GILLES MARTIN-RAGET

New Zealanders Mark Turner (*left*) and Tim Smyth have been running the BMW Oracle build programme since the team's debut in the ACC class. Remarkably, working with former partner Richard Gillies, Smyth was also the last person other than Killian Bush to build a Volvo Ocean Race winner – Paul Cayard's *EF Language* way back in 1996. In the main photo note the static twist that can be generated in *USA*'s 68m wing rig

PIERRE ORPHANIDIS / VALENCIASAILING.COM

Silent heroes – Part I

Given the number of different iterations produced of the BMW Oracle trimaran *USA* it is no surprise that the sailing team saved their greatest respect for the American syndicate's build team led by Tim Smyth and Mark Turner…

The 33rd America's Cup began for the build team with the call to prepare for both a 90ft monohull and a 90ft x 90ft multihull. As the legal story unfolded we kept our heads down and pondered the best route to keep our options open.

2007 was drawing to a close and agreement with Alinghi seemed very near, though with two vastly different build scenarios. We had made little real practical progress in either direction and the worry was we would be late, whichever yacht was chosen, if we did not commit soon. A key decision was made to extend our oven to accommodate a wide 90ft monohull, as it was originally built for narrow V5 yachts.

This proved to be a costly error. Soon afterwards the talks broke down and a multihull became the call. And we had to live with an extra-wide oven for the rest of the project. The luxury of having enough time and space to modify our ovens again would prove to be an elusive commodity while we worked non-stop at breakneck speed throughout the next two years building the 'beast'.

At the end of 2007 the original timeline for the regatta was, of course, a lot less than two years and we had committed ourselves to launching the yacht within eight months. We were looking at an 80,000-hour build with the launch booked some time in August 2008. ▷

NEIL RABINOWITZ/BMW ORACLE RACING

The main hull nears completion in Anacortes with the primary structural beam elements as the floats and remaining beam fairings are worked on 25 miles away. Without the benefit of an established multihull yard improvisation became a key theme throughout the build

Mark Turner, myself and Chris Sitzenstock had worked out a plan whereby we would subcontract the floats to a third party and distribute the rest of the work between two workshops in Skagit County, Washington State. The design team were committed to facilitating the rapid build we needed and Hall Spars would be building the first two masts.

A typical V5 America's Cup Class boat might take approximately 25,000 hours to build, launch and prepare ready to sail. So, divide by six months while promising not to kill your workforce and you will need about 22 builders. This time, however, for us the major challenge was to assemble over 50 builders in order to have a chance of meeting the delivery target. (By the end of the project we had employed upwards of 70 people at our busiest times and changed most of the team at least once apart from a small core of people).

An America's Cup yacht build is always done in a rush, compressed between design and sailing time, and the construction programme is always up against time constraints. Attracting the type of specialist builder with the experience we require is also always a challenge; we tend to import upwards of 75 per cent of the team from various parts of the world, relying on experienced locals and a good training programme to get the rest.

Work permits, accommodation, furniture, schooling and relocation soon all become as big a part of the job as fibre selection and test panel work.

Workspace is the other key ingredient in any construction programme and we had chosen to go back to Anacortes, WA, in the USA due to our previous experience building there. The shed we were in was ideal for a single 90ft monohull build but less than ideal for a 90x 90ft trimaran!

Our initial plan to farm out the floats had soon unravelled due to our lack of confidence that any sub-contractor would have the resources to deliver on time with such short notice. Our solution was to set up another workshop nearby.

Concurrent with our logistical planning we had been undergoing a thorough quantity survey of the enormous amounts of material that would go into this yacht. Equivalent to nearly five complete V5 yachts in terms of surface area, the massive rigging loads and extra large appendages also meant that we were in for some very thick laminates. The flip side was that fortunately, and to our great excitement, the Deed of Gift had unleashed the designers from the strait-jacket of modulus restrictions and core minimum densities and allowed us access to all manner of exotic material and process options.

Come the end of December 2007 and we had both of our workshops ready to go and a plan in place...

Our main facility at Anacortes was where we would build the beam uni-flanges and the main hull, as well as all the internal structure and appendages. A second facility at Sedro Wooley, near Janicki Industries, was where the floats and beam shells would be built. Finally, a huge tent would be erected outside our Anacortes shop in which to assemble everything.

