Under Sail

What's Inside:

Edited By David Schmidt

BMW/Oracle Racing's *BOR90* trimaran flies to windward during a training session

America's Cup Special

Are Three Hulls Better than Two?

If BMW/Oracle can keep everything together, they should win in a walk | BY IAN CAMPBELL

Will Alinghi's catamaran, *A5*, or BMW/Oracle's trimaran, *BOR 90*, be the faster boat in the 33rd America's Cup Deed of Gift match, scheduled to be held off Valencia, Spain, in early February? There are strong opinions on both sides.

Despite the secrecy that is part of every America's Cup, we used data collected on both boats by *SAIL* and then applied it to the Wolfson Unit's velocity prediction programs (VPP), in particular the WinDesign VPP developed in conjunction with Clay Oliver's Yacht Research International.

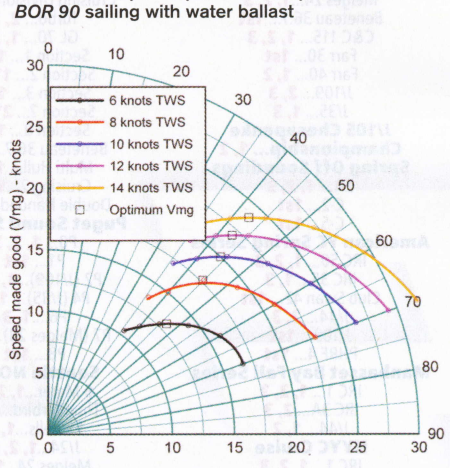
Although the actual sailing weights of these boats are well guarded, weight is an integral part of the VPP analysis. For reference we scaled a C-Class catamaran, another class that has no weight restrictions, up to 90 feet. Interestingly, the estimated sailing weights for both *A5* and *BOR 90* compare favorably with the scaled up C-Class cat, even though the C–Class cat has just half the beam and sail area (**Table 1**). Although the estimated lighter weight of the powerful *BOR 90* seems counterintuitive given the simpler two-hull platform of *A5*, the calculations show that this is indeed the case.

In fact, lighter weight is not necessarily an advantage upwind because weight provides stability and power to carry sail. However, water ballast, rumored to be used aboard both boats, will provide *BOR 90* with added stability upwind, much like a crew trapezing from the windward hull of a C-Class. And when it is no longer needed, the water can be dumped, which moves the advantage back to the lighter boat.

We used boat geometry and the VPP's internal hydrodynamic and aerodynamic models to derive baseline upwind speed polars for *BOR 90* when sailing with water ballast in the windward ama (**Figure 1**). When true wind speeds go up to 14 knots—which is just below the 15-knot maximum allowed by the Notice of Race that existed in early December—the VPP suggests that *BOR 90* can sail to windward at twice the true wind speed (TWS) and can reach velocity made good (Vmg) speeds that are about 50 percent higher than true wind speed.

Because of the shallow resistance curves

FIGURE 1: Upwind performance polars for *BOR 90* sailing with water ballast



	BOR 90	A5	DIFFERENCE	C-CLASS SCALED TO 90'
EST. SAIL AREAS	ft²	ft²	ft²	ft²
Main (soft)	5,700	5,400	300	
Jib	3,250	2,700	550	
TOTAL	8,950	8,100	850	3,888
Code 0	5,700	5,400	300	
EST. SAILING WEIGHTS (LBS)	25,920	33,790	-7,870	34,292

TABLE 1: Sail areas made from photographic analysis; both boats have several rigs. Sailing weights assume first-rate engineering/construction

and the strong link between boatspeed and apparent wind speed, the true-wind angle for the optimum Vmg—represented by the top of the curves—is not well defined and the apparent-wind angle hardly changes as the boat bears away and accelerates. This means that the performance potential for both boats will depend on how well each team has learned its boat's optimum sailing angle for a given wind strength.

