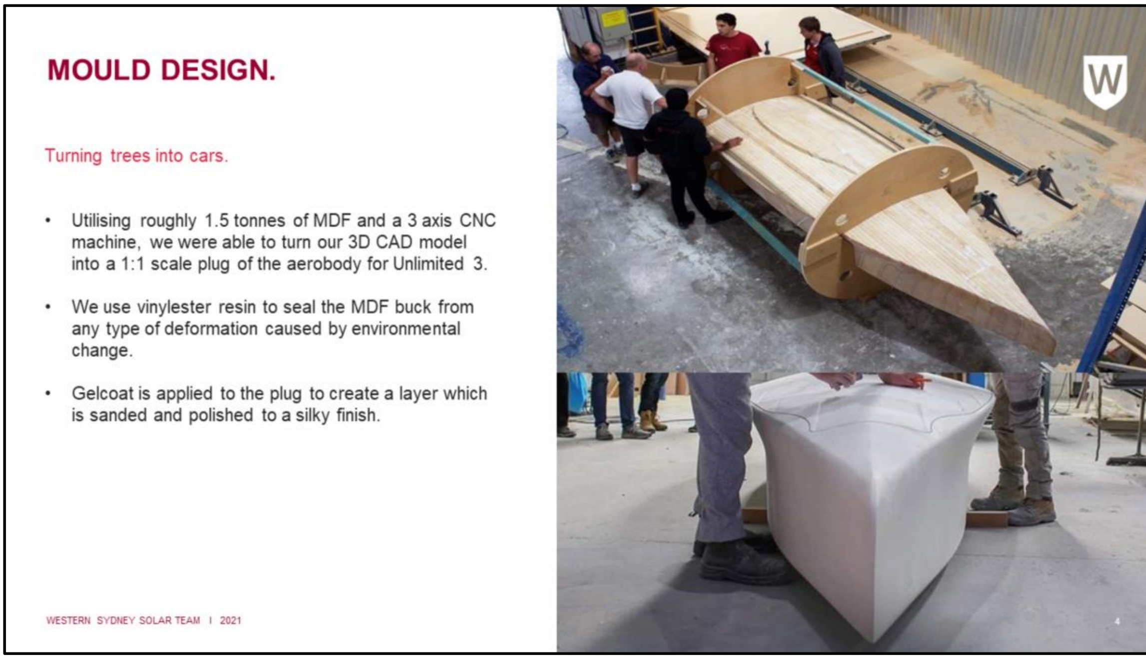
Composite Manufacturing | 2021
WESTERN SYDNEY SOLAR TEAM

Western Sydney University acknowledges the Darug, Eora, Dharawal (also referred to as Tharawal) and Wiradjuri peoples and thanks them for their support of its work on their lands (Greater Western Sydney and beyond).

We are Western Sydney Solar Team and our mission is to develop new innovations as well as leaders of the future to take a stand in the inevitable shift towards sustainable solutions. Our project is a multidisciplinary student led venture which encompasses all aspects including designing, manufacturing, and racing solar powered vehicles. We have a rich 10 year history and have placed top-in-class during the Bridgestone World Solar Challenge in 2017, 1st in the American Solar Challenge in 2018 and broke the record in 2019 for the lightest solar powered vehicle ever to race weighing only 116.8kgs.
Today, we want to embark on a deep dive into Composite Manufacturing with you.

