Catalyst

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As examples, the polar diagram p16 of *Catalyst 28* was re-created from a second generation photocopy, photos of shunting in the Champion article in *Catalyst 27* (pp 19-21) were screen grabs from a video supplied on DVD. The rest of the images in that article were scanned from photographs, and the text was OCRed (Optical Character Recognition software) or keyboarded.

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Features

Regulars

Bill Sunnuck's Vampire does a wheely! Bill reports they now have that kind of behaviour under control! Photo: by Tim Bees

Catalyst
Journal of the
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Catalyst is 50!

When Tom Blevins, back in 1999, tabled the idea of rolling up the AYRS UK and US (NEG) newsletters into a single larger format magazine I never thought I'd still be involved some 16 years and 50 issues later. Yet here we are.

Tom's vision was of something that would grow and come to be the place to find the new ideas and be required reading for people at the cutting edge of yacht development people in the main who study these things for love (the true meaning of an amateur) and not simply because someone else has paid them to do it (although there are always those lucky people who get paid for doing the things they love). I don't think we have quite achieved that yet but I do think we are on that road.

Mind you Tom's vision was also of something that would be produced regularly preferably quarterly, and in that I have to plead that I'm failing. It was easier when I could go home at the end of the 9 to 5 working day and had the evenings free to think about Catalyst. Now I run my own business there are no free evenings so Catalysts come fewer and further between. Maybe I should retire.

So that is why this issue is late but to make up for it (I hope) it is close to three times as thick as normal. That leaves a problem though – there is very little for the next edition. Because I firmly believe that an Editor's task is to edit, not to write, I need more articles from you. How about it?

New AYRS website

In the meantime have a look at the redesigned AYRS website. It's been put together by Robert Deaves (who also does the Finn class website) and whilst there are still minor things to be sorted out you can visit it at http://www.ayrs.org/en/ (that URL will change to www.ayrs.org in due course but for the time being both new and old sites run in parallel). The new site will give us a more modern look, and provide for more interaction with members' projects' blogs and a structured discussion forum (which will replace the unstructured one on Yahoo).

Simon Fishwick

Czesław (Tony) Marchaj 1918 - 2015

C A (Tony) Marchaj died on 21 July 2015 in Warsaw at the age of 97. Born and brought up in Krakow, in southern Poland. At the outbreak of the Second World War he was studying aeronautical engineering at Warsaw University and qualified as a glider pilot.

In the fifties he was the Polish Finn class dinghy champion, but was not allowed by the communists to go to the Helsinki Olympic Games. He was at this time in and out of jail for his outspoken views and he wrote his first book - 'Sailing, Theory & Practice' at this time, mostly in jail.

In the early sixties his wife Janina translated the first few chapters of his book into English and sent them to Southampton University in response to the Wolfson Unit seeking a research assistant.

There he instigated and designed the low speed wind tunnel and balance system in the return section of the universities's wind tunnel, where all low speed & the sail performance tests are carried out to this day.

He remained in Southampton for many years. Writing in his terrace house where Janina eventually joined him.

His investigations covered many traditional rigs, including the Polynesian crab claw, which when they tried it in the wind tunnel the results were not believed. So the test were halted; the tunnel balance system was re-calibrated and found it to be correct.

Many third world fishing fleets are now using this rig. It works basically as a delta wing developing strong vortices and giving very stable flow. Tony also developed other similar simple rigs for fishing fleet around the world.

After the Fastnet tragedy he wrote 'Seaworthiness, the Forgotten Factor'. He showed that all modern racing yachts are designed to get the maximum performance out of the rating rules with very little thought given to to seaworthiness, apart from having effective washboards to secure the main hatch.

When their Southampton house was demolished to allow for a local school expansion, they retired to France and Tony bought himself a motor glider.

They had bought a derelict farm house in France, in the foot hills of the Pyrenees. They would spend their summers there restoring the house to a very high standard and growing ecological vegetables in the field. Returning in the winter to Southampton to write & lecture.

Tony is survived by his wife, who lives in Warsaw, and son - now a retired captain of French merchant navy.

Ian Hannay

Louis Vuitton America's Cup World Series, Portsmouth, July 2015.

Following the usual shenanigans after the extraordinary comeback of Oracle Team USA to beat off challengers Emirates Team New Zealand (ETNZ) in the 34th America's Cup in San Francisco in 2013, the build up to the 35th event began at the end of July off Southsea, UK, in the main shipping channel outside Portsmouth Harbour. This was the first of this year's World Series regattas using the one-design AC45 catamarans that made an appearance in Plymouth in 2011, only this time they were equipped with lifting foils, to emulate the excitement of the AC72 catamarans and designated the AC45F. Via some rather tortuous point scoring system, doing well in the World Series contributes, rather tenuously, to decide who the eventual challenger for the Cup will be, thereby encouraging teams to take part.

