Course to be raced separately by the teams
- Points awarded according to finishing order

The rubric can be found in the [Test Phase Judging Rubric](#) appendix.

Awards Ceremony

The Awards Ceremony is held on the [same day](#) as the races. The team with the highest point total will be the winner. Superlative awards will also be distributed.

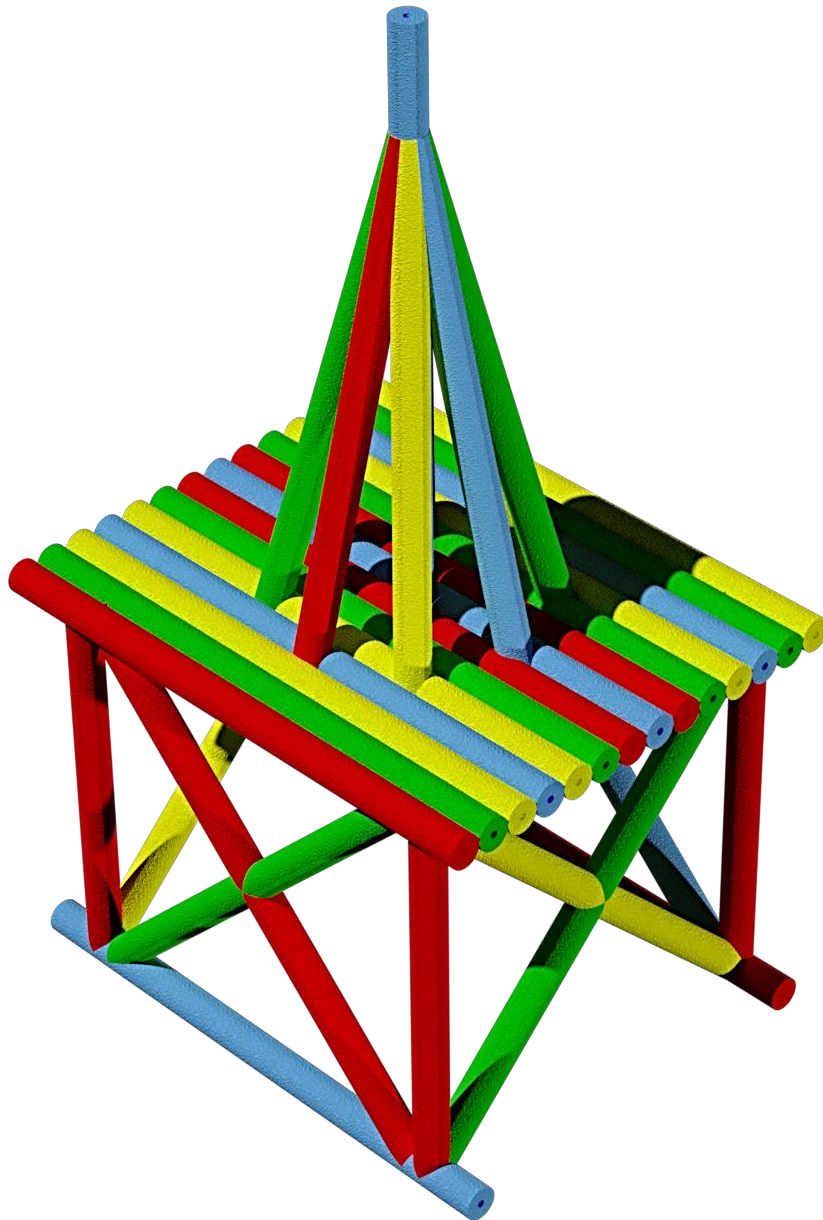
The finalist teams will be allowed to keep their boats after the competition. However, safe transportation as determined by the competition officials shall be provided by the team to remove the boat from the competition site.



APPENDIX A: SCENARIO

Required Payload

Each boat will be designed as an ocean-going tug capable of towing an oil rig (made from pool noodles). The oil rig towing attachment will be determined by the construction team and does not need to be shown on the Drawing Set. The oil rig will be towed approximately six feet behind the boat.



Approx Size: 4'7" Length x 3'6" Beam
(built may appear different than design)



Race Courses

1st Stage – High Speed Race

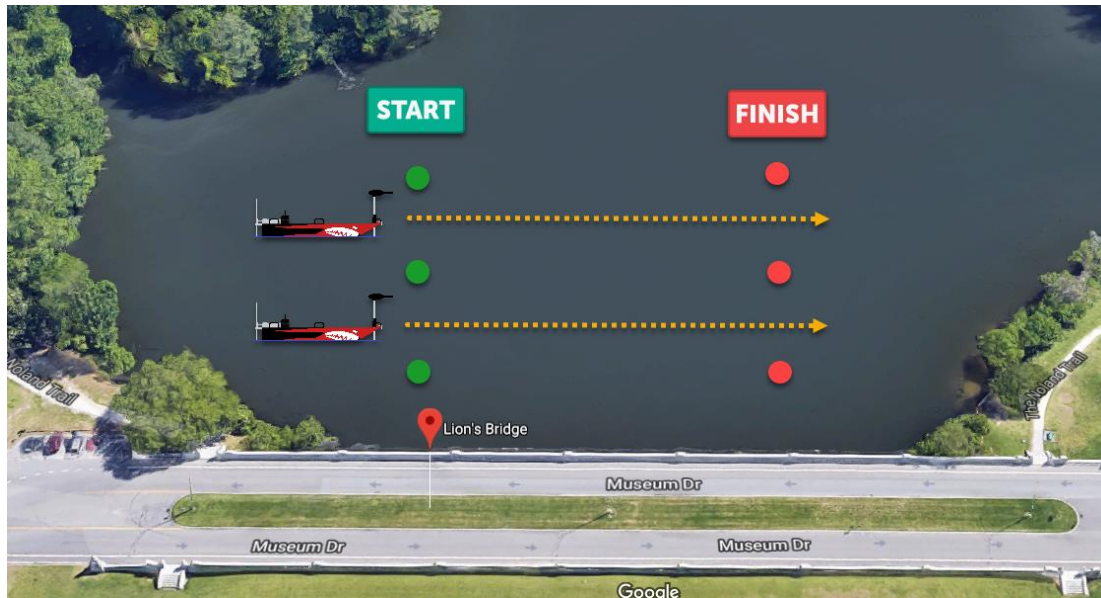


Figure 1 - High Speed Race Course

****Course is subject to change on Race Day (payload towing determination will be made on race day)****

2nd Stage – Scenario Race



Figure 2 - Scenario Race Course

****Course is subject to change on Race Day****



APPENDIX B: LIST OF MATERIALS

Construction Material



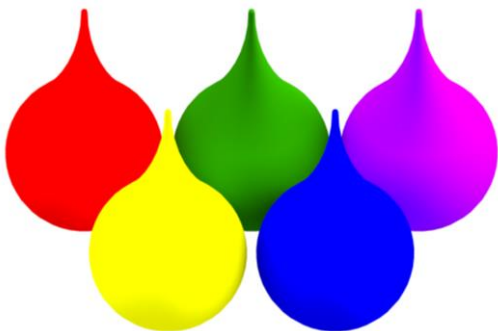
(2x) Steel Plates

- Description: Used to construct the boat's hull(s). Weld metal is used to join the steel parts.
- Dimensions: 4' x 8' x 1/8"
- Density: 5.7 lbs/ft²



(4x) Carrying Handles

- Description: Used to lift the boat. Does not count against the steel allotment of the Nesting Plan.
- Dimensions: 9" long
- Weight: 1 lb [per handle]
- Center of Gravity: 3" above main deck and centered along length of handle
- Special Requirements:
 - Shall be shown with longitudinal locating dimensions (vertical dimensions not necessary) on the Construction Drawings.
 - Must be affixed to fore-aft/longitudinal plate (i.e. plates essentially parallel to the centerline) and spaced appropriately along the length of the boat.



Paint

- Description: Used to coat the boat's hull for appearance and corrosion protection.
- Colors: Any (entirety of boat will be of single color)

Teams shall specify a paint color and an alternate on the registration form. Teams should use the Luncheon Drawing to express their creativity.



Optional Ballast



Water Jugs

- Description: One gallon jugs used as ballast in order to correct trim/list conditions. Jugs can be placed anywhere in the hull(s). Teams may elect to use none or as many as required. Jugs can be filled to any level with 62.4 lb/ft³ water.
- Dimensions: 6" x 6" x 10" H (all approx.)
- Weight: As determined by the team
- Center of Gravity: Calculated by the team
- Special Requirements:
 - If a team anticipates the use of ballast, it shall be located and labeled (with required individual weight) on the Loading Diagram and figured into the calculations. Ballast shall be designed to be held in place to prevent shifting while underway.
 - Ballast accounts for total weight in the water and therefore will count towards the minimum freeboard requirement.