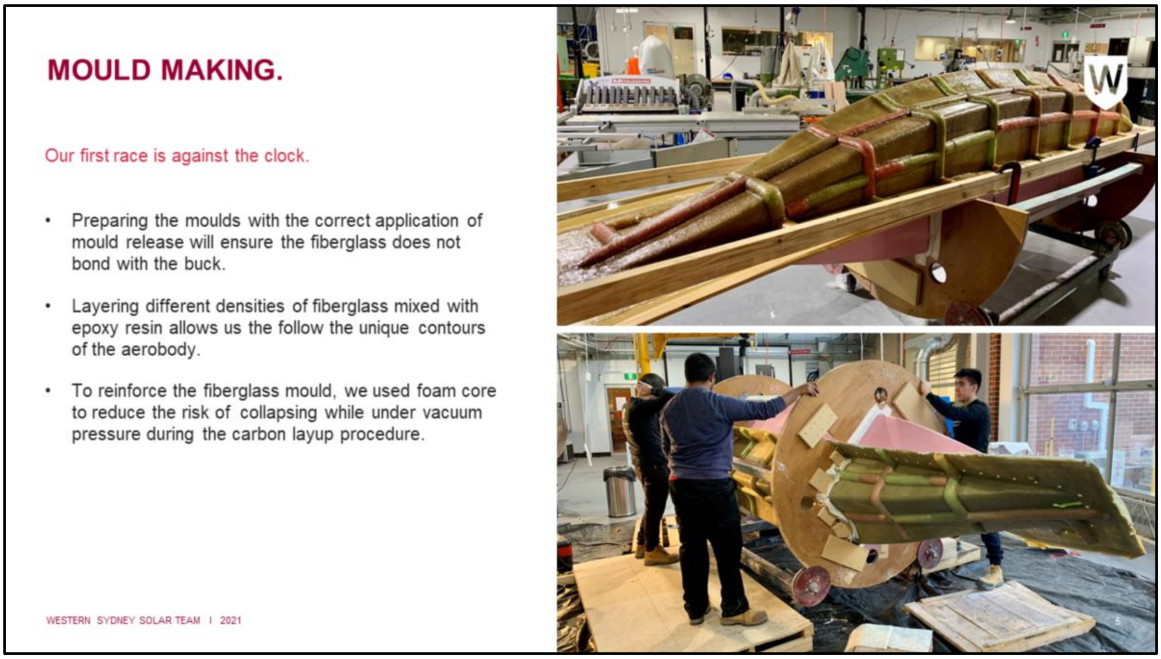
Composite materials are made from two or more different materials, and when their properties are combined, they are stronger than the individual materials by themselves. The most common form of composites are fiber-reinforced polymer composites (FRP). They are made from a polymer matrix, such as epoxy, which is then reinforced with an engineered fiber, such as glass, carbon and kevlar. The polymer matrix allows the fibers to be protected from environmental damage and its other critical purpose is to transfer the load between the fibers. This allows the fibers to provide strength and stiffness to reinforce the polymer matrix, reducing the likeness of cracks and fractures. By using these materials throughout our vehicle, we can engineer the car to have great tensile, shear, and compressive properties. As well as increasing the strength of our vehicles by using composites, we are capable of reducing the overall weight of the vehicle compared to alternative structural methods.



To make this first section comprehensive I'll refer to our Unlimited 3 vehicles aerobody – Essential just the external aerodynamic surface or, shell of the vehicle.

The first step to manufacturing TED 3's body was to use our computer generated design file and send it to a manufacturer to be CNC machined out of MDF. After this process was completed we were left with a 1:1 replica of the car. This is referred to as the tool or buck. From here, the MDF was coated with Vinyl Ester Resin to seal it from being exposed to the environmental changes in the air which could cause warping or swelling. Then, the buck was coated with gelcoat, a very similar paint to what's used in marine applications. The reason we chose to machine the plug out of MDF is because it is a cheap material to source and machines well.

In 2019 this machining process was sourced externally to the University as we did not have the resources to be able to machine such a large scale buck on campus. Thankfully, due to major upgrades to our Advanced Manufacturing Precinct, we will be able to perform this task on campus in future using our new Belotti 5 axis CNC. When outsourced, we use a 3 axis cnc which we're limited by how advanced the contours can be in our models, as the machine can only move in the x,y, and z axis. Due to this, the cost of the machining was quite high as you could only machine half the car on one side, and then the cnc would have to be stopped and re-loaded to machine the other side. Our new Belotti 5 axis cnc can cut along the x,y,z,a and b axis, providing us with the capability to create the majority of the car tooling in one go, no problems with contours that have a 90º overhang.



When we finish sealing the buck, we spray it with 2-3 thick coats of tooling gelcoat with added dye, generally red, or a bright colour. Once tacky to touch, we can start laying the fiberglass to the buck. It is imperative that we have pre cut sections of fiberglass to apply. As we layer the buck with these pre cut sections of fiberglass, we slowly apply epoxy resin and use specialised tools to knead the epoxy through the fibers. We only have a limited time to get this done before the epoxy starts to cure.

You may see something laminated inside the mould that looks suspiciously like pool noodles… and this is, well, pool noodles. We are a team on a tight budget, so we constantly have to innovate and this is all part of the day to day workings for us. Pool noodles were cut in half using a bandsaw and adhesive down, giving us a structure to lay more fiber glass over. This method was designed to increase material height, inherently increasing stiffness which is crutial.