On the design side of things we had made enough progress to get our main hull mould and float moulds underway; these were straightforward enough but the beams produced a lot of head scratching.

At this stage we had also already met our French naval architects VPLP several times, along with the French engineering firm HDS (Hervé Devaux Structures). We had quickly established a good rapport and they had been continually feeding us plenty of the lessons learnt in France over their many years of building these types of yachts. The trouble was that they tended to take upwards of 18 months to build a multihull of this size, whereas we had only eight months.

The major challenge to meeting a timeline is usually to have all the major inputs arrive in time for the assembly, a bit like serving up a multi-course meal to a table of expectant diners. It all needs to happen smoothly for the right result.

Clearly design compromises were also being made to meet the construction time available; one of the more important ones was to run the two beams straight across to be able to share the same 'shell' fairing geometry. A big saving in tooling was also made with the decision to build a single male mould for the beam fairings, there being just about enough time to build both fore and aft beams over the one mould.

Received wisdom suggested that these ▷

beams would be built in female tools, with various methods being employed to lay what was a phenomenal amount of high-modulus fibre in the appropriate places, one of the most awkward being the tightly radiused leading edge of each beam. But the scale we were operating at meant that the ergonomics and practicality of applying large amounts of unidirectional fibre have big implications for the speed and quality of what we could ultimately achieve. This can and should trump the desire for the better final finish using a female tool, if for quality reasons alone. The male tool we employed also facilitated the easier laying of the 110x25mm M46J uni-beams along through the leading edge of these structures.

This is a very hands-on process. The careful laying, smoothing and consolidating of these plies while gently distorting them around their chosen path, without wrinkles, fluttering of the edges or trapping of any air are critical.

Work at waist height with room to drape fibre onto a male tool, compared to leaning into an 800mm-deep female tool with a tightly constricted lower radius... it was an easy choice to make (except perhaps for the local chiropractors).

The beam flanges consisted of two tapering uni-bundles 90ft long x 90-135mm thick and 70mm wide. These sat on each edge of a 70mm-thick Kevlar honeycomb panel that formed the aft face of each beam.

We built these as four separate pieces on a large W-shaped tool (*right*) with four shelves corresponding to the geometry of each particular flange. A team of eight people walked up and down that tool over 500 times over a few weeks laying unidirectional carbon and various vacuum consumables. Once complete they were released and flopped over to lay flat on a 90ft-long table alongside, ready to be glued to the top and bottom edges of the flat panel that was already built and waiting for them.

Meanwhile, the hull was alongside in the same shed and the floats next to the beam fairings were in a shed some 25 miles up the road. So far all had been following their respective timelines closely enough.

The biggest headache for Mark and myself was plotting the movements of the various pieces through the tooling/build and cure process and the subsequent manoeuvring that must go on to get the large parts where we wanted them to be. We were often short on vacuum pumps, ovens and oven heaters, operating three separate shops and trucking parts, people and equipment between each facility on a daily basis.

The biggest restriction, however, was space. Room to manoeuvre 90ft-long parts was always at a premium. For example, removing each complete beam, now with one main hull and two float bulkheads attached from the main shed, down a steep ramp from the main shed and around the corner into the assembly tent required two stout trolleys with a high-load lazy-susan on each one. This allowed the beam to align itself as we steered the trolleys around and down the slope and into the tent. Thirty people and most of one day were necessary for each such movement.

Inside the tent, with no overhead cranes possible, we gingerly lifted these parts up, over and down onto the main hull using two forklifts.

Building the main hull and floats of the trimaran was relatively straightforward. We adopted an interesting split wooden tool option for the main hull which saved a lot of time and money, and for the floats we made do with one fully infused carbon tool.

Compared to a regular V5 ACC boat the construction is fundamentally similar in the sense that both are thin carbon skins either side of an alloy core. A critical difference is how the hulls are stiffened. On the tri this is dealt with by the placement of monolithic uni-bundles in the outer extremes of the hull shape (typically the sheer and near the hull centreline). These bundles might be approximately 200mm wide and 25mm thick, and in some regions they are even wider and thicker.