Propulsion



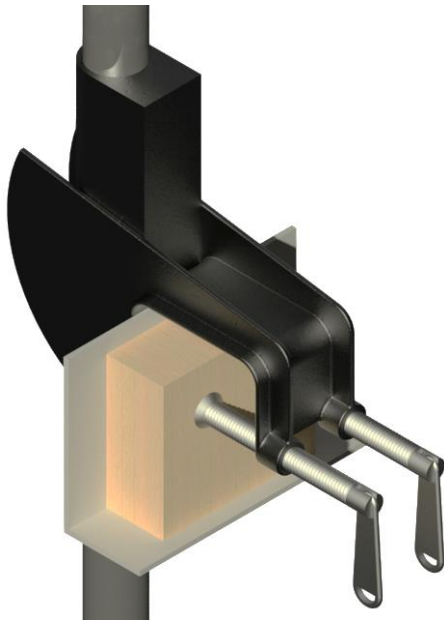
(1x) 12 Volt Marine Battery

- Description: Used to provide power to the Propulsion Motor and Steering Assembly. Sits within or on top of the boat.
- Dimensions: 13" x 7-1/4" x 9.5" H
- Weight: 51 lbs
- Center of Gravity: Geometric center of battery



(2x) Power Cables

- Description: Used to provide source power from the battery to the Steering Assembly and relay power from the Steering Assembly to the Propulsion Motor.
- Dimensions: 5' (relay) – 8' (source) long (stretched dimension)
- Weight: Negligible
- Center of Gravity: Negligible



(1x) Motor Mount

- Description: A 2" x 4" angle bar fabricated from the steel allotment. Used to mount the Propulsion Motor.
- Dimensions: In accordance with [Figure 3](#)
- Weight: As determined by the team (block of wood is negligible)
- Center of Gravity: Calculated by the team
- Special Requirements:
 - Mount shall be shown on the drawings.
 - Required for catamarans with simple supports connecting the hulls. Monohulls and trimarans may elect to use a variation of the Motor Mount if the Propulsion Motor is not affixed to a typical location (e.g. transom or hull plate), provided the support is of sufficient dimensions (i.e. as large as the Motor Mount), resists torsion, and clearance is provided to install the motor.



(1x) Bass Pro Shops® Prowler™ T55/40 [Propulsion] Motor

- Description: Used to propel the boat. The trolling motor is comprised of an electronic throttle located in the upper body, a mount and clamp screws, and a propeller capable of providing 55 pounds of thrust. The throttle is controlled remotely from shore.
- Dimensions: See [Figure 4](#)
- Weight: 17.8 lbs
- Center of Gravity: Midpoint of the 40 inch shaft
- Special Requirements:
 - Shall be able to be quickly attached/detached via the screw clamps without interference or require disassembly of other components or require disassembly of the motor itself (i.e. the motor is one piece). Clearance for *all* hull types shall be provided according to [Figure 3](#). The clearance box is the imaginary three-dimensional envelope that allows the motor to be installed in one piece.
 - Motor will be in a fixed orientation relative to the boat during the race and cannot be turned while underway. Steering will be accomplished via the rudder instead. Adjustments (i.e. tilt, rotation, depth) shall be specified on the Loading Diagram if the adjustments differ from normal (upright, forward, perpendicular, depth in line with rudder, etc.).