PREPARING FOR LAY-UP.

Surface prep. Surface prep. And more surface prep.

- Being careful not to cut your fingers while you inspect the mould, fiberglass splinters are not fun!
- Be sure to clean all the space around you from dust particles before cleaning the moulds.
- Take your time applying mould release, ensuring that all inside surfaces have been covered.
- Prepare your carbon layup before doing the final surface prep of the moulds.

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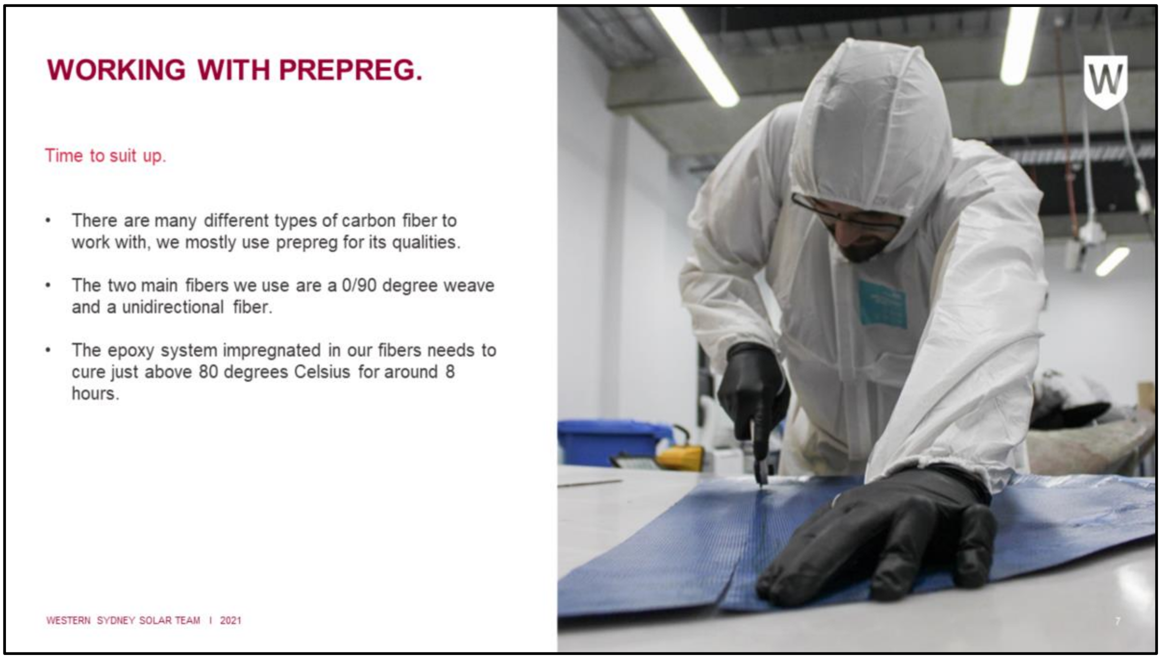
Once the mould cures, it needs to be pried off the buck. There are a variety of tools to use including PTFE wedges and air powered blasters. As you pull the mould off, you are able to see if there was any sticking thanks to that red or any bright coloured pigment used with the gelcoat.