Curing such large bundles of resin and high-strength fibre has big implications for distortion in your final shape. Essentially the bundles are laid on a few layers of off-axis fibre, which is very susceptible to resin shrinkage in the uni-bundle curing on top of it. Couple this with any mismatch between the coefficient of thermal expansion (CTE) of the product and the CTE of the tool and you have all the ingredients for a big banana. Taking the necessary extra steps and processing solutions to minimise this risk was an important part of meeting the timeline without having to deal with unwanted problems.

The consensus among the build team was that the massive uni and Quasi isotropic (designed to accept unforeseen loads in any direction) patch reinforcements were the biggest processing challenge. These large-scale reinforcements were there because of the big loads – the custom mechanical parts that appeared regularly on Chris Sitzenstock's desk impressed us all with their size and chunkiness. And also with what they meant for our carbon structure; the structural combination, for example, of titanium, high-strength steel, autoclaved carbon and

NEIL RABINOWITZ

***Clockwise from top far left*: working in the hull and floats was never anything other than cramped and difficult; final assembly in the team's largest 'tent' in Anacortes; plugs for the male-moulded beam fairings leave the shop in Sedro Wooley; preparing to secondary bond the float frames; one half of the main hull comes out of the mould with frames other than the beam frames in place – cut-outs are just large enough to allow human access; layer upon layer upon layer of unidirectional carbon goes onto one of the giant load-bearing beam flanges**

exotic plastics designed to encase an 8m daggerfoil while allowing it to swivel and slide smoothly under load and be controlled from a safe distance...

The cutting, drilling and grinding involved in fitting these parts was a big challenge and a testament to the skill of all those involved. For example, two people disappeared for several days under a tent on each float to carefully cut and excavate the perforation for the foils. Sixty tons of side load meant a hole approximately 1m long through 45mm of solid carbon cut at an exact bevel over 70mm long, in order for the curved board to pass through at a tolerance of around 1mm if it were to successfully handle the bearing loads.

Another team were responsible for laminating each of the beam attachments to the floats. These guys had to enter through tiny hatches and then crawl through small holes in each bulkhead (one every 2m or so), before positioning themselves in cramped quarters to accurately lay over 50m² of fibre in way of bulkhead taping.

A frequent observation made by the build team was 'how many V5 boats had we built so far?' In terms of fibre usage the consensus was at least eight by the time we had finished the whole campaign. And at least four of these V5 equivalents came after the actual launching of the trimaran.

While we hit the target date for the launch, in the end the sailing programme began with a lot more time available than first envisaged thanks to the various legal outcomes. Thus the designers went back to work and we went back to building. It was clear by now that this was becoming an arms race and with each new weapon there was plenty to trial and learn.

First up was a new set of floats. Concurrent with these a study was being run on replacing the central daggerboard and float foils with just two semi-lifting daggerfoils. This was risky stuff and the answer was not sufficiently clear for the team to commit until we were well into the build programme for the new floats.

This caused a large amount of rework and extra reinforcement to be done when the call came to go ahead with the daggerfoils. Overlay this with the fact that we then had to figure out how to build 8m long x 140mm thick curved daggerfoils with some 90 tons' side load where they exited the hull.

And, of course, these needed to be delivered in good time, since the new floats were now designed with them in mind (actually this one was impossible, so we came up with temporary bearings for the old foils in the meantime). Add to this a modification programme that now included fitting a complete new bow and sprit combination and we had a lot on.

Fortunately, we had brought forward the cockpit modification and engine installation so they would not have to take place at the same time. These had gone well, thanks to a well-organised shore team led by Wolfgang Chamberlain and a group of key technical people from BMW.

So in the months of May/June/July 2009 we effectively fitted a new cockpit, an engine, a new bow and new floats along with a myriad relevant details and other improvements. The first of the new daggerfoils would come soon afterwards and almost immediately prove to be a big success.

But this was by no means the end of the work on the platform. There was the issue of balance, of bowsprits and continuous weight reduction, as well as ongoing optimisations too numerous to mention.

And then we had two more major modifications to deal with once the daggerfoils were fitted and functioning correctly, including the alterations needed to accept the wing – in addition to a few other measures we were taking thanks to Alinghi's gradual relaxation of the sailing rules...

Tim Smyth

Next month: Mast world ❑