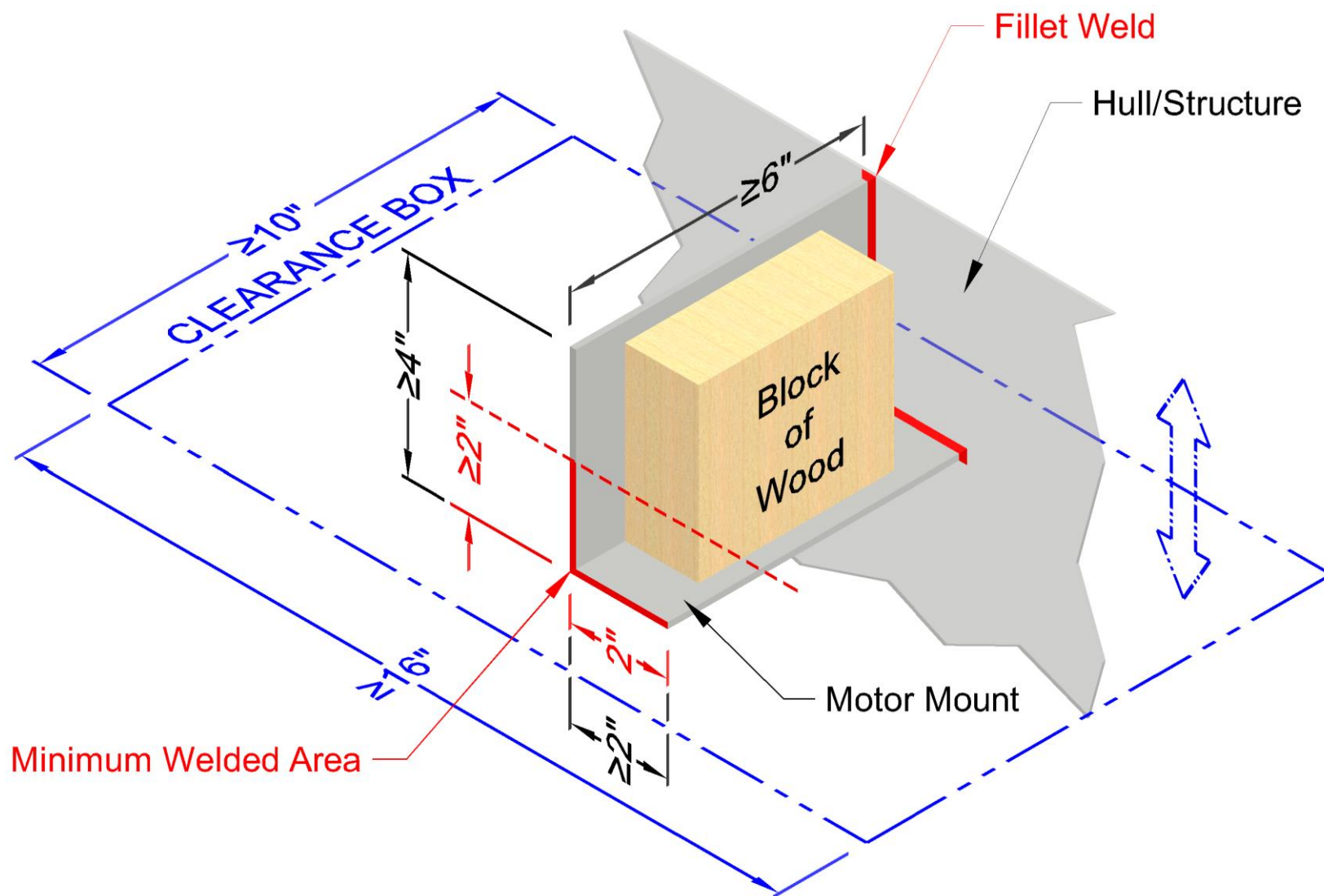


Figure 3 – Motor Mount Template

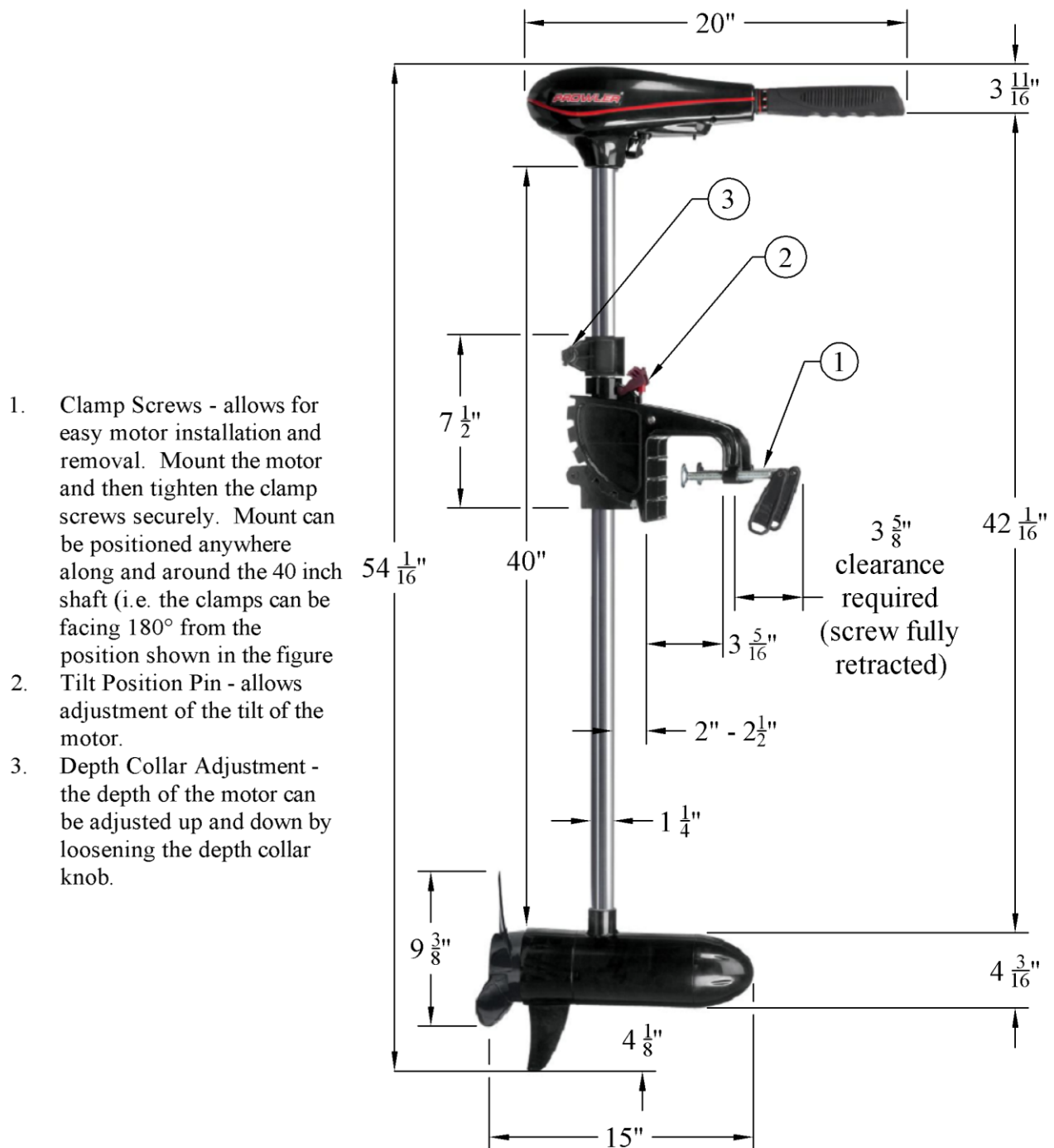


Figure 4 - Dimensioned Propulsion Motor

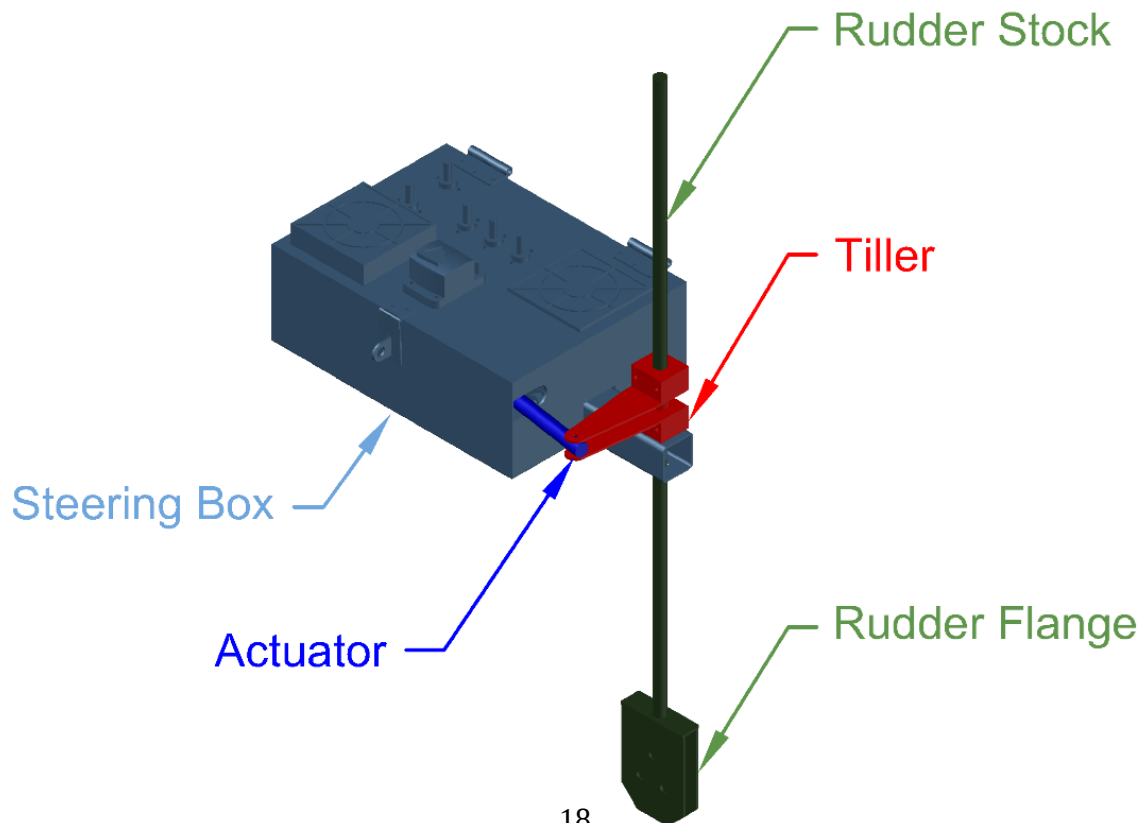


Steering

(1x) Steering Assembly

(consists of Steering Box, Actuator, Tiller, Rudder & Rudder Flange/Stock)

- Description: Used to steer the boat. The assembly is controlled remotely from shore. The actuator is capable of rotating the rudder stock through 60° of rotation (i.e. 30° port and starboard from neutral position). The assembly is mounted via the box by three bolts.
- Dimensions (of Steering Box): 15-5/8" L x 11-3/8" W x 5-1/2" H
- Dimensions (of Rudder Stock): 3/4" diameter, 36" long
- Weight: 35 lbs
- Center of Gravity: Geometric center of Steering Box
- Special Requirements:
 - Shall be able to be quickly attached/detached via the bolts without interference or require disassembly of any components. Clearance shall be provided according to [Figure 5](#). The clearance box is the imaginary three-dimensional envelope that allows the assembly to be installed in one piece.
 - Shall be adequately and reliably secured, whether directly to the hull, a horizontal mounting plate, etc. Take into consideration torsion and utilizing breaks to stiffen plates. Mount must be *at least* as large as the **base** dimensions of the Steering Box (i.e. no slats). Mounting holes from [Figure 5](#) shall be shown on the drawings.
 - Steering Box shall be located at least six inches above the load waterline.
 - Adjustment to the depth of the rudder stock shall be specified on the Loading Diagram if different than normal (i.e. rudder surface in line with propeller).



