2024

TasNetworks

Tasmanian Model Solar Challenge, version 3, August 2024

TMSC Boat Kit Instructions

A Brief Introduction

With the support of Tas Networks there's again a free, entry-level kit of parts available to help schools and individuals starting out in the 2024 solar boat challenge. It provides all the basic materials needed to get an entry together at next to no cost.

The aim of the competition is to design and build a model solar powered boat to travel along a purpose-built race pool in the shortest possible time.

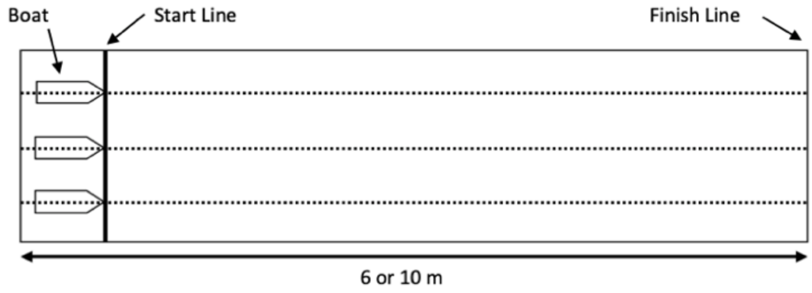

Figure: The competition pool will have 2 or more guide lines for boats to follow and race side by side

These instructions will provide some information to assist you. It's recommended that students, teachers, parents and other mentors have a bit of a read-through before getting started.

Model solar boats are typically made from a lightweight and buoyant material and a block of Styrofoam or XPS has been included as part of this year's kit. Teams don't need to use this and are free to consider a range of other materials such as foam trays, balsawood, recycled polystyrene, plastic bottles, milk cartons, etc. You're also able to make modifications to the kit components or use only certain parts in your overall design.

A short video clip of a top performing boat made from this kit can be found at the following link:

www.facebook.com/tassolarchallenge/posts/pfbid0NfSayT7Z88s1owzMAJz74SJT74x6i3WAjpA8ySMHQX5vtsbqoGjtKd2rXUkJbuXhl

Rules

The main rules for 2024 are:

- There are two age divisions. One for children up to Yr6 and the other from Yr7-Yr12.
- Boats cannot be any longer than 550mm long and wider than 300mm.
- The cell area of the solar panel must be no greater than 350 sq cm.
- Boats in the primary school division must use a motor costing $10 AUD or less. There's no cost restriction in the secondary school division.
- Boats must have a way of following the pool guide wires. Each lane will have its own line suspended at 200mm above the water surface.

Please download the full set of rules for this year's boat event from:

www.tassolarchallenge.org/regulations/

For younger students it might simply be a case of completing a boat that will make it to the finish line. Older students will be better equipped to attempt some more advanced designs and really aim to push the limits in performance.

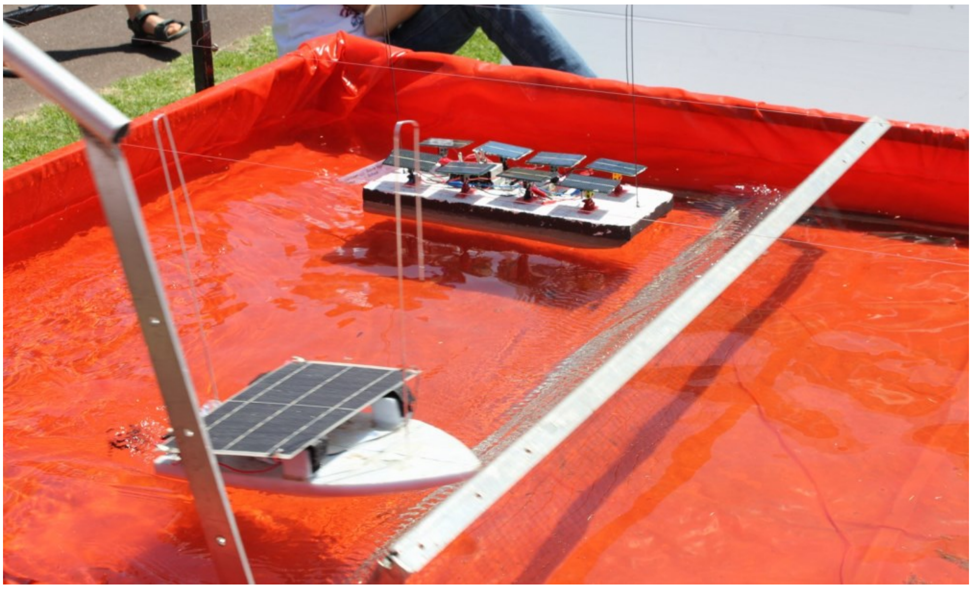

Figure: A couple examples of boats shaped from styrofoam or polystyrene

A Few Quick Design Considerations

Some of the key areas to take into account when designing a model solar boat include:

- Hull Type - Planing vs Displacement Hulls. Planing hulls are intended to skim over the water and are capable of obtaining faster speeds at higher sun/power levels. Displacement hulls push water around the boat and are more efficient at lower sun/power levels.
- Buoyancy - The boat must be able to support its own weight, including the solar panel, without sinking.
- Surface Finish - A smooth, water-resistant hull will help reduce boat drag.
- Weight - Boats that weigh less accelerate more quickly and are faster due to displacing less water or taking less power to plane.
- Shaft Angle - The angle of the propeller shaft determines how much thrust goes into lifting the boat up out of the water and how much drives it in the forwards direction. There will be a balance between the two that optimises boat performance.
- Solar Panel Angle - Solar cells produce the most power when facing the sun at 90 degrees. Tilting the panel may give a power advantage but can also make the boat less stable or catch more of a headwind to slow it down.
- Solar Panel Shading - Accidentally shading even a small section of the solar panel can drastically lower its total power output.
- Stability and Weight Distribution - More stable boats are less likely to roll over and sink. An unbalanced boat that’s too nose or tail heavy will affect how it performs.

We’ll cover a few of these points again in a bit more detail later on. Please also consider checking out the TMSC Facebook page to find plenty of examples of boats from past events at:

www.facebook.com/media/set/?set=a.752439693343840

Kit Components

This kit contains many similar components to the JUNIOR SOLAR BOAT KIT available from Scorpio Technology ($35.60). In fact, we even include a Scorpio SM403 motor due to its excellent performance for under $10 (the cost limit in the primary division). We also use light weight carbon fibre rods instead of the heavy steel ones from Scorpio.

A list of included parts is given below. You'll become more familiar with these as you go through the kit and start building your boat.

- 1x Styrofoam/XPS block
- 1x SM403 solar boat motor
- 1x Yellow plastic propeller shaft tube
- 1x Carbon fibre propeller shaft with 2-bladed propeller
- 1x Silicon rubber coupling piece
- 2x Carbon fibre guide poles