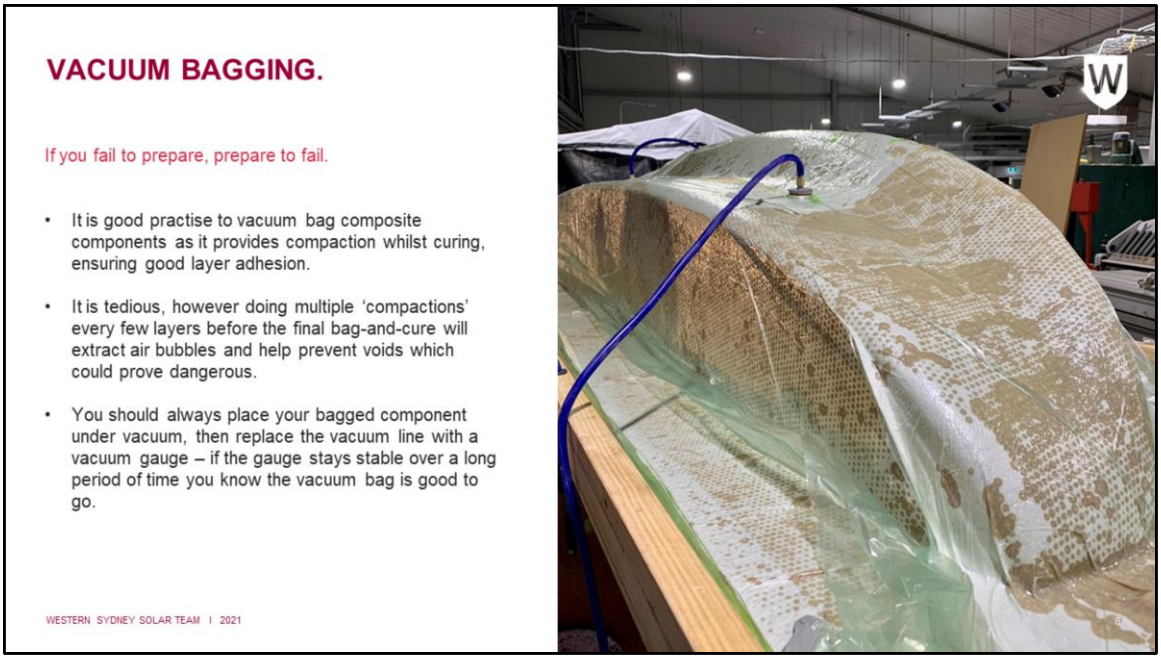
It is critical to inspect and repair any surface imperfections. Any slight swirls, cracks, scratches or chips due to voids will perfectly transfer onto the composite part you create from it. Once you have inspected and repaired any imperfections, the surface needs to be sealed and a release agent needs to be applied. We use two Loctite branded products to do this, B15 and 710NC. B15 helps seal the surface and acts as a bonding agent for the 710NC. Two layers of B15 are lightly applied using a lindt free cloth, leaving half an hour between each application. Then, 710NC is applied 6 to 8 times, only waiting for the product to ‘flash off’ between layers. After this process is complete, you are ready to move into the next phase.

Now that I have talked you through the tooling, mould design and preparation before use, I’d like to talk about the composites we use to create components.