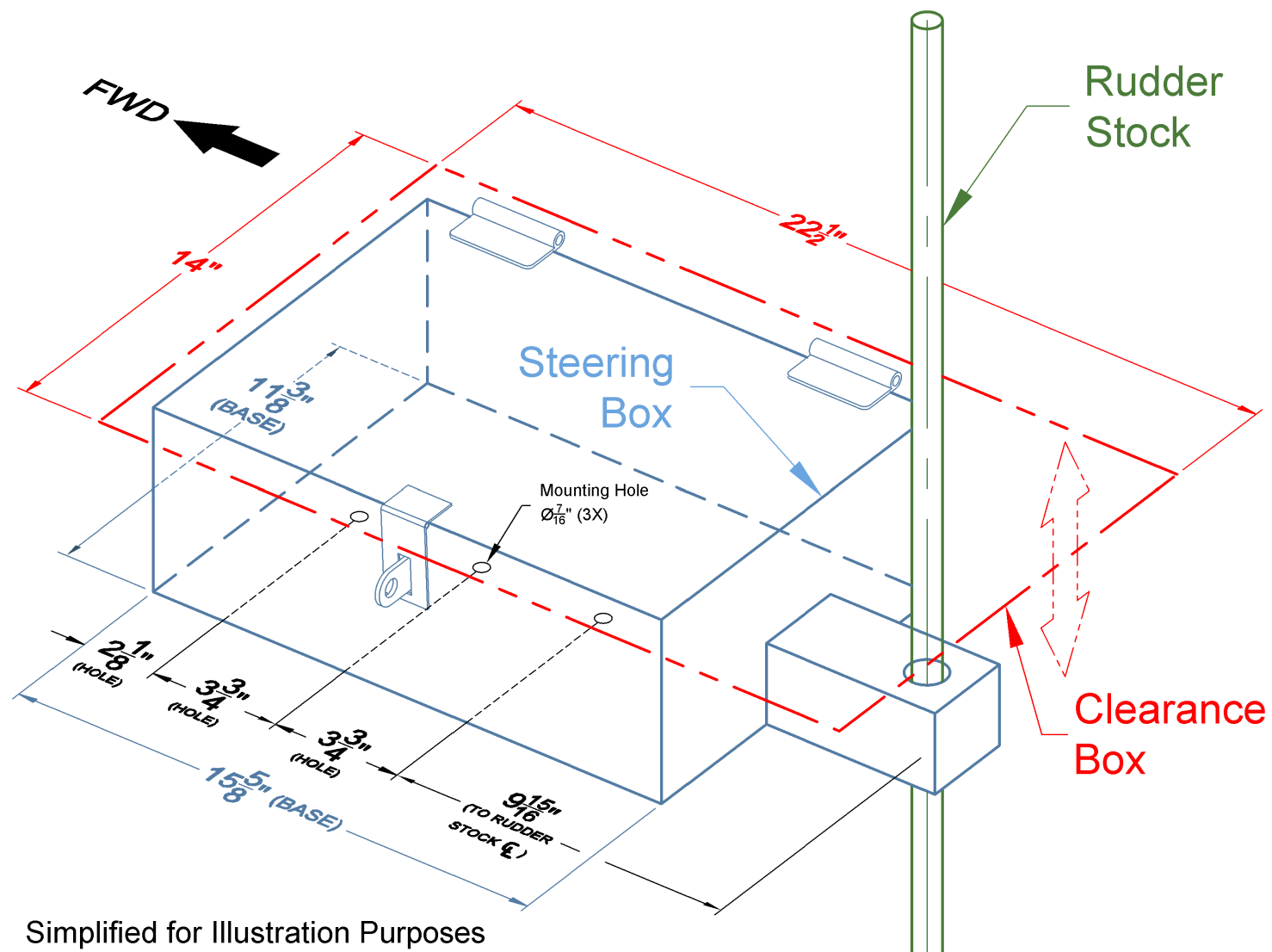


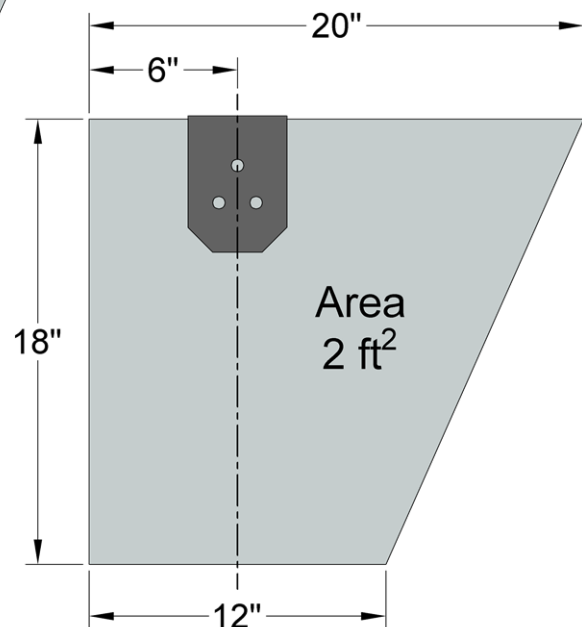
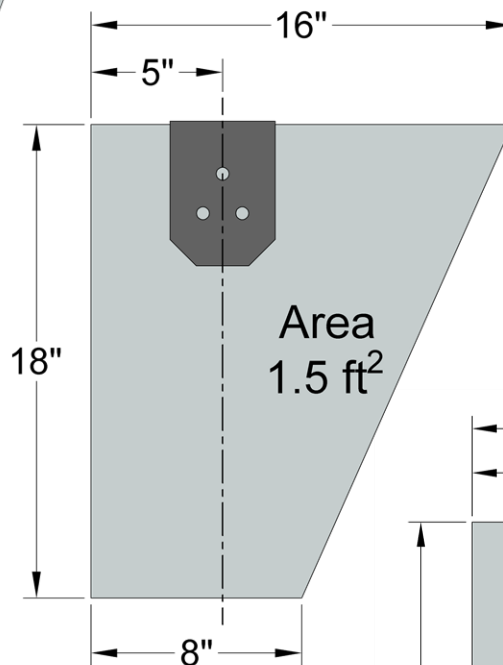
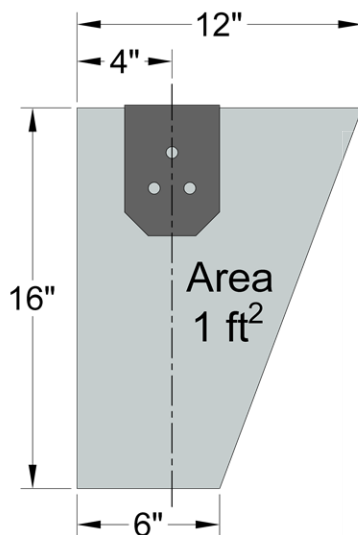
Figure 5 – Steering Assembly Template



(1x) Rudder

- Description: Surface to steer the boat.
- Dimensions: As shown
- Weight: Negligible
- Center of Gravity: Negligible

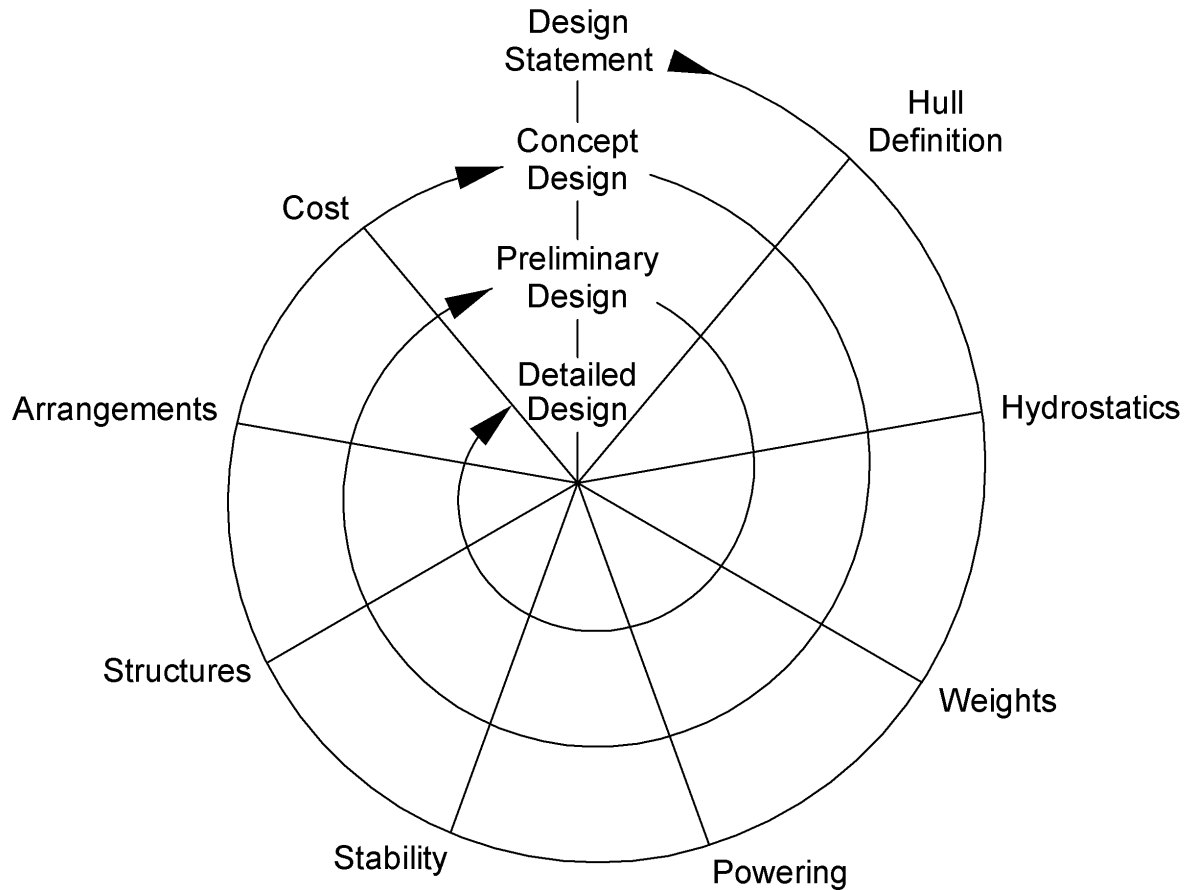
Teams shall choose one rudder size of those shown and specify choice on the Loading Diagram. If the rudder is too small, maneuverability will be sacrificed. If the rudder is too large, speed will be sacrificed since the rudder area will create additional drag. Rough maneuverability calculations can be found in the Glossary.