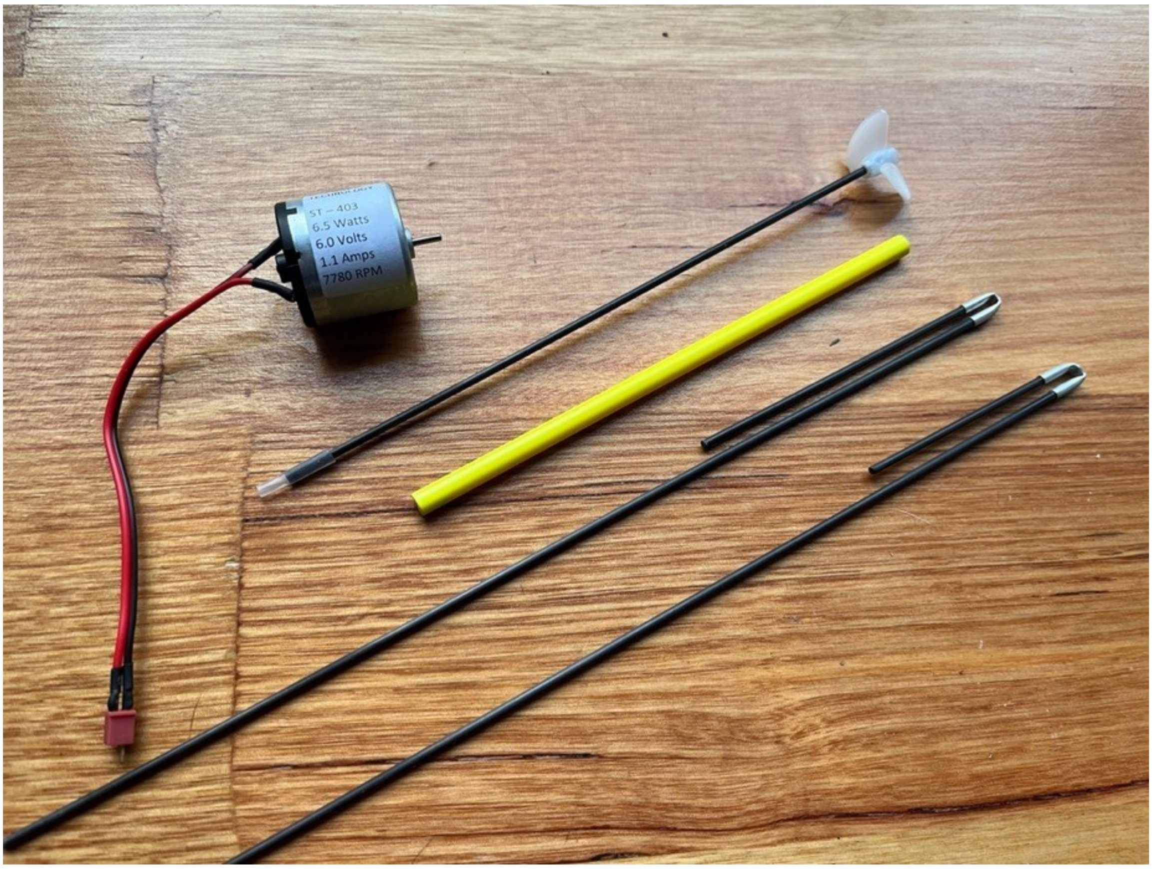

Figure: A layout of the key components included in the TMSC boat kit

A small solar module (not shown) may also be included as an example but not intended to be used for racing. This module can be connected to the motor and should provide enough power to make it spin in bright sunlight.

Please contact us at the Tasmanian Model Solar Challenge if you need any extra bits and pieces and we'll see what we can do to assist. If we don't have what you need then we'll provide some direction on where to go.

Some Additions

Each kit contains all the basic components required to build a model boat but doesn't include the full-sized solar panel for racing. But you don't necessarily need your own to participate at the Tasmanian event. Please read on for a bit more information.

Solar Panel

Many different solar panels were once used in the first boat events across Australia. Teams were measuring and making up their own panels by sourcing and combining smaller modules, even bare solar cells. The goal was to produce the lightest and most powerful solar panel while keeping the active cell area under 350sq cm (the limit in the rules).

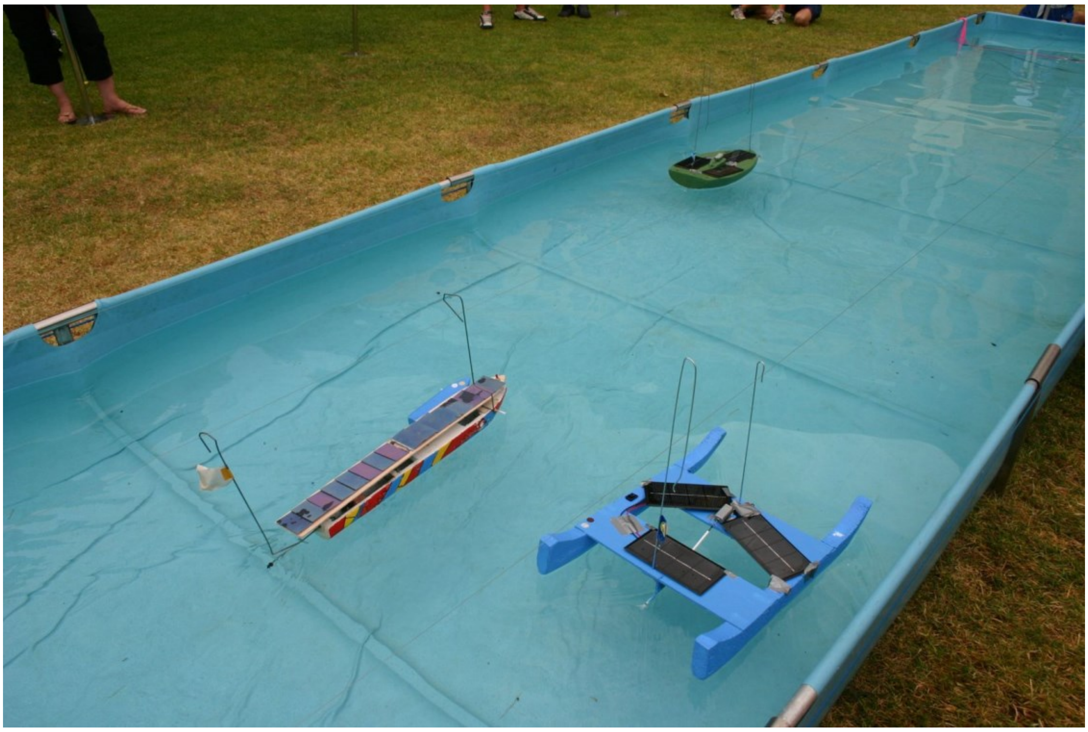

Figure: Examples of some different solar panels that teams used to race with

These days Scorpio Technology in Victoria offer a solar panel that's been specifically designed for the solar boat competition. This is the SOLAR26 from their Solar Challenge Catalogue at the following link:

https://static1.squarespace.com/static/556646a4e4b0bda793faf918/t/66df9b464705256b544fc6de/1725930337939/2024_Solar_Catalogue_Sep24.pdf

These are made using high efficiency solar cells which are then encapsulated between a pair of very thin fiberglass sheets for protection. The panels are approximately 250mm long x 160mm wide and weigh no more than about 50g. The only way of topping their performance would be to construct your own from even higher efficiency cells and backing them onto something that weighs less. It's certainly possible but any gains may only end up being marginal. Teams are instead advised to first refine all other aspects of their boat.

Teams competing in the Tasmanian competition will have the option of either:

1) Using a SOLAR26 solar panel provided by event organisers on race day or
2) Purchasing and using their own panel of which the SOLAR26 is the recommendation

SOLAR26 panels are priced at $111.50 in 2024 and so costs can escalate very quickly for schools building several boats. It's for this reason that we're helping supply panels for participants to share and use on race day. An example of such a panel is pictured below.