Our analysis using *BOR 90*'s soft-sail rig shows her flying a hull in just 8 knots of true windspeed, even when she is carrying water ballast. Above that windspeed, the VPP controls the sail forces to limit heeling moment, which means the crew will have to control the sails very carefully to keep *BOR 90* on its feet. An interesting comparison comes from the 32nd Cup match, which was also sailed off Valencia, but in monohulls. When true wind reached 9 knots, those crews also had to start controlling their sails' power. But in that case they wanted to optimize sail efficiency rather than limit heel angle, because unlike a multihull, the righting moment kept increasing with heel.

FIGURE 2: Downwind performance polars for ***BOR 90*** sailing without water ballast

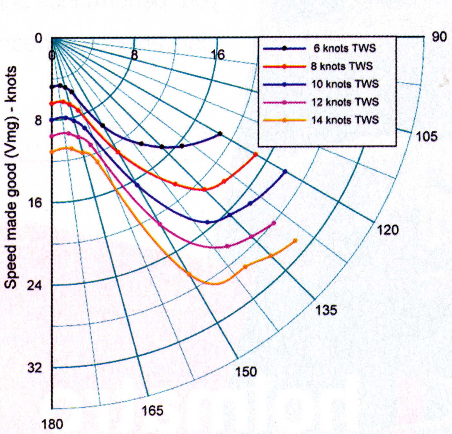


PHOTO BY CARLO BORLENGHI/ALINGHI

Apparent wind angles for both these boats are remarkably similar across a wide range of wind speeds and true-wind angles, because once they bear away, they sail so fast that their apparent wind is always well forward. For *BOR 90*, predicted apparent wind angles vary between 14 and 16 degrees, which makes it very close-winded. This is another interesting contrast with the America's Cup Class monohulls that sailed with apparent-wind angles of around 17 degrees. Although both multihulls do sail upwind at narrow apparent-wind angles, their optimum upwind true angles of 40–45 degrees are relatively wide compared to a monohull because their boatspeeds are so much higher relative to true-wind speed: In other words, foot fast upwind rather than point higher and go slower.

Once a baseline performance is established, the VPP can assess other differences between boats. If, for example, *A5* really is heavier than *BOR 90*, can it sail successfully upwind against *BOR 90* without water ballast while *BOR 90* sails with water ballast?

In 8 knots TWS, the VPP shows *BOR 90* sailing on its leeward ama and the catamaran flying a hull. Because both are sailing with the same weight, they have similar drag, but *BOR 90* should have an advantage of 5–10 seconds a mile because the increased water ballast converts directly into power and speed. *A5* can also add water ballast, but since *BOR 90* can add more (it has three hulls, not two) it should maintain a relative advantage. In seven knots of true-wind speed, performance is not limited by stability and *BOR 90* can sail without water ballast and still fly a hull when *A5* may not be able to do so.

DOWNWIND

The predictions for *BOR 90* in **Figure 2** show that optimum downwind Vmg speeds, with a Code 0, come at apparent wind angles of 22–28 degrees. (The VPP can account for the improved lift generated by a Code 0 type of sail used at narrow angles.) Because of its sail area and ability to fly a hull downwind in 7 knots true, *BOR 90* might be as much as 20 seconds/mile faster than *A5* in 8 knots of true wind. This advantage disappears at 12 knots true, and in higher windspeeds *A5* appears to be quicker. However, *BOR 90* can regain an advantage of 5 to 10 seconds a mile by adding water ballast. Just as in the upwind mode, whenever *A5* adds water *BOR 90* can add more. So anytime these boats are

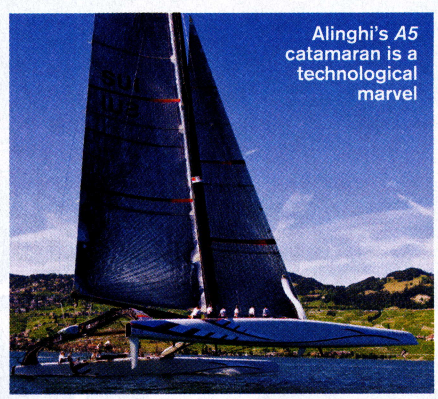
ESTIMATED WEIGHTS (IN POUNDS)