APPENDIX C: DESIGN SPIRAL

Ship design is typically an iterative process in which various aspects of the design are balanced in a certain order to arrive at an optimal design. Most of these broad requirements cannot be analyzed and/or determined independently of the other criteria on the Design Spiral. The Design Spiral and its parameters generally takes the following form:



This general process can apply to a naval ship, a commercial ship, or something as simple as a row boat. The process starts very broad and progressively becomes more detailed as the design moves from the concept design phase, to preliminary design, and finally to detailed design. Each parameter is connected by both the spiral and by radial lines since the process is as much a consecutive one as it is a concurrent one. While the design will not necessarily address each of the parameters, it can provide a useful approach to designing a boat. The process starts with defining the mission of the boat in a one or two sentence design statement based on the prospective owner's requirements.

Hull Definition: Determine the general shape of the hull and its principal dimensions. Later steps involve the creation of a lines drawing for the ship which describes the hull form in detail.



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Speed: Speed calculations require effort, modeling, and calculations beyond the scope of this competition. Calculations are not required to predict the actual speed of the boat for this competition; however, recommendations are provided in the calculations appendix.

Maneuverability: Maneuvering calculations require effort, modeling, and calculations beyond the scope of this competition. Calculations are not required.

Hydrostatics: Consider the properties of the hull as it sits at rest in the water. This includes the volume, displacement, design waterline, center of buoyancy, and metacentric height of the hull.

Weights: Estimate the weight of all shipboard structure and components and their location and determine the boat's weight and its center of gravity.

Powering: While the Propulsion Motor is already chosen, propulsion considerations normally include speed, fuel availability, fuel rate, space, and weight.

Stability: Calculate the boat's tendency to right itself when its position in the water is disturbed by an outside force like wind or waves. Stability is critical to the safety and comfort of the boat and its passengers and cargo.

Structure: Design the structure needed to maintain structural integrity through all sea and weather conditions that the boat can expect to see during its lifetime. Considerations include type of material, thickness of the material, the location and size of all frames, and how the materials are joined to one another.

Arrangements: Determine how much space each function of the boat requires and where that space should be located for the most efficient operation of the boat. The final step in determining the boat's arrangement is to develop a detailed plan of the boat depicting every space on the boat, its purpose, as well as how equipment will be located in each space.

Cost: It is important to consider the cost of the boat as the final parameter during each pass through the Design Spiral. Cost estimation consists of an educated guess as to what materials and labor will be required for the construction of the boat.

From this point forward, the designer continues to follow the steps of the spiral, re-examining each parameter in more detail than on the previous pass. The team's travel through the Design Spiral should be documented in the Design History Notebook.

A description of the overall design process for a boat can be found in "The Design Spiral for Computer-Aided Design" by Stephen Hollister at www.newwavesys.com/spiral.htm.



APPENDIX D: DRAFTING GUIDELINES

The four drawings required for this competition are:

1. Design Drawing: The Design Drawing will include the body, plan, sheer, and isometric views of the *structural* design (i.e. excluding the Steering Assembly, payload, etc.). Any additional views that help visualize the completed design may be included on additional sheets. The principal dimensions shall be compiled in a table. Principal dimensions that can be shown as labeled dimension lines shall also be included on the views most appropriate to receive them. These should be the *only* dimension lines on the Design Drawing.

Principal Dimensions:

- Length Overall
- Length Between Perpendiculars
- Beam
- Depth
- Displacement (Unloaded)

2. Loading Diagram: The Loading Diagram will include the body, plan, sheer, and isometric views of the *loaded* design. Any additional views that help visualize the completed design may be included on additional sheets. The payload, Steering Assembly, Propulsion Motor (including any special adjustments), battery, rudder (with size), and optional ballast (with individual weight) shall be labeled. Locating dimensions/wording shall be used for clarity when needed. The following principal dimensions shall be compiled in a table:

Principal Dimensions:

- Draft
- Length at Waterline
- Displacement (Loaded)

3. Nesting Plan: The Nesting Plan is a full-sized 2D drawing that shows the layout of each piece on the steel plates to show that all required pieces can be cut from the provided material. Each piece on the Nesting Plan should be numbered according to the Construction Drawing's bill of material. A 1/2 inch gap between pieces is required since the width of the cutting tool must be accounted for.
4. Construction Drawings: The Construction Drawings shall provide the views, details, dimensions, bill-of-material, reference lines/planes, part numbers (corresponding to material list), and notes necessary for the construction of the boat. Steering Box mounting holes and carrying handles shall be shown.



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Additionally, optional drawings for this competition include:

1. Luncheon Drawings: Since the designs will be showcased at the Luncheon for competitors and officials to view, additional drawings may be provided. These creative drawings may use any paint scheme/hull art and can consist of additional views or renderings. Label all Luncheon Drawings specifically as such. Luncheon Drawings shall be submitted separately from the rest of the Drawing Set.
2. Calculation Supplement Drawings: These drawings help enhance the Calculations Packet and illustrate [to the judges] that the calculations were performed correctly. By compiling these drawings, team members can develop a better understanding of the methods used and readily spot mistakes in the calculations. Calculation Supplement Drawings shall be submitted separately from the rest of the Drawing Set.

Examples of these drawings may include: showing waterplane and station areas of the hull, showing the design waterplane area and attributes, showing centers of gravity and buoyancy, and showing trimmed conditions.

Drawing Judging Criteria

Bending and breaking allows for the transition of the hull form without the need for welding, thus simplifying the construction. Bending and breaking are not required; however, because they decrease welding, teams will be judged (in accordance with the [Design Phase Judging Rubric](#)) on how bends and breaks are used to simplify the construction. A team's design that could have benefited from bends/breaks, but did not specify any, will score lowly. If a team's design could *not* have implemented bends/breaks, then that team will not be penalized for not specifying any bends/breaks. For instance, a team that designs a box will be scored lowly for a Nesting Plan that shows five separate pieces because every seam would require welding (as opposed to an unfolded piece).

While utilizing bends/breaks is encouraged, it is important to understand that the finished boat will differ from the design. The experienced lofting department of the shipyard will rearrange pieces of a nesting plan to best suit fabrication. This should not hinder a team from utilizing bends/breaks on the design.



APPENDIX E: CALCULATIONS

All required calculations for the Final Design Package are indicated in Calculations Summary sheets. These values are considered the final answers.

All work behind the calculations should be shown. Work should be neat and organized. Use the templates found online:

<https://communities.sname.org/designcompetition/downloads/calcs>

Any additional medium to convey work (e.g. notes, screenshots, etc.) may also be submitted as part of the Calculations Packet file.

All numbers (except those of the Calculations Spreadsheet) should be accompanied by units.

All calculations may be calculated manually. Values from CAD programs may only be used when instructed. Show work behind calculations that are not lifted from a CAD program.

Round all decimals [that are not expressed as equivalents of a ruler] to two places.

The reference point from the Glossary shall be used.

Calculation tutorials are available online via YouTube:

<https://communities.sname.org/designcompetition/videotutorials>

Speed

Listed below are some good practices that should be followed to maximize the boat's speed. These calculations are not required, as indicated by the Calculations Summary sheets; however, if followed, they should be discussed in the Design History Notebook.

1. Design for a length to beam ratio of between 6 and 8. Within this range, the higher ratio should lead to a faster boat.
2. Finer hull forms go faster than fuller hull forms (block coefficient).
3. Minimize the wetted surface to reduce friction.
4. Minimize abrupt transitions and shapes to streamline the hull.



Weight & Center of Gravity

- All weights (steel, battery, payload, etc.), including the anticipated use of optional ballast (this may be a condition that will need to be reconsidered based on results from draft and trim later on) contribute to displacement and need to be tallied.
- All steel pieces should be an individual row (i.e. regardless of breaking or welding).