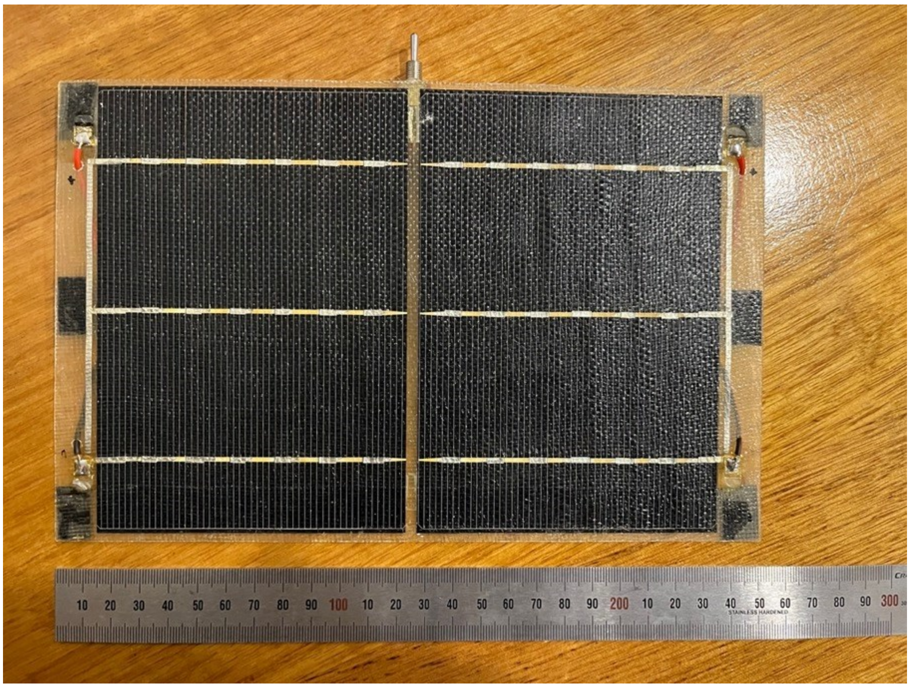

Figure: An example of the SOLAR26 solar panel that's provided on race day

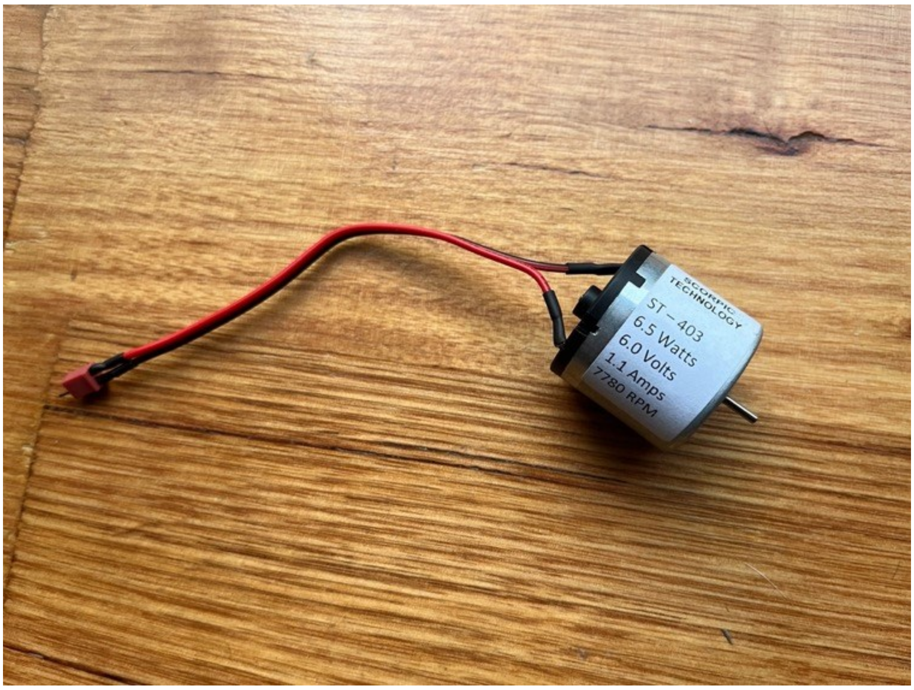

Figure: Older kits come with the SM403 motor wired to a micro deans connector. Newer kits come without any wiring and have spade connectors attach on to the motor terminals.

The panels provided at events come wired with either a micro deans or mini spade connectors for plugging directly into the motor in this kit. No soldering is required. Some further pics plus a few additional details can be found at the following facebook post:

www.facebook.com/tassolarchallenge/posts/pfbid0oDynako6J3jaE4HQX7y8EVXjn8xa2RC94uyfyX2z1tEKfaqVM7jivWBJapzb8XEfl

Motor Upgrade

The winning boat from last year's secondary division still raced with a kit motor. This doesn't mean that a better motor wouldn't have improved its performance but clearly demonstrates that design and build quality are by far the most important factors in determining how your boat is going to go. Top primary school boats will regularly outperform many high school entries even though they're using a much lower cost motor.

There are plenty of options for older students wanting to consider upgrading their motor. The most common one used is the 6V Faulhaber 2232 due to it being readily available from Scorpio Technology ($127.28). This is the top performing motor in the solar car competition but also does extremely well in the boats. It's a highly efficient motor that's been manufactured from the best materials and to very exact tolerances in Germany.

Electronics Maximiser

An electronics controller, often referred to as a maximum power point tracker, maximiser, optimiser, or starting-current multiplier, can drastically improve the performance of a model solar car. These boards help deliver more power to the motor at a greater range of loads and shaft speeds which is particularly useful during car acceleration from a standstill.

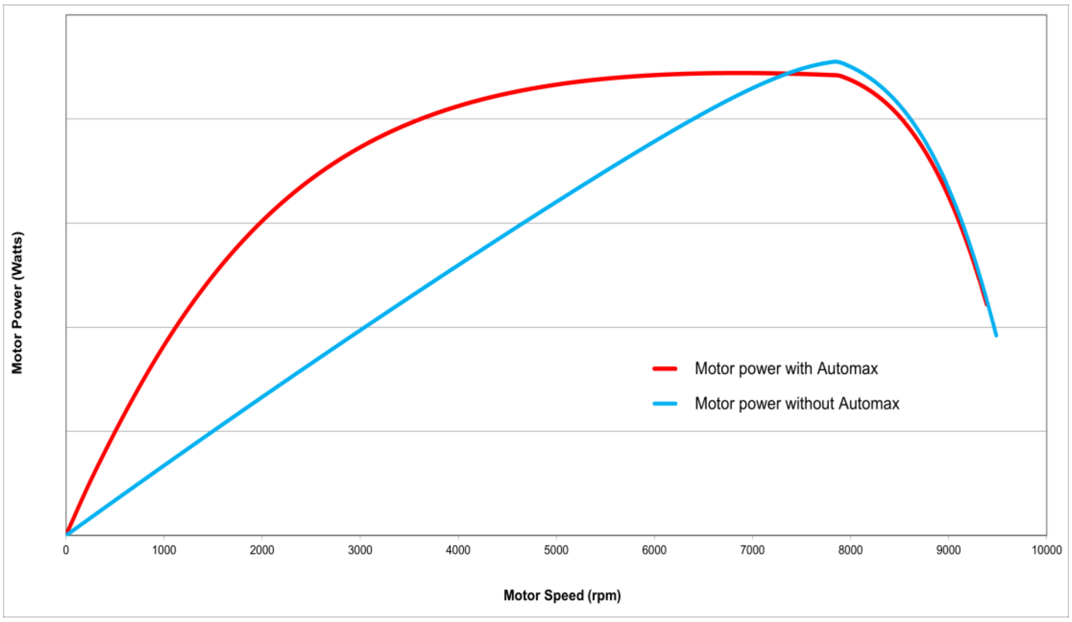

Figure: An electronics controller like the Automax isn't 100% efficient but can deliver more power across a greater range of motor speeds

The effectiveness of such a controller is however less clear in the boat event since top speeds are reached much more quickly and there's also a lot less load being placed on the motor at the start line (the propeller is already free spinning in the water). The added weight of such a controller is also much more significant in relation to the overall weight of the boat (<300g) compared with the cars (>700g).

Adding a controller may be a bit advanced for younger participants but high school teams might like to investigate this a little further, especially if a motor like the Faulhaber 2232 is also being used. There are a couple of options we recommend from Scorpio Technology and they are as follows:

1) The Automax ($127.36) which comes fully assembled and continually tracks the maximum power point of any connected solar panel.