ALINGHI 5

Cross beams 2 @ 5,000	10,000
Center pole	4,000
Hulls 2 @ 6,000	12,000
SUB TOTAL	**26,000**
Mast	2,000
Rigging	500
Deck equipment (with engine) and miscellaneous	2,500
Crew (est. 6-8) and gear	1,500
SAILS	
Main (soft)	660
Jib	350
Code 0	280
TOTAL EST. SAILING WEIGHT	**33,790**

BMW/ORACLE RACING *BOR 90*

Cross beams 2 @ 5,000	10,000
Amas 2 @ 2,500	5,000
Center hull	3,000
SUB TOTAL	**18,000**
Mast	2,000
Rigging	500
Deck equipmentt (with engine) and miscellaneous	2,500
Crew (est. 6-8) and gear	1,500
SAILS	
Main (soft)	700
Jib	420
Code 0	300
TOTAL EST. SAILING WEIGHT	**25,920**


Alinghi's *A5* catamaran is a technological marvel

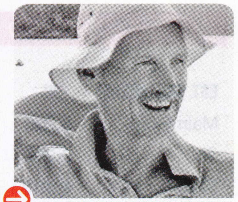
flying a hull, upwind or down, the VPP gives the advantage to *BOR 90*.

Even though the two reaching legs used on the 39-mile triangular course required for the second race will be a little tighter than the optimum downwind gybing angles used for the 20-mile windward-leeward courses called for in the first and third races, *BOR 90* should retain the power and speed advantage similar to that established for the downwind Vmg.

Because both boats will be flying a hull in most conditions, there will also be some aerodynamic differences. For example, even though there is additional windage from *BOR 90*'s amas—representing a loss of about 0.5 seconds/mile—the main hull also acts as a seal between the sails and the ocean, a feature that *A5* does not have. This loss of seal can be simulated in the VPP by reducing the span of *A5*'s rig. A redution of just three feet can make a speed difference of up to 5 seconds/mile, or 1.5 minutes on a windward leg. Both boats are so close winded that their rigs can produce the very high efficiencies that come from having large spans.

BOR 90's wing mast and solid sail has less sail area than its soft sail, but it is reportedly much more efficient, especially in light airs. It is also reported to be able to quickly produce more camber coming out of a tack and that can help it to fly a hull more quickly. Downwind, a wing mast can produce more lift than a soft sail, although with no sail area restrictions, both teams can use large Code O headsails. In fact, *A5* has reportedly increased its bowsprit to accommodate larger downwind sails.

The basis for these predictions could be wrong, of course, and with boats as large, powerful and complex as these two are, anything can happen. But if the engineers and builders have done their job and the *BOR 90* team can keep the rig in the boat and avoid other structural breakdowns, they stand to prevail over *A5*, and possibly by a considerable margin.



Ian Campbell has been at the University of Southhampton's Wolfson Unit in England for 36 years and has done research for many AC contenders. In the last cup, he was the senior scientist for the *Luna Rossa* syndicate

TRUE WIND SPEED (KNOTS)	COMMENT	MARGIN (IN MIN) UPWIND OVER 20NM	MARGIN (IN MIN) DOWNWIND OVER 20NM
6	*BOR 90* is lighter with more sail	6 (*BOR 90*)	7 (*BOR 90*)
7	*BOR 90* is first to fly a hull	8 (*BOR 90*)	6 (*BOR 90*)
8	Water ballast loaded in both boats	3 (*BOR 90*)	6 (*BOR 90*)
9-16	Both have water ballast but *BOR 90* has more	4 (*BOR 90*)	3 (*BOR 90*)