I had reported for Catalyst on the AC45 regatta in Plymouth, a thoroughly entertaining event with a combination of fleet races, match races and 500m sprint races held over a full week. Plymouth Sound provided a natural theatre for what is now called stadium racing, with the Hoe providing an excellent elevated viewing position. As only the second regatta of its type, Oracle billionaire Larry Ellison seemed to have paid for the whole event, which toured the world on a container ship specially chartered for the purpose. For the viewing public it had been a fantastic free show.

Four years on and times have changed. I had the distinct impression that the circus must now pay its way, so unlike Plymouth, I was shocked to find that Southsea Common had been boarded off. Two areas, designated the Waterfront Arena (the common) and the Fanzone (by Southsea castle) had been created, and although entry to the common was "free", visitors had their bags searched for food so as to maximise the takings of the concession-holders (i.e. hot dog stalls). This generated considerable ill feeling amongst the locals, as you can imagine, the story even making it onto the local TV news.

I had already booked tickets for the Fanzone, and thanks to AYRS, had managed to procure a media pass. The media centre, in the D-Day museum car park and right behind the grandstand seating that had been set up behind the VIP pavilion, provided a welcome refuge for what was to come.

Thursday 23th July

Billed as "First Thursday", this featured exhibition racing of half a dozen Moths, a couple of kite-foilers, the grand arrival of the Cup itself and, eventually, a Parade of Sail of the competing teams.

There was just sufficient wind for the Moths to fly on the foils, and to add interest a Moth had been set up in the Fanzone for punters to inspect. After 15 years or so of development, in the modern era at least, the Moths have pretty well got foiling down to a fine art, being able to fly up wind, down wind and remain foiling through tacks and gybes. Mind you, we were watching some of the best Moth sailors around: Jason Belben, Rob Greenhalgh, Simon Hiscocks, Dylan Fletcher, Mike Lennon and current UK champion Chris Rashley, who won most of the races. I didn't see where they were launching from, part of the problem with the venue was that you couldn't see upstream towards Portsmouth, but later in the afternoon Chris came to explain the workings of the Moth.

The Moth on display was an Exocet, designed by Kevin Ellway and built by Maguire Boats to a high standard. The basic concept is that flying height is controlled automatically by virtue of a height-sensing wand linked to a trailing edge flap on the main lifting foil at the bottom of the dagger board. Pitch stability is provided by a T foil rudder. The behaviour of the craft in flight depends on the precise relationship between the position of the wand, the trailing edge flap and the rudder foil incidence, as well as crew position and sail trim. For the Exocet, adjustment can be made on the fly to the rudder lifter incidence,

Moth - rear foil, main foil and wand

wand length, wand-to-flap gain (or gearing, as they call it) and the wand-to-flap offset. Chris explained that the aim when sailing was to keep the main foil immersed and the gearing as low as possible. Depending on the height of the sea chop, the wand length would be adjusted so that the wand would be at a fairly steep angle. Sailing through “following” waves was not a problem since the gearing could be increased, if need be, but high gearing was generally considered to cause higher drag and slower speed. Certainly, watching the boats as they whizzed to and fro, I had the impression that the slower ones showed a high frequency pitching motion, just as if the gearing was too high. All of these adjustments interact, for example increasing the wand length would require the wand-to-flap offset to be adjusted to maintain the same flying height, and would also change the effective gearing. Another visible difference between this boat and others is that the pivot position of the wand is further forward, mounted on a short bowsprit. Take-off boat speed is between 7.2 and 7.3 knots (as precise as that!). Fortunately there was just enough wind for them to fly.

Later that morning the America’s Cup came ashore on a Royal Marines landing craft and was paraded down the seafront promenade for all to see. After opening speeches by Sir Keith Mills (Team Origin, who were organising the event) and Dr Harvey Schiller (America’s Cup Commercial Commissioner), the Cup was moved to the bandstand next to the Moth for people to have a close look (and have their photo taken with).

Lunchtime and the Parade of Sail, led by HMS St Albans, came past, our first chance to see the AC45Fs. No racing was scheduled so they just mooched around, but it was still quite exciting to see such large boats get up on their foils. Later, the skippers came ashore and were introduced on stage in the Fanzone: Ben Ainsley (Land Rover BAR), Glenn Ashby (Emirates Team New Zealand), Frank Cammas (Groupama Team France), Nathan Outteridge (Artemis Racing), Dean Barker (Softbank Team Japan) and Jimmy Spithill (Oracle team USA). Two brief moments of humour as Ainsley and Ashby conspired to set Frank Cammas’ chair lower than theirs, and once Jimmy Spithill was seated Glenn Ashby presented him with a (presumably un-weighted) AC45 main beam strut, a joke that perhaps didn’t go down too well and was lost on the crowd. The usual Q&A followed, everyone saying how happy they were to be in Portsmouth, delighted they were to be racing again and thrilled they were with the reception they had.