2) The Picaxe 08M2 Solar Panel Controller which must first be self-assembled and soldered together but costs much less ($29.15) and weighs a bit less too. It's a great lower cost alternative and provides students with an additional learning experience in electronics and circuit board assembly. Just be sure to ask Scorpio to send you the pre-programmed Picaxe chip unless you're interested in playing around with loading the program onto the microcontroller yourself.

Figure: Scorpio's two electronic controller recommendations

Tools Required

Some of the basic tools recommended to assist you in completing your boat are as follows:

- Paper, ruler and a pencil/pen/marker
- Scalpel or stanley knife
- Sandpaper
- Hot glue gun and glue sticks
- Scissors
- Serrated knife (ie steak or bread knife) or hacksaw
- Scales - to compare materials and weigh your boat

Other more specific equipment may be required depending on the choice of hull material/s and complexity of design. For example, a hot wire foam cutter may make it easier to cut and shape a hull made from styrofoam or polystyrene. A 3D printer may be used to make up specialised parts like motor or guide pole mounts, etc.

Teams choosing to race with their own solar panel or use a different motor will likely also require some soldering equipment to wire everything together.

Kit Assembly

In this next section we'll take a look at how the kit parts go together. Knowing this you'll then be able to have a think about how to include them as part of your own design.

A quick overview of the entire setup is given in the example below:

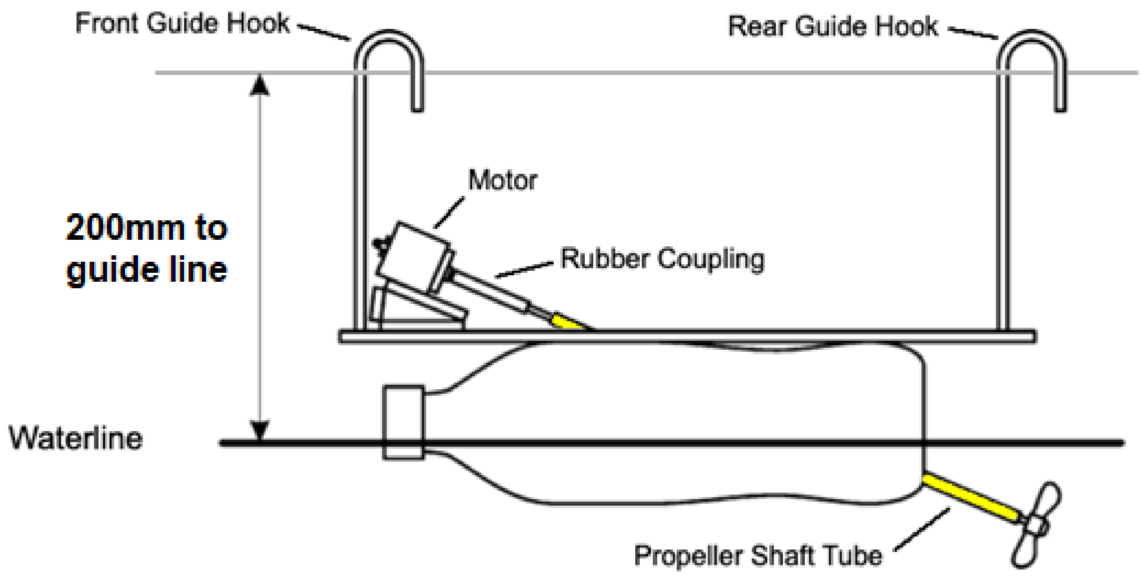

Figure: The kit as part of a recycled bottle-based design

Yellow Shaft Tube

The yellow tube in the kit has had a short white plastic bush inserted at each end. This helps reduce friction as only the very ends are then in contact with the spinning propeller shaft.

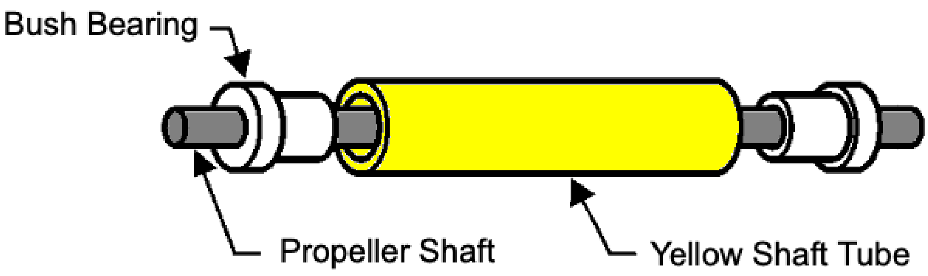

Figure: A diagram showing an exploded view of the guide tube with bush inserts

This then needs to be fitted to your boat in such a way that ensures the propeller ends up being submerged in the water. A thin wooden skewer is often enough to make a guide hole through the bottom or rear of any polystyrene or styrofoam-type designs. Balsawood or plastic will need a scalpel or knife to cut a hole or slot for the tube to pass through. Whatever the design, fit this yellow tube in place once you're happy with the angle and position. Some hot glue should do the trick at holding it in place.

Figure: An example of the yellow tube pushed through the back of a styrofoam hull

Make sure that the tube remains perfectly straight. Any bend will start applying pressure on the propeller shaft and affect how easily it can spin. Also be careful if you plan on shortening the tube. You'll need to insert a new bush where you make the cut or the shaft will otherwise wobble around and have far too much play. You can either try to recover the white bush out of the section that's been cut off or contact us about getting a replacement.

Propeller Shaft

The propeller shaft consists of a 2.5mm diameter carbon fibre rod. This is significantly lighter than the steel rod supplied in Scorpio's JUNIOR SOLAR BOAT KIT and will help reduce the weight of your boat.

The shaft is approximately 80-90mm longer than the yellow guide tube. This should give plenty of length for the propeller to reach the water. Teams interested in shortening the shaft can easily do this by removing the silicon coupling and making a cut. Younger students may require an adult to help them with this.

Use a fine-bladed hacksaw, serrated knife or even a Dremel cutoff wheel but avoid pliers or side cutters as these will crush and split the carbon fibre. Clean the end up with some sandpaper or a file after cutting.

Any cutting or sanding of carbon fibre should also be done in a well-ventilated area outside or under an extraction fan in a workshop. Consider using a dust mask to help reduce the risk of inhaling any airborne carbon particles.

The forward thrust and vertical lift created by the propeller will vary according to the angle of the shaft. The diagram below shows how the magnitude of these forces will change with angle.

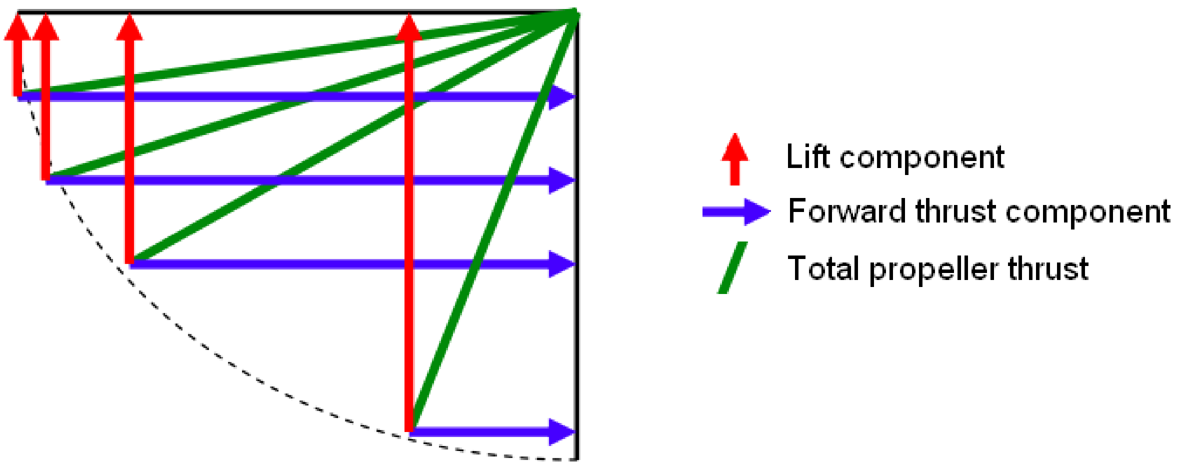

Figure: Lift and forward force will vary with the angle of the propeller shaft (green line)

Looking at this you may come to the conclusion that a perfectly horizontal propeller shaft gives the most forward thrust. This is technically correct but how would it be implemented without submerging or dragging the motor through the water? A small angle is instead more practical and only slightly reduces the forward thrust. Some lift can also be beneficial and assist with planing. Teams may like to experiment with a few different angles and determine what works best for their particular design.