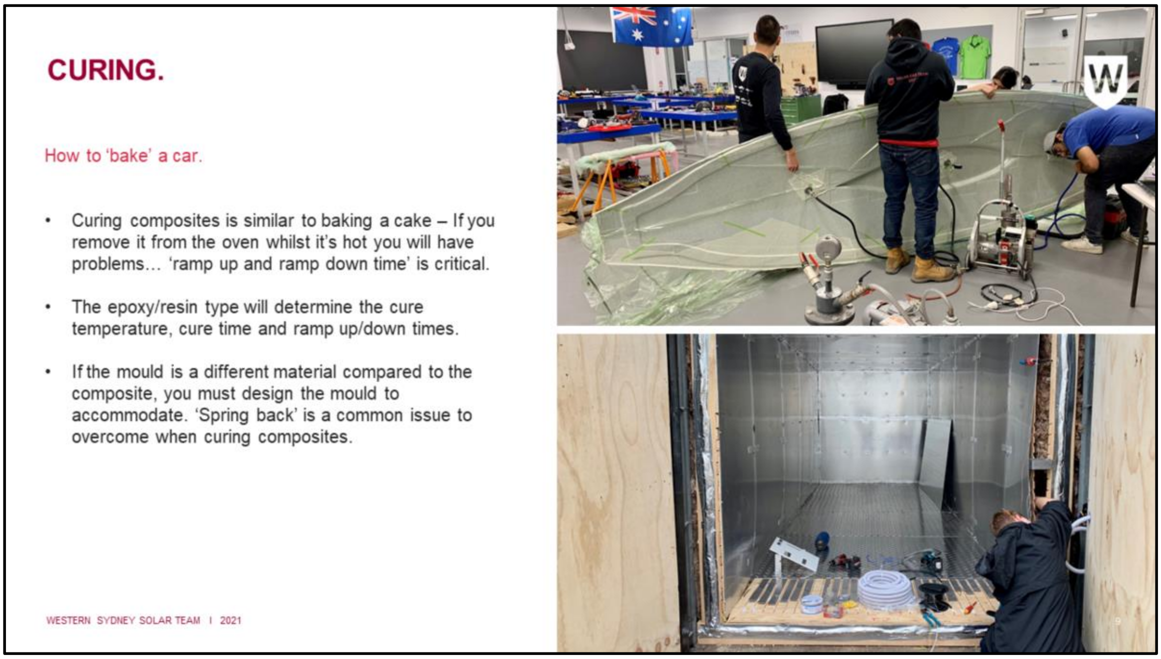


Carbon fiber is an incredible material and is highly regarded for its lightweight, high strength and chemical inertness. There are many different types of carbon fiber materials and manufacturing methods, but we mainly use two types; Pre-preg bidirectional and pre-preg unidirectional – Pre-preg means the carbon fibers are pre impregnated with the optimal amount of epoxy. This ensures that the fibers are at peak strength whilst remaining as light as possible. There is a range of core materials we use in conjunction with these pre preg carbon fibers such as honeycomb nomex (essentially a kevlar paper) and foam cores. Think of a sandwich, where you ideally have two symmetrical pieces of bread on the outside with core materials acting as the filling.

The pre-preg carbon fibers are stored in a freezer and thawed before use to prevent the epoxy slowly curing. Once thawed, applying the carbon is very similar to contacting a book. You have to ensure there are no contaminants or air bubbles; we have control measures in place and use methods such as compaction while we work through the layers to ensure the highest quality and safest possible component is created. The fiber direction, type, amount of carbon as well as what core materials to use where is all determined by our team of engineers through finite element analysis and communicated through what's called a lay-up schedule.

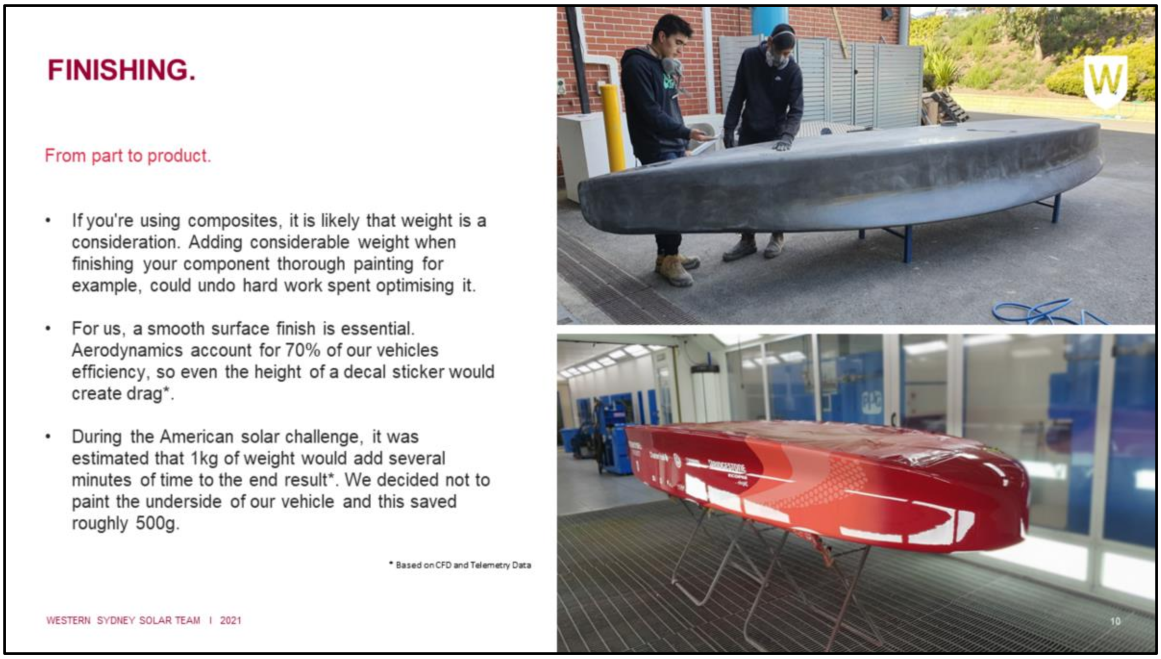


Once the layup schedule has been complete, It's time to 'bag' the part. The term 'Bagging' is jargon and describes the process in which the composite part is sealed and placed under a vacuum to cure, ensuring good layer adhesion and accurate tolerance.
All vacuum bags are hand made to suit the application. Imagine wrapping a napkin around a sandwich before cling wrapping it. The component gets wrapped in some specialised materials, sometimes including peel ply and breather cloth to distribute the vacuum evenly and ensure ease of de-constructing after curing. Then, a vacuum port is strategically placed and it gets sealed in a plastic material, except instead of scrunching it shut, it gets sealed around the edges with 'tacky tape', a bluetac like substance. An incision is made near the vacuum port and a vacuum line is fed in.