Do the following to complete the Weight tab of the Calculations Spreadsheet:

1. Steel pieces are to be entered in the buff-colored section while components (i.e. those that do not contribute to the weight of the unloaded boat) are to be entered in the red-colored section. Delete any unused rows.
2. Enter the side that the part is on (i.e. port/starboard for a monohull or port inboard, port outboard, etc. for multiple hulls). Type center if the part lies on the centerline.
3. Enter the part number that corresponds to the material list on the drawings.
4. Enter the part's description.
5. Enter the part's bounded dimensions (if a plate is curved, use the dimensions before bending since the volume of the plate is unchanged). Leave blank for components.
6. Label the general shape of the part. Leave blank for components.
7. Calculate the part's area from CAD (or by using the appropriate geometric equation) in conjunction with the Nesting Plan. Leave blank for components.
8. Enter the part's density. Leave blank for components.
9. Calculate the part's weight. Enter component weights as given by the Guidelines.
10. Enter the VCG, LCG, and TCG for each part. These are the vertical, longitudinal, and transverse distances respectively from the reference point to the part's individual center of gravity. Follow the sign convention.
11. Calculate the VMOM, LMOM, and TMOM (the moments that each part exerts from the reference point) for each part by multiplying the weight by the distance.
12. Sum the weights, VMOM, LMOM, and TMOM columns for both loaded and unloaded (i.e. structural) conditions. Find the composite VCG, LCG, and TCG of the entire loaded boat (together they make up the three-dimensional location of the CG):

$$VCG = \frac{VMOM_{Total}}{Weight_{Total}} = \underline{\hspace{4cm}}$$

$$LCG = \frac{LMOM_{Total}}{Weight_{Total}} = \underline{\hspace{4cm}}$$

$$TCG = \frac{TMOM_{Total}}{Weight_{Total}} = \underline{\hspace{4cm}}$$

Understanding the Results

The weight of the boat is crucial because it affects every other calculation. If the port and starboard sides of the hull are symmetrical and all additional weights are on the boat's centerline, the TCG should equal zero (a TCG other than zero complicates subsequent calculations unless the angled waterplane/station areas are accounted for). Likewise, the boat will not list.



Displacement & Draft

Unless the boat's volumetric displacement is linear with draft or the shape of the hull is simple (or the team makes a perfect initial guess), finding the point where the weight of the boat equals the volumetric displacement requires repeated calculations. For accuracy, this volume will be found by using both waterplane areas and station areas. Each has a dedicated tab in the Calculations Spreadsheet and will be completed using an iterative process as outlined below (only the last iteration needs to be submitted in the Final Design Package):

1. Using waterplane areas and the Waterplane Area tab of the Calculations Spreadsheet:
 - a) Estimate a draft (that correlate to ruler equivalents) in the header.
 - b) With a minimum of nine waterlines from the baseline (0) to the estimated draft (8), find the distance from each waterline to the baseline. The end cell in this column should match the draft guess in a). Extra rows may be added to accommodate a greater amount of waterlines.
 - c) Fill the header with the h value, where h is the spacing between the waterlines. This spacing should equal any cell in b) subtracted by an adjacent cell.
 - d) Determine the areas of each waterplane associated with each waterline.
 - e) Determine the sequencing of Simpson's Multipliers.
 - f) Multiply the area by the multiplier and sum entire column [$\sum f(V_i)$ is equivalent to everything in the parentheses of Simpson's Rule equations].
 - g) Find volumetric displacement, displacement (in lbs), and draft:

$$\nabla = \frac{h}{3} \left(\sum f(V_i) \right) = \underline{\hspace{10cm}}$$

$$\text{Convert from in}^3 \text{ to ft}^3 \Rightarrow \frac{\nabla}{1728 \text{ in}^3/\text{ft}^3} = \underline{\hspace{10cm}}$$

$$\Delta = \nabla * 62.4 \text{ lb}/\text{ft}^3 = \underline{\hspace{10cm}}$$

2. Using station areas and the Station Area tab of the Calculations Spreadsheet:
 - a) Estimate a draft (that correlate to ruler equivalents) in the header.
 - b) With a minimum of nine stations from the FP (0) to the AP (8), find the distance from each station to the FP. The end cell in this column should match the LBP of the boat. Extra rows may be added to accommodate a greater amount of stations.
 - c) Fill the header with the h value, where h is the spacing between the stations. This spacing should equal any cell in b) subtracted by an adjacent cell.
 - d) Determine the partial area (from baseline to estimated draft) of each station.
 - e) Determine the sequencing of Simpson's Multipliers.
 - f) Multiply the area by the multiplier and sum entire column [$\sum f(V_i)$ is equivalent to everything in the parentheses of Simpson's Rule equations].
 - g) Find volumetric displacement, displacement (in lbs), and draft:

$$\nabla = \frac{h}{3} \left(\sum f(V_i) \right) = \underline{\hspace{10cm}}$$

Convert from in^3 to $\text{ft}^3 \Rightarrow \frac{\nabla}{1728 \text{ in}^3 / \text{ft}^3} = \underline{\hspace{2cm}}$

$$\Delta = \nabla * 62.4 \text{ lb/ft}^3 = \underline{\hspace{2cm}}$$

Understanding the Results

If the displacement is greater than the weight of the boat, then the team has overestimated the draft. Repeat the iteration using areas calculated to a lower draft. Repeat vice versa if the team has underestimated the draft. Iterations should be discontinued when displacement and weight are within ten pounds of each other.

Further increasing the number of areas (e.g. a boat can have complicated waterplanes in relation to relatively simple stations) can increase the accuracy of Simpson's Rule.

The density of the lake water is 62.4 lb/ft³. If the boat were to be placed in a denser environment (e.g. seawater), its displacement and draft would be different.

Choose whether the calculations from waterplanes or stations will be carried throughout the remaining calculations:

Choice = _____

Write down the area of the design waterplane (the waterplane at the design waterline/draft):

$$A_{WP} =$$

Calculate the PPI immersion:

$$\text{PPI} = \frac{A_{WP}}{27.7 \text{ in}^3 / lb} = \underline{\hspace{2cm}}$$



Buoyancy

The vertical center of buoyancy can be found by filling in the last two columns of the Waterplane Area tab of the Calculations Spreadsheet by generating a moment about the baseline using the waterline heights as moment arms. The moment, or lever arm, indicates how many “h” values the waterline is away from the baseline. Therefore, the first number in the column is a zero. Multiply each waterplane area by the Simpson’s Multiplier and the vertical lever arm to find the last column. Sum the column and solve:

$$VCB = \frac{h * \sum f(V_i N_i)}{\sum f(V_i)} = \underline{\hspace{10cm}}$$

A low VCG, especially when compared to the VCB, is appreciable. The formula below is an approximation included to help determine if the VCB is correct:

$$VCB_{\text{Approx}} = T * \left[\frac{A_{WP}}{A_{WP} + \nabla / T} \right] = \underline{\hspace{10cm}}$$

The longitudinal center of buoyancy can be found by filling in the last two columns of the Station Area tab of the Calculations Spreadsheet by generating a moment about the bow using the station spacing as moment arms. The moment, or lever arm, indicates how many “h” values the station is away from the bow. Therefore, the first number in the column is a zero while Station 3 is three stations from Station 0. Multiply each station area by the Simpson’s Multiplier and the longitudinal lever arm to find the last column. Sum the column and solve:

$$LCB = \frac{h * \sum f(V_i N_i)}{\sum f(V_i)} = \underline{\hspace{10cm}}$$

The longitudinal center of flotation can be found using the CAD program. It is the geometric centroid of the design waterplane:

$$LCF = (\text{from CAD}) \underline{\hspace{10cm}}$$

Understanding the Results

A TCB is not found since, when the boat is upright, it is equal to zero in a geometrically symmetrical hull (almost always the case).



Stability

The boat's stability is determined by the relationship between the center of gravity, the center of buoyancy, and a point called the metacenter. For the equations below to work as is, ensure the x-axis is aligned along the centerline and the y-axis is parallel to the waterplane. Moment of inertias may be easily calculated by hand if the waterplane is composed of simple geometric shapes. These formulas are readily available online by searching for second moment of area/area moment of inertia (this should not be confused with mass moment of inertia, which is more commonly known as moment of inertia).