Propeller

A 2-bladed propeller is included and comes fitted to the shaft. These are sourced from either Scorpio or direct from China and both versions give almost identical performance. Kits that include a pre-wired motor should see the propeller spin in the correct direction when using one of our event solar panels. If not, this is easily fixed by switching around the polarity of the motor terminals, plug or by using one of our quick-fix adapters available on race day.

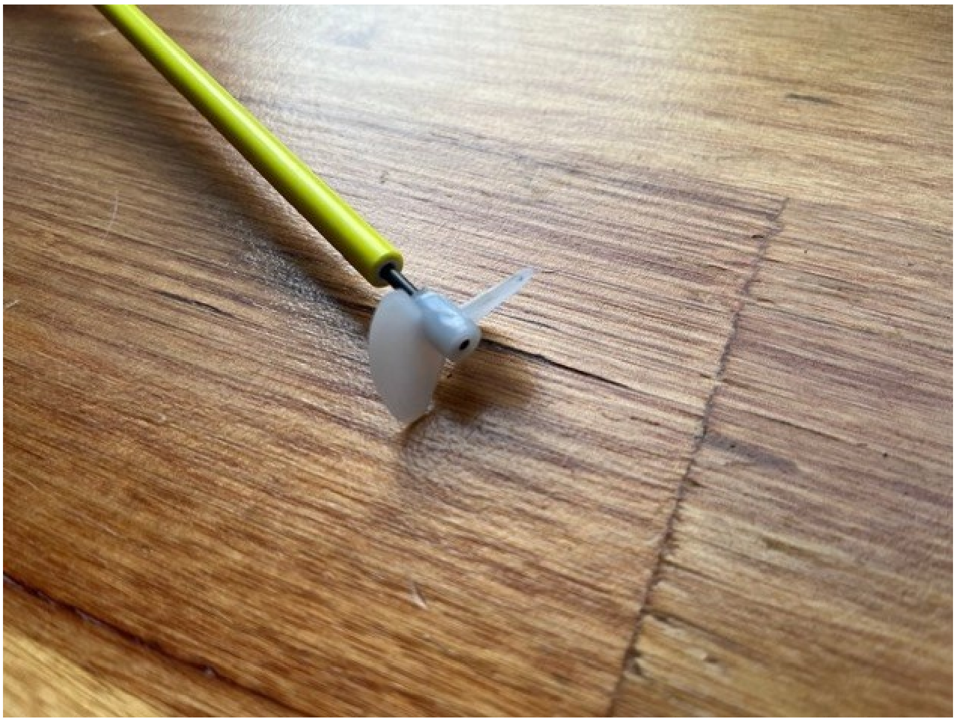

Figure: Each kit is supplied with a 2-bladed nylon propeller

The kit propellers give some great baseline performance and many top boats have used these in the past. Better options are almost certainly out there but we'll leave this up to you to investigate. Ian Gardner in Victoria has performed static thrust tests on various props and this is the first bit of data we'd recommend having a look at. Please contact us for some more details on this.

Figure: Just one example of an almost countless number of other model boat propellers

Shaft Coupling

A short piece of silicon tube is supplied. This connects the motor and propeller shafts together and provides sufficient grip strength without any slippage.
Teams using a different motor and propeller combination, a gearbox or an electronics maximiser may need to consider switching to a more rigid or even solid coupling capable of withstanding higher turning forces.

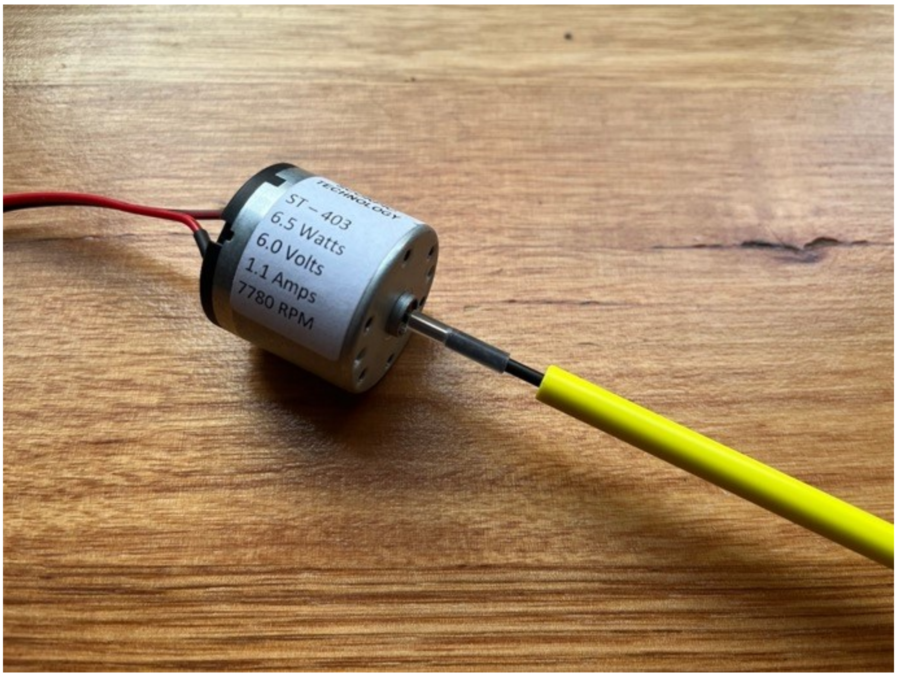

Figure: A short piece of silicon tube connects the motor and propeller shafts together

The two shafts must be perfectly aligned to minimise any power loss. Shaft misalignments or shafts at different angles should be avoided if possible.

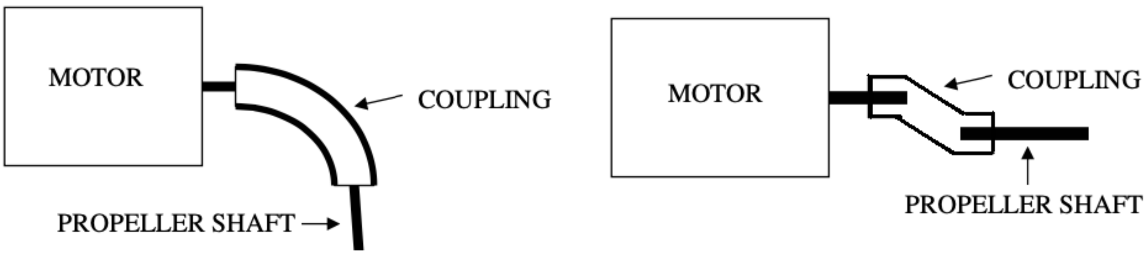

Figure: Two examples where shafts have not been aligned

Motor

The kit motor weighs approximately 80g. This is the single heaviest component and will make up a significant proportion of your overall boat weight. Placing this too far forward or too far back can make your boat nose or tail heavy. Teams often try to correct any imbalance by adding counterweights as an afterthought. Looking through photos from past events on facebook you'll notice numerous boats with large nuts, washers or even coins added for balance.