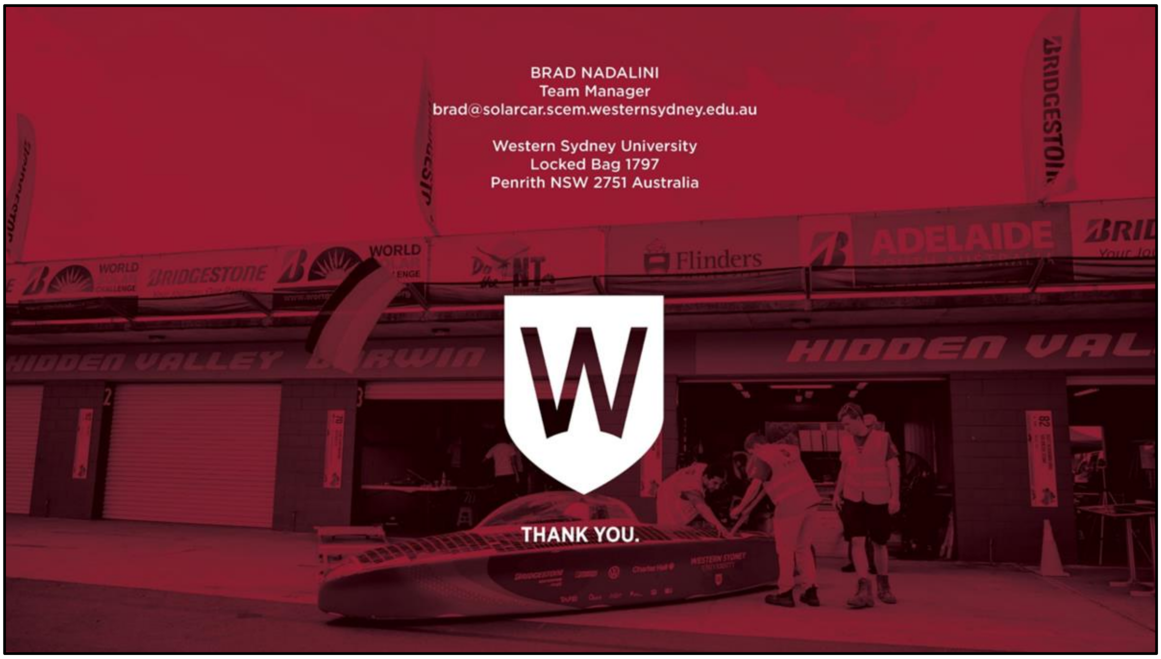


Whilst under vacuum, our prepreg composite parts need to be cured inside an oven, at temperatures ranging from 80 degrees celsius to 120 degrees celsius. An important thing to remember is ramp up and ramp down times - this refers to how quickly the temperature increases or decreases to ambient temperature. For our type of prepreg, this is usually around 1-2 degrees celsius per minute.

If you haven't already noticed the last vehicle we created, Unlimited 3.0 is quite long. Just under 5 meters in fact. This set us with a challenge as the entire shell was cured as one piece and ovens don't generally come that big to consumers. We had to innovate, and ended up purchasing a shipping container, converting it into an oven that was up to the task.



Now that you have a part that has been properly optimised and manufactured, you of course need to put it to work! Before you do however, there are a few things to consider. In the case of our aerobody, we had to colour it ‘Western Sydney’ red. There were a few options we could have gone with including vinyl wrapping, however we ran multiple tests with PPG, one of our partners, to determine which method would be the lightest and best for aerodynamics. We ended up creating our own mixture of light weight filler to fix surface porosity as a primer before painting. When painting, we used stencils to paint on the decals underneath the final layer. Most race cars use stickers, but the slight bump created would produce unwanted aerodynamic drag and genuinely effect performance.



Hopefully, this presentation has covered the key aspects of composite manufacturing. Our team operates on a tight budget relative to what we're trying to do. This means we are constantly coming up with crafty solutions (such as building our own shipping container oven) to get things done. This presentation and the contents within won't necessarily suit all applications, but it worked well for us. If you'd like to get in contact with our team or have any general questions, or questions in regards to composite manufacturing please reach out using the contact details provided on this page.