Use the following process to find the transverse metacenter relationships:

Find the transverse moment of inertia of the design waterplane:

$$I_T = I_{CL} = I_X = (\text{from CAD}) \underline{\hspace{10cm}}$$

Calculate the transverse metacentric radius:

$$BM_T = \frac{I_T}{\nabla} = \underline{\hspace{10cm}}$$

Then calculate the distance between the keel and the transverse metacenter:

$$KM_T = VCB + BM_T = \underline{\hspace{10cm}}$$

Finally, calculate the transverse metacentric height:

$$GM_T = KM_T - VCG = \underline{\hspace{10cm}}$$



Repeat the process to find the longitudinal metacenter relationships:

Find the longitudinal moment of inertia of the waterplane at the design waterline (if the UCS in the CAD program is located at the center of flotation, then the parallel axis theorem is not needed; otherwise the parallel axis theorem applies to shift the reference point from the bow to the LCF):

Parallel axis theorem:

$$I_y = (\text{from CAD}) \underline{\hspace{10cm}}$$

$$I_L = I_{LCF} = I_y - A_{WP} * LCF^2 = \underline{\hspace{10cm}}$$

where: A_{WP} is the area of the design waterplane

LCF is the distance from the bow to the center of flotation

If the parallel axis theorem is not used, then I_y from CAD is already the longitudinal moment of inertia:

$$I_L = I_{LCF} = I_y = (\text{from CAD}) \underline{\hspace{10cm}}$$

Calculate the longitudinal metacentric radius:

$$BM_L = \frac{I_L}{\nabla} = \underline{\hspace{10cm}}$$

Then calculate the distance between the keel and the longitudinal metacenter:

$$KM_L = VCB + BM_L = \underline{\hspace{10cm}}$$

Finally, calculate the longitudinal metacentric height:

$$GM_L = KM_L - VCG = \underline{\hspace{10cm}}$$

Understanding the Results

The transverse moment of inertia should be smaller (if the boat is longer than it is wider) than the longitudinal moment of inertia. Likewise, GM_T should be smaller than GM_L . This is plausible since GM represents initial stability and a boat much more easily capsizes from rolling over on its side than pitchpoling (capsizing end-on-end).



Trim

Find the moment required to trim the boat one inch (units do not simplify). It requires the displacement in pounds, GM_L in inches, and the LWL in inches:

$$MT1'' = \frac{\Delta * GM_L}{LWL} = \underline{\hspace{4cm}}$$

If the LCB and LCG are located in the same spot along the length of the boat, then there will be no trim. If the LCG is forward of the LCB, then the boat will trim by the bow (bow deeper in the water) and vice versa. Calculate the trim by multiplying the displacement in pounds times the difference in inches between the LCB and LCG and divide by the MT1'':

$$\text{trim} = \frac{\Delta * (LCB - LCG)}{MT1''} = \underline{\hspace{4cm}}$$

Use the absolute value of the trim for the following equations since the plus-minus sign takes care of the trim condition (e.g. if the boat trims by the bow, then $T_F = T_M + f$ and $T_A = T_M - a$, while the signs are opposite if the boat trims by the stern). For the purposes of the Boat Design Competition, T_M is the design draft. Calculate the drafts at the bow and stern:

$$f = \left(\frac{LCF}{LWL} \right) * |\text{trim}| = \underline{\hspace{4cm}}$$

$$T_F = T_M \pm f = \underline{\hspace{4cm}}$$

$$a = |\text{trim}| - f = \underline{\hspace{4cm}}$$

$$T_A = T_M \pm a = \underline{\hspace{4cm}}$$

The minimum required freeboard as specified in the Design Phase Parameters is six inches. This is required along the entire length of the hull (i.e. an eight inch freeboard at the stern does not compensate for a four inch freeboard at the bow).

$$\text{Freeboard (at bow)} = D - T_F = \underline{\hspace{4cm}}$$

$$\text{Freeboard (at stern)} = D - T_A = \underline{\hspace{4cm}}$$

Understanding the Results

Boat design is an iterative process. If the freeboard does not meet the criteria, then the process needs to be reworked. Also, just like TCG, trim affects the assumed waterplane and station areas that were used to calculate displacement (though in this case displacement was calculated before being able to calculate the trim). The larger the trim, the more likely the previous calculations are incorrect since the boat was assumed to be upright and level when calculating areas.



Calculations Summary

Reference

Length Overall, LOA [$\leq 144'$]

Length at Waterline, LWL (determine after draft)

Beam [$\leq 50'$]

Depth, D

Mean Draft, T_M (choose one from below)

Weight & Center of Gravity

Weight (Loaded), Δ (from Calculations Spreadsheet)

Weight (Unloaded), Δ (from Calculations Spreadsheet)

Vertical Center of Gravity, VCG

from baseline

Longitudinal Center of Gravity, LCG

from FP

Transverse Center of Gravity, TCG

from centerline



Displacement & Draft

From Waterplane Areas:

Draft, T

Volumetric Displacement, ∇

Displacement, Δ

From Station Areas:

Draft, T

Volumetric Displacement, ∇

Displacement, Δ

Area of Design Waterplane, A_{WP}

Pounds Per Inch of Immersion, PPI

Buoyancy

Vertical Center of Buoyancy, VCB

from baseline

Longitudinal Center of Buoyancy LCB

from FP

Longitudinal Center of Flotation, LCF

from FP



Stability

Transverse Moment of Inertia, I_T

Transverse Metacentric Radius, BM_T

Transverse Metacenter, KM_T

from baseline

Transverse Metacentric Height, GM_T

Longitudinal Moment of Inertia, I_L

Longitudinal Metacentric Radius, BM_L

Longitudinal Metacenter, KM_L

from baseline

Longitudinal Metacentric Height, GM_L

Trim

Moment to Trim One Inch, $MT1''$

Trim

Difference Between Bow Trim and Draft, f

Draft (at bow), T_F

Difference Between Stern Trim and Draft, a

Draft (at stern), T_A

Freeboard (at bow) [$\geq 6''$]

Freeboard (at stern) [$\geq 6''$]



APPENDIX F: DESIGN PHASE JUDGING RUBRIC

DESIGN HISTORY NOTEBOOK					
JUDGING CRITERIA		Poor (0 pts)	Fair (3 pts)	Good (6 pts)	Excellent (9 pts)
EXPLANATION OF DESIGN	Design Spiral	Incorporation of design journey (Design Spiral) lacking	Incorporation of design journey (Design Spiral) is minimal	Incorporation of design journey (Design Spiral) needs improvement	Incorporation of design journey (Design Spiral) is thorough
	Illustrations	Most (5+) illustrations are not helpful/not needed; no illustrations used	Some (3-4) illustrations are not helpful/not needed	Few (1-2) illustrations are not helpful/not needed	Appropriate illustrations are used to complement the understanding
	Content	Overall content lacking	Minimal content, wording, and explanation given	Content, wording, and explanation needs improvement	Content, wording, and explanation thorough
	Payload	Payload consideration not mentioned	Payload consideration mentioned	Payload consideration explained	Payload consideration elaborated
FORMAT	Team Name (9 pts unless as directed by Lead)	Team name is unprofessional; not included	N/A		Team name is professional
	Appearance	Many (5+) unprofessional errors; unprofessional	Some (3-4) semiprofessional errors	Few (1-2) semiprofessional errors	Professional appearance
	Organization	Dates/headings not included	Separation of meetings is difficult to decipher, flow interrupted	Some improvement to flow or organization needed	Dates/headings/formatting helps distinguish meetings, easy to follow
	Illustrations	No illustrations are used or many (5+) illustrations are not labeled/referenced, aligned, sized, and cropped	Some (3-4) illustrations are not labeled/referenced, aligned, sized, and cropped appropriately	Few (1-2) illustrations are not labeled/referenced, aligned, sized, and cropped appropriately	All illustrations are labeled/referenced, aligned, sized, and cropped appropriately
SPELLING & GRAMMAR	Spelling	Spelling errors throughout (10+)	Abundant (4-9) spelling errors	Few (1-3) spelling errors	No spelling errors
	Grammar	Grammatical errors throughout (10+)	Abundant (4-9) grammatical errors	Few (1-3) grammatical errors	No grammatical errors



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DRAWING SET					
JUDGING CRITERIA		Poor (0 pts)	Fair (3 pts)	Good (6 pts)	Excellent (9 pts)
FORMAT	Design	(3+) errors of the following: principle dimensions (whether tabulated or dimensioned) missing, views missing	(2) errors of the following: principle dimensions (whether tabulated or dimensioned) missing, views missing	(1) error of the following: principle dimension (whether tabulated or dimensioned) missing, view missing	All principal dimensions labeled and tabulated
	Construction	(3+) errors of the following: bill-of-material incomplete, missing part numbers, missing necessary views/pieces	(2) errors of the following: bill-of-material incomplete, missing part numbers, missing necessary views/pieces	(1) error of the following: bill-of-material incomplete, missing part number, missing necessary view/piece	Construction process clear
	Nesting	(3+) errors of the following: pieces not accounted for, pieces not numbered, not laid out properly	(2) errors of the following: pieces not accounted for, pieces not numbered, not laid out properly	(1) error of the following: a piece not accounted for, a piece not numbered, not laid out properly	All pieces accounted for, numbered, and laid out properly
	Loading	(3+) errors of the following: views missing, components missing, labels missing, locating dimensions/wording missing (when appropriate), loading condition does not match calculations, principle dimension missing	(2) errors of the following: views missing, components missing, labels missing, locating dimensions/wording missing (when appropriate), loading condition does not match calculations, principle dimension missing	(1) error of the following: view missing, component missing, label missing, locating dimension/wording missing (when appropriate), loading condition does not match calculations, principle dimension missing	All components shown, labeled, and located (when appropriate) in all required views; loading condition matches the calculations, principle dimensions labeled and tabulated
	Dimensions	Many dimension lines are cluttered, overlap, detract from professional appearance	Some dimension lines are cluttered, overlap, detract from professional appearance	Few dimension lines are cluttered, overlap, detract from professional appearance	All dimension lines are clean, do not overlap, add a professional appearance
	Title Block	(3+) errors of the following: title block is missing, title block not filled out appropriately, unprofessional	(2) errors of the following: title block is missing, title block not filled out appropriately, unprofessional	(1) error of the following: title block is missing, title block not filled out appropriately, unprofessional	Professional title block included for all sheets
	Spelling	Spelling errors throughout (10+)	Abundant (4-9) spelling errors	Few (1-3) spelling errors	No spelling errors