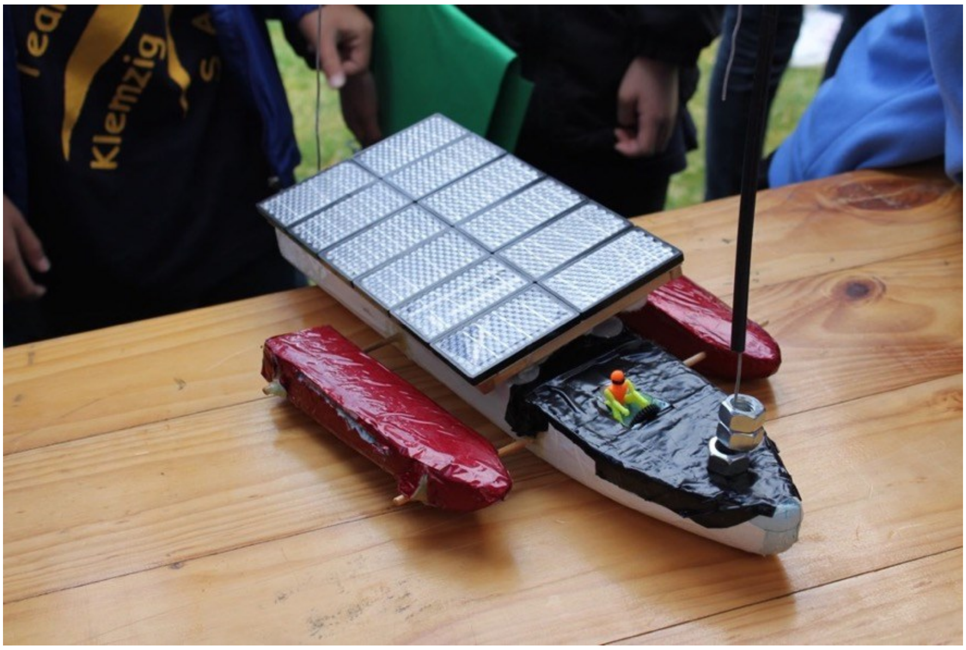

Figure: An example where several large nuts have been added as a counterweight

Any added weight like this should be avoided at all costs if you want to make your boat as light and fast as possible. It's recommended that teams consider the balance of their boat at a time when it's still easily adjusted during the build process. Sit your boat in a sink or tub of water and move the motor around before deciding on its position.

There are several ways to secure the motor in place on your boat. Perhaps the easiest and most common method is by hot glue. This works well but doesn't allow the motor to be moved or adjusted unless breaking it loose again. Another option might be to instead attach it to a motor mount by tape, cable ties, rubber bands, etc. This mount can then be fixed in place but the motor itself still be removeable and free for some adjustment.

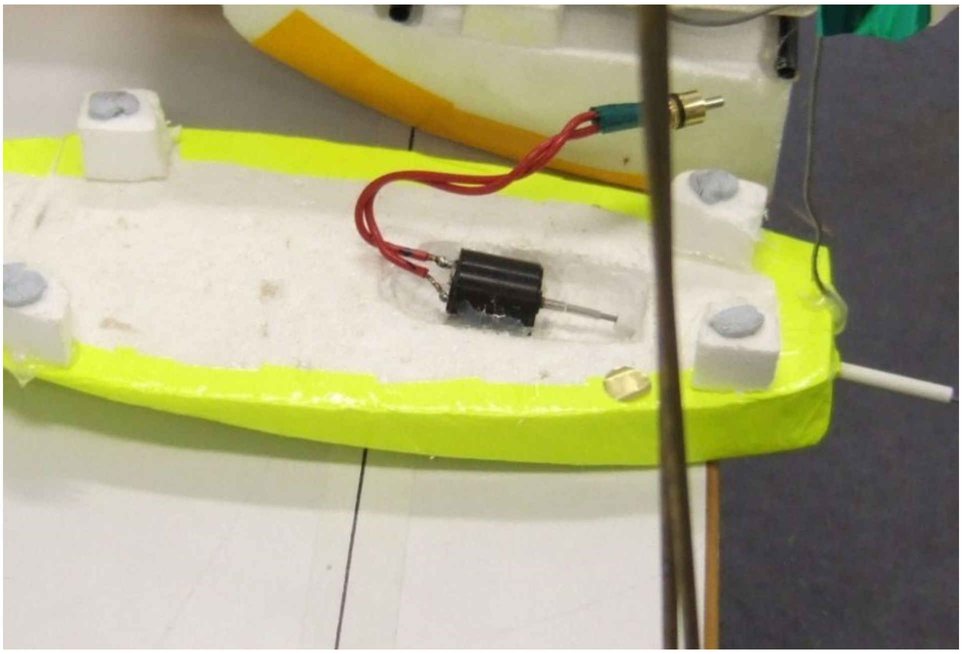

Figure: A small amount of hot glue might be all that's needed to seat and hold the motor in place

Guide Poles

2x guide poles are provided in the kit. These are made from the same 2.5mm diameter carbon fibre rod as the propeller shaft. They need to be fitted to at least the front and usually also rear of the boat to help guide it along the length of the pool. The guide lines typically consist of fishing line spanned tightly between the pool ends at 200mm above the water surface.

Some designs may get away with just a single guide at the front of the boat. This would help save on some boat weight but needs to be tested. If it’s windy on race day then even one of these boats will likely need a pole at the rear or risk getting blown off course.

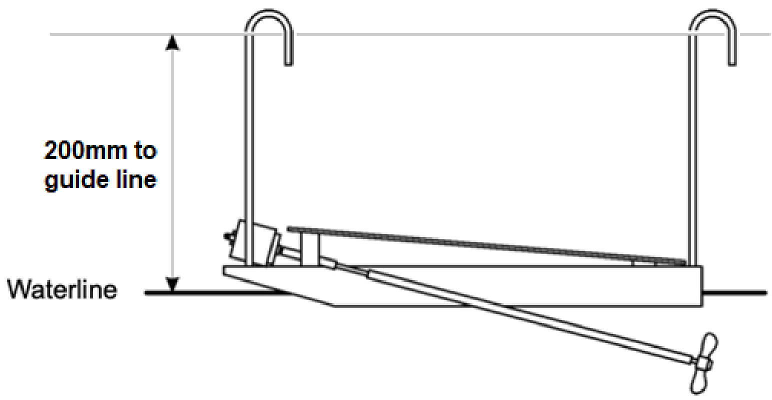

Figure: A boat diagram with front and rear guide poles attached

The poles come in 250mm lengths and teams may need to shorten them to suit their particular design. The front and rear may also need to be different lengths depending on where they’re attached and how the boat sits on the water. If the poles are left too long then the hook will end up being too high and cause the boat to lose its guide line. Too short and the boat will hang from the line, either slowing it down or preventing it from moving at all.

Figure: The hook at the top of the poles is intended to slip over the guide line

It’s recommended that teams only cut down and attach their poles after having completed the rest of the boat and tested how it sits on the water under full race weight. Teams may also need to allow for some possible further adjustment to account for different heights when the boat is in motion. For example, a boat that planes will likely sit higher on the water when racing. Poles can be cut down as per the propeller shaft with a hacksaw, serrated knife, Dremel, etc.

Have a bit of a think about how to attach the poles and whether these should be glued in place or made detachable. Removable guides will make the boat much more compact and easier to store away or transport. Just be careful that the hooks are attached rigidly enough to remain at 90 degrees to the guide line. You don’t want them twisting on the spot and act like a brake.

It can be a good idea to bulk up or add some extra material where the poles get attached. This makes the anchor points a lot stronger and more robust. Styrofoam designs might simply use some excess material that’s been left over when cutting the hull to shape. The following example shows a boat where the team has used a bottle cork.

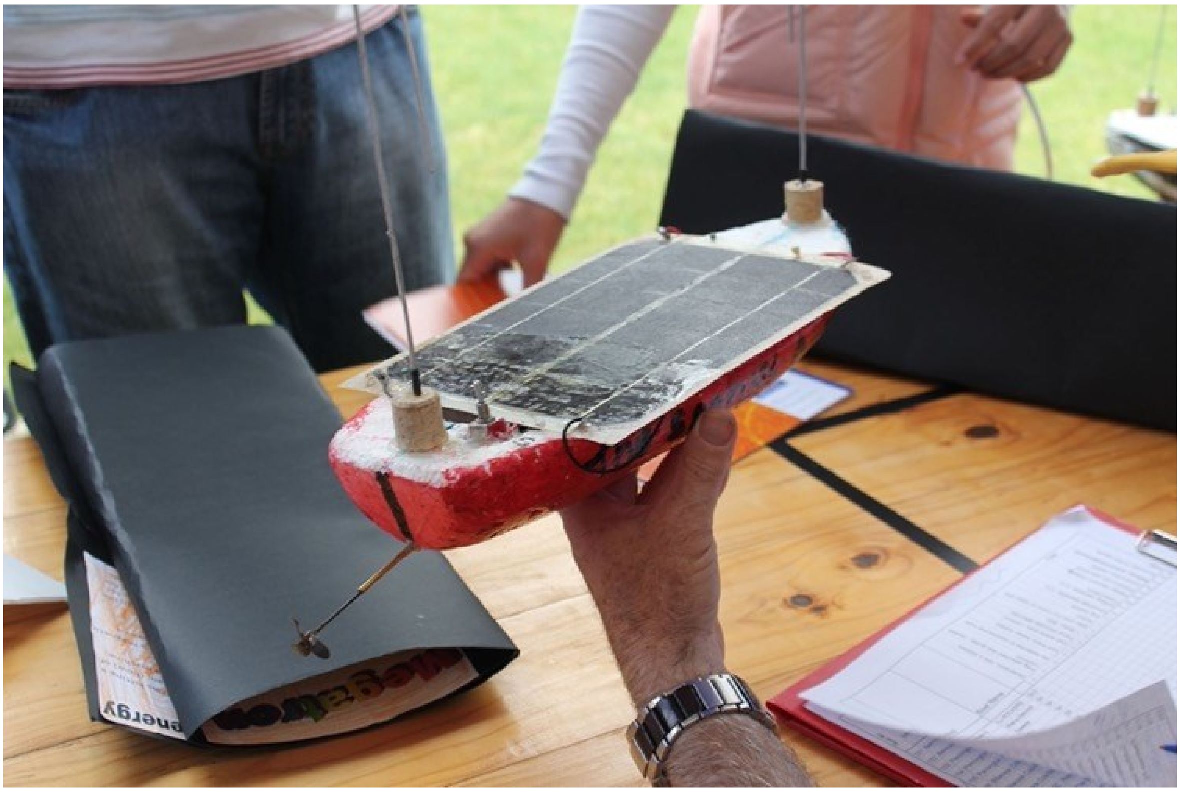

Figure: An example where a bottle cork has been used to help anchor the guide poles

Solar Panel Placement

A Scorpio SOLAR26 solar panel weighs approximately 50g. This isn’t quite as heavy as the motor but its placement still plays an important role. Teams may like to investigate shifting it around on their boat and seeing how this affects performance. Most panels are just held in place using velcro so it’s just a matter of moving the pads around.

If you don't have your own solar panel then it's recommended you cut out and use a piece of cardboard with the same dimensions (250mm long x 160mm). Add some weight so it ends up close to the 50g and one solution might be to simply tape on a few coins. This will give you something physical to work while building and testing how the boat sits in the water.

Many designs end up with the motor sticking up so there's no longer a flat surface for attaching the solar panel. This problem is usually solved by adding some support blocks to raise the panel as seen in the following pic:

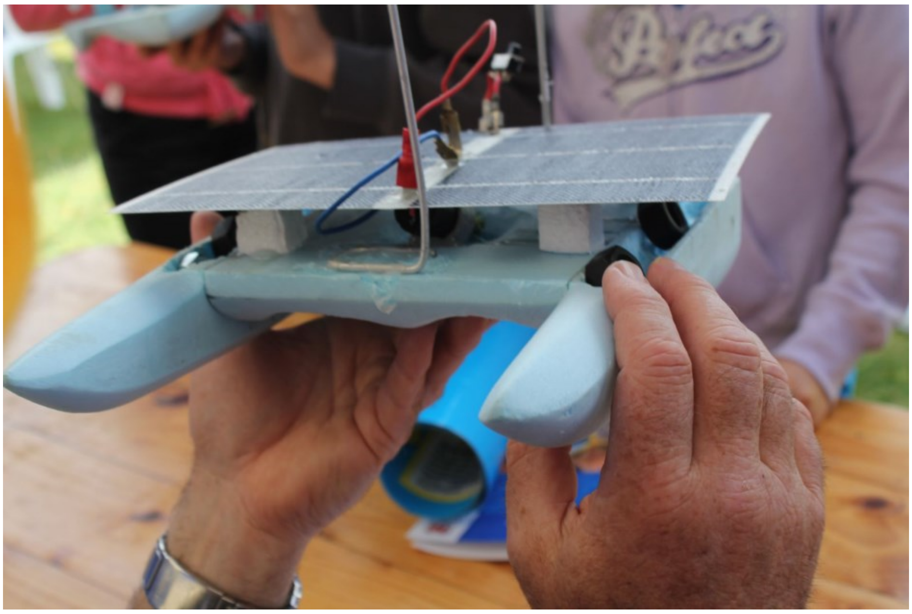

Figure: Extra blocks are often required to support the solar panel above the motor

Panel Angle and Shading

The competition requires boats to travel in a straight line and this means that the position of the sun isn't going to change during a race. It's sometimes possible to take advantage of this and tilt the panel towards the sun to produce more power. This would be most significant during earlier morning races when the sun is still lower in the sky and at more of an angle. Races at around mid-day will see very little benefit as the sun will then be almost directly overhead. Be careful as steep solar panel angles can raise your boat's centre of gravity and make it less stable. Panels can also act as a sail and catch the wind causing the boat to slow down or become unstable.

Teams should also be careful not to shade any part of the solar panel. Shading even a small section of the solar panel can drastically affect its overall power output. Designs should ensure that the only possible shadows being cast on the panel, if any, are those of the thin guide poles.

Hull Design, Weight and Materials

In the real world there are many different types of boat hulls. These have all been engineered for many different purposes but can generally be categorised as being either a planing or displacement type design. Teams are encouraged to do some research on various designs before starting on their solar boat.

Pure displacement hulls like canoes or large cargo ships are designed to move efficiently through the water at relatively low levels of thrust. The most efficient designs will have smooth rounded curves for least resistance and a minimal wake. How fast these can travel is largely governed by the hull speed equation and related to the waterline length of the boat. Speeds plateau around this point even with further increases in propeller thrust.

Planing hulls like speed boats are designed to generate lift and move the boat over the top of the water much more quickly. Parts of these designs tend to be less rounded and may even have steps to help with planing at lower powers. Such shapes however make them slower and less efficient at low speeds when planing isn't possible.

Planing requires a certain amount of power and flat bottom hulls typically require the least. Such hulls are most commonly seen on inland lakes, swamps and rivers where the water is generally pretty calm and flat. Most wilder, open-water speed boats are instead V-shaped for rider comfort and stability but this isn't much of a concern in the model solar boat competition.

The following video clip shows a solar boat race where planing occurs:

www.facebook.com/tassolarchallenge/videos/807747836993806/

Such boats can cover the length of the race pool in around 4 seconds in full sun. If there isn't enough sun then there won't be enough solar power for planing to occur. A displacement type design will instead be more efficient under these circumstances.