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DRAWING SET					
JUDGING CRITERIA		Poor (0 pts)	Fair (3 pts)	Good (6 pts)	Excellent (9 pts)
EFFICIENT CONSTRUCTION	Access	Boat cannot be easily produced	Boat has many (3-4) tight/restricted areas	Boat has few (1-2) tight/restricted areas	Boat can be easily produced considering the design
		Boat has watertight compartments	N/A		Boat does not have watertight compartments
	Dimensions	Many (10+) of dimensions are not in fractions of an inch	Some (4-9) dimensions are not in fractions of an inch	Few (1-3) dimensions are not in fractions of an inch	All dimensions are in fractions of an inch (where achievable)
		Many (5+) calculations are needed to find remaining dimensions; dimensions are not present	Some (3-4) calculations are needed to find remaining dimensions	Few (1-2) calculations are needed to find remaining dimensions	All dimensions needed for construction are present/no need to request additional dimensions
	Piece Parts	Many (5+) piece parts are used	Some (3-4) piece parts are used	Few (1-2) piece parts are used	Boat only has piece parts where needed
	Waste (dependent on required buoyancy and team's desire to maximize payload)	Complete disregard to utilizing space for payload/components	Disregard to utilizing space for payload/components	Little wasted space in boat for payload/components	Most efficient use of space in boat for payload/components
	Steering Assembly	Assembly requires disassembly to fit	N/A		Assembly easily fits without disassembly
	Propulsion Motor	Motor requires disassembly to fit	N/A		Motor fits easily without disassembly
	Bends/Breaks	Design has no bends/breaks and could have utilized them	Design requires mostly welded seams, but could have utilized more bends/breaks	Design shows attempt at incorporating mostly bends/breaks where possible	Design utilizes bends/breaks wherever possible



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DRAWING SET					
JUDGING CRITERIA		Poor (0 pts)	Fair (3 pts)	Good (6 pts)	Excellent (9 pts)
EFFECTIVE CONSTRUCTION	Reasonable	Boat is longer than 12'	N/A		Length overall $\leq 12'$
		Boat is wider than 50"	N/A		Beam $\leq 50''$
		Structure/appendages/hulls (catamarans/trimarans) poorly supported	Structure/appendages/hulls (catamarans/trimarans) simply supported	Structure/appendages/hulls (catamarans/trimarans) conservatively supported	Structure/appendages/hulls (catamarans/trimarans) adequately supported
		Payloads/components not supported/secured (4+)	Some (2-3) payloads/components secured	Few (1) payloads/components not secured	All payloads/components secured
	Achievable	Construction is not possible based on drawings; many (4+) modifications are necessary	Construction is difficult; some (2-3) modifications are necessary	Construction can be accomplished with only minor/few (1) modifications	Construction can be accomplished with no modifications
		Boat uses complex curvature	N/A		Boat does not use complex curvature
	Steering Assembly	Assembly mounting holes not provided; mount not sturdy	N/A		Assembly mounting holes provided; mount sturdy
		Assembly not located at least 6" above <i>load</i> waterline	N/A		Assembly located at least 6" above <i>load</i> waterline
	Propulsion Motor	Motor Mount not provided; mount not sturdy	N/A		Motor Mount provided (as required); mount sturdy



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CALCULATIONS PACKET					
JUDGING CRITERIA		Poor (0 pts)	Fair (6 pts)	Good (12 pts)	Excellent (18 pts)
COMPLETENESS	Completion	Teams used outside methods to complete calculations	N/A		Teams used currently provided material to complete calculations
	Freeboard	Freeboard not met at any length of the boat/freeboard less than 4”	Freeboard met at one end of the boat/freeboard is at least 4”	Freeboard met at one end of the boat/freeboard is at least 5”	Minimum freeboard conditions met along the entire length of the boat
	Cleanliness	Many (5+) calculations cannot clearly be followed or read	Some (3-4) calculations are difficult to follow or read	Few (1-2) calculations are difficult to read or follow	Calculations are provided in order; easy to read and follow
	Units	Units are not provided	Some units are provided	Most units are provided	Units included
	Weight & Center of Gravity	(3+) errors of the following: piece/part/component /payload missing, payload not separated as directed, does not match loading diagram	(2) errors of the following: piece/part/component /payload missing, payload not separated as directed, does not match loading diagram	(1) error of the following: piece/part/component /payload missing, payload not separated as directed, does not match loading diagram	Weight spreadsheet complete; payloads separated as directed; matches loading diagram
	Displacement & Draft	Calculations are not provided	Some calculations are provided	Most calculations are provided	All calculations are provided
	Buoyancy	Calculations are not provided	Some calculations are provided	Most calculations are provided	All calculations are provided
	Stability	Calculations are not provided	Some calculations are provided	Most calculations are provided	All calculations are provided
	Trim	Calculations are not provided	Some calculations are provided	Most calculations are provided	All calculations are provided



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CALCULATIONS PACKET					
JUDGING CRITERIA		Poor (0 pts)	Fair (6 pts)	Good (12 pts)	Excellent (18 pts)
ACCURACY	Weight & Center of Gravity	Calculations are not accurate	Calculations are not accurate within 30-50%	Calculations are accurate within 10-20%	Calculations are accurate within 10%
	Displacement & Draft	No evidence of iterations	(2) errors of the following: too few areas taken for complexity of hull, last iteration not carried out to improve accuracy	(1) error of the following: too few areas taken for complexity of hull, last iteration not carried out to improve accuracy	Iterations carried out to accuracy; plentiful areas are taken; waterplane area matches the one on the table, displacements match
	Buoyancy	Calculations are not accurate	Calculations are not accurate within 30-50%	Calculations are accurate within 10-20%	Calculations are accurate within 10%
	Stability	Calculations are not accurate	Calculations are not accurate within 30-50%	Calculations are accurate within 10-20%	Calculations are accurate within 10%
	Trim	Calculations are not accurate	Calculations are not accurate within 30-50%; trim not reworked to minimize error	Calculations are accurate within 10-20%; trim not reworked to minimize error	Calculations are accurate within 10%; trim minimized to increase accuracy



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DESIGN					
JUDGING CRITERIA		Poor (0 pts)	Fair (3 pts)	Good (6 pts)	Excellent (9 pts)
COMPLETENESS	Creativity	Design is unimaginative; replica of previous entry	Design simply fulfills requirements; copies previous entry	Design shows creative approach; inspired by previous entry	Design is unique, creative, inspired
PAYLOAD			N/A		



APPENDIX G: TEST PHASE JUDGING RUBRIC

JUDGING CRITERIA	2 Points	4 Points	6 Points	8 Points	10 Points
WEIGHT (Unloaded)	Weight calculations were accurate within 25%	Weight calculations were accurate within 20%	Weight calculations were accurate within 15%	Weight calculations were accurate within 10%	Weight calculations were accurate within 5%
CENTER OF GRAVITY (Unloaded)	Center of gravity calculations were accurate within 25%	Center of gravity calculations were accurate within 20%	Center of gravity calculations were accurate within 15%	Center of gravity calculations were accurate within 10%	Center of gravity calculations were accurate within 5%
DRAFT (Loaded)	Waterline calculations were accurate within 25%	Waterline calculations were accurate within 20%	Waterline calculations were accurate within 15%	Waterline calculations were accurate within 10%	Waterline calculations were accurate within 5%
RACES	POSITION	1 st Place = 20 pts 2 nd /3 rd /4 th Place = Scalable based on race time compared to 1 st Place			
	PENALTY	Striking a buoy (with either the boat or the oil rig) will result in a 10 second addition to race time. The penalty can be incurred each time a buoy is struck.			
	BONUS	There are no bonus points available for this year's race.			



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GLOSSARY

The illustrated glossary can be downloaded from:

<https://communities.sname.org/designcompetition/glossary>