Weight is super critical in solar boat racing. Every extra 5-10g will slow you down and teams should be aiming to make their boat as light as possible. Top boats typically weigh under 300g including the 50g solar panel. A set of scales (ie electronic kitchen scales) are handy to compare weights when selecting materials and building your boat.

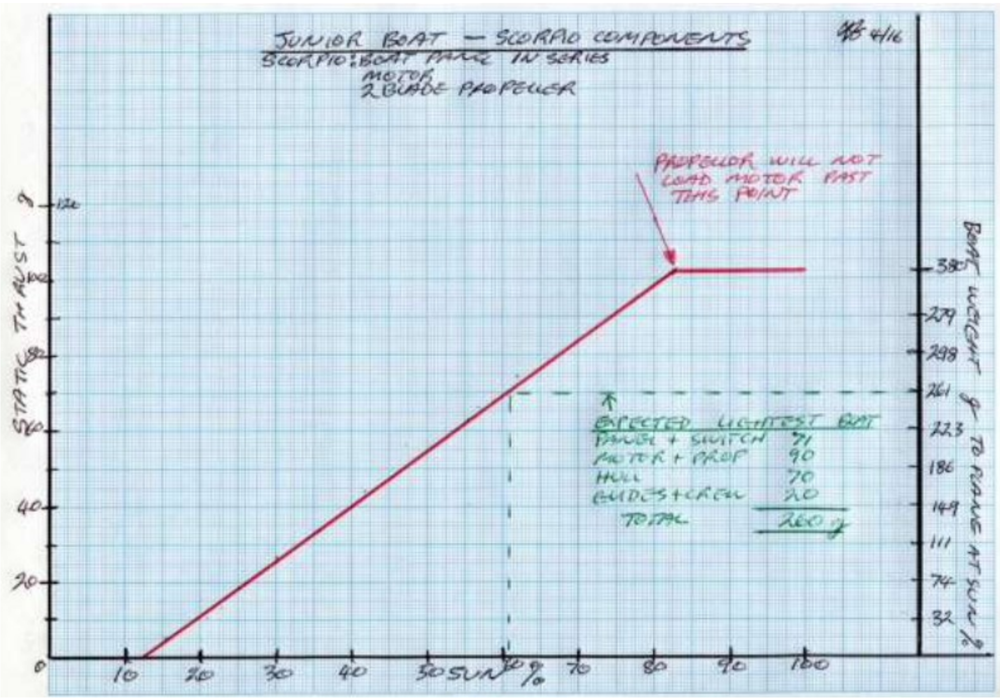

Figure: A plot relating how much sun % is needed for boats of different weights to plane.

The previous plot comes from a solar challenge expert in Victoria and looks at how boat weight affects the amount of sun is needed for it to plane. The lighter you can make your boat the less sun is required. The lightest expected boat comes in at 260g but something under 200g could even be possible using the components in this kit.

A common material currently used in the competition is Styrofoam or XPS foam and a block of this has been included for those receiving a kit in 2024. This originally comes in large sheets of various thicknesses and is generally used as an insulation product in the construction industry. You're free to shape and even hollowed out your block however you like. You can also cut it into strips to make a multi-hull design like a catamaran or trimaran.

If you require further blocks or a different size to what you've been given then please get in touch. You can source your own large XPS sheets from some Mitre 10 trade centres or grab a smaller one from Bunnings. They come in thicknesses of 25-50mm.
Scorpio Technology also stock conveniently-sized Styrofoam blocks if you're already doing an order from them anyway.

Another low weight option is the foam trays used for food packaging. These are most commonly seen in the meat section of supermarkets. Scorpio stock several sizes and the following example was made from a 14 x 11 inch tray. These "meat" trays are available from elsewhere but you'll normally need to buy them as a large pack of 50+ pcs.

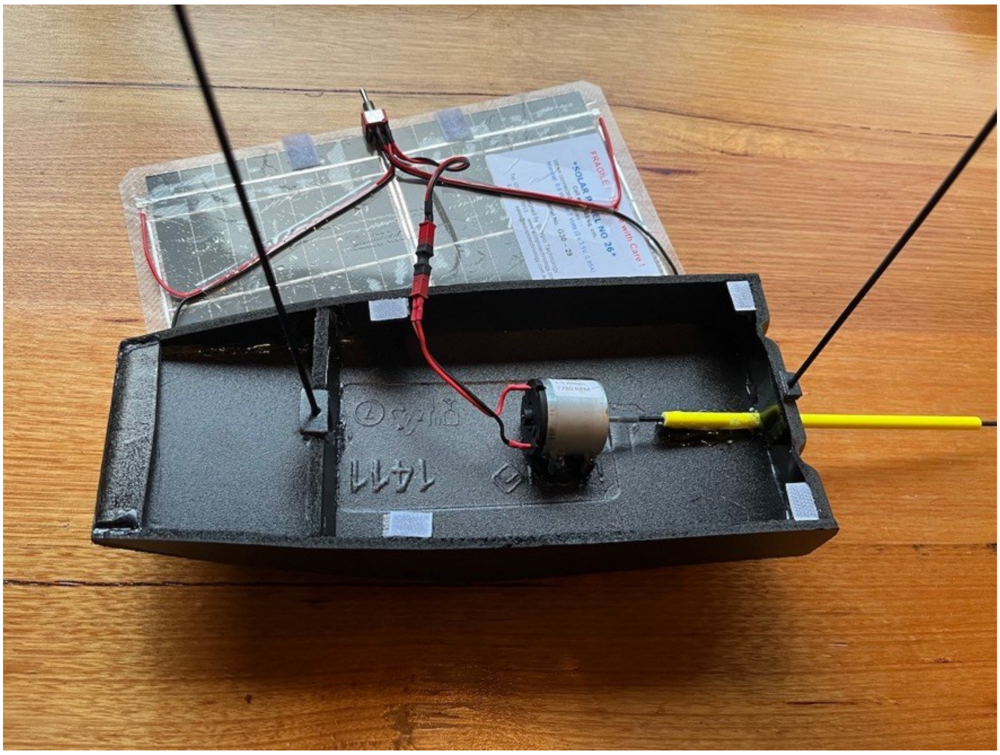

Figure: A 14 x 11 foam tray was used to make this example boat

Another couple of very light materials worth considering are balsa wood and depron. Recycled materials also offer a zero-cost option and there's often an award presented to the team that's made the best use of these. Polystyrene packaging is similar to Styrofoam but less dense and won't sand as well to give as smooth a finish. Plastic bottles may also be used in some more basic catamaran designs but a way of connecting the 2 sides will be needed.

Some materials require a special glue, waterproofing or coat of paint to give the best results. Styrofoam designs starting out as a larger block and being cut down, shaped and hollowed out will need very little glue whereas boats made from thin balsa or foam sheets will instead need more gluing but have much less excess waste material.

Hot glue will work well on a lot of materials to hold the motor down in place. Be careful as too much may however melt a hole in thinner sheets of foam.

<u>Solar Panel Wiring and Electronics</u> – Coming shortly in the next version update

Figure: Event panels include a series-off-parallel switch and plugs directly into all kit motors

<u>Testing</u> – Coming shortly in the next version update

<u>Summing Up and Further Help</u>

The main purpose of these instructions have been to give some background information and basic assembly instructions of the components included in the 2024 TMSC boat kit.

Some of the simplest boats can be put together in just a couple of hours while more complex designs will take much longer. For a bit of further information please head on over to the Tasmanian or Victorian websites or facebook pages. We can also send you a copy of Ian Gardner's Boat Design Guide which offers a comprehensive read for anyone wanting to get their teeth stuck into the more technical aspects of model solar boats.

Or feel free to contact us. We're more than happy to answer any questions about the rules, kits or anything else Challenge-related. We can sometimes even send someone along to your school if you need any extra help getting started.

Good luck with your boat and we look forward to seeing you on race day in Term 4!