Friday 24th July

A damp day with light – moderate easterly winds. Billed as “Fast Friday”, it was too cloudy for the Red Arrows, but the Moths were out again and after lunch the AC45Fs were preparing for a couple of practice races, which included practice of the TV coverage, replayed to big screens in the viewing areas. If you have not seen it I recommend watching the TV coverage – the superimposed graphics is brilliant in explaining what is happening and I find Tucker Thompson and Ken Reid most entertaining as commentators.

At some point during the day Paul Larsen and Helena Darvelid of Sailrocket fame made an appearance and were visibly moved on seeing the video of their record-setting 65 knot run in Vestas Sailrocket in Walvis Bay a few years back. Paul said that after a break the Sailrocket team were coming together again with a view to seeing if what they had learned can be applied to ocean sailing, the aim being to routinely cross oceans at record speeds, in “normal” conditions rather than having to wait months and months for exactly the right weather window. I will be surprised if their knowledge of high speed foils is not eagerly sought after by any number of Cup teams...

Photo: Ian Roman

With the easterly wind, the practice races started near the viewing areas and I found that the view from the grandstand was actually pretty good. But just as the second practice finished the heavens opened and everyone ran for cover. That evening's concert in the main area was cancelled.

Saturday 25th July

"Big Saturday – the day the sailing gets serious and points are won or lost".

For the morning I had booked onto a press tour of the team bases in the naval dockyard. The rain from the previous day had cleared away leaving a bright, sunny day with a moderate south-westerly breeze – perfect sailing conditions. The teams' boats were housed in marquees set up in the dockyard around once of the basins and had use of a crane for lifting the wing sails onto the boats, and then to lift the boats into the water. Moorings both inside the basin and just outside in the harbour provided temporary holding areas.

The AC45F is a one-design, designed by Oracle and built in New Zealand by Cookson Boats and Core Builders. The wing sails look much the same as they were four years ago, with a non-twisting leading element and three trailing elements or flaps. One of the tour guides, the daughter of a former North Sails UK boss, said they were new and enabled the top flap to be pulled to reverse camber to increase righting moment, albeit at the expense of increased drag.

Other details:

- Build: honeycomb core & carbon fibre sandwich
- Length: 13.45m (44.1ft)
- Beam: 6.90m (22.6ft)
- Weight: 1,290–1,320kg (2,840–2,910 lb)
- Maximum draught : 2.7m (8ft 10in)
- Rig height: 21.5m (71ft) without extension, 25.5 m (84ft) with extension
- Wing: 20m (66ft) 83.5m^2 (899sq ft) wing element with three slotted flaps
- Extension: 4m (13ft) high, 8.7m^2 (94sq ft) area
- Jib area: 48 m^2 (520 sq ft), manufactured by a sail loft of team's choice (which means North Sails)
- Gennaker area: 125 m^2 (1,350 sq ft)
- Crew: 5 + 1 guest (so far I have not received an invitation...)

The incidence of the twin inverted T rudder lifters can be adjusted but has to be locked in place for racing and not changed during a race.

The main foils, only one of which can be deployed when racing except during tacking and gybing, is of the type that evolved in New Zealand in the last Cup cycle, and feature a curved "vertical" section ending in a straight "L" lifter. When the foil is retracted, the lifting section is almost horizontal but when the foil is lowered, the curvature of the main part means that the lifter is inclined, resulting in a "V" foil some way inboard from the hull. The cross section of the foil is asymmetric, and as well as raising and lowering, the crew can, under manual control, rake the foil fore-and-aft to trim lifter incidence. The control takes the form of rocker switches on the deck next to the helmsman's position. Power to move the foil comes from batteries. I was told that the actuator that moves the foil is also electric, but others say it is hydraulic. So far as I can tell the foils are not trimmed continuously, rather they are trimmed for the conditions and prior to manoeuvres, for example to assist raising or lowering the foils.

This configuration of lifting foils has come in for criticism for being inefficient, but it evolved from a rule dodge and is a compromise between simplicity, stability and performance. For starters the "V" is inboard of the hull which reduces the righting moment. Secondly the two sides of the V are fighting against each other, creating more drag

than is necessary to support the weight of the boat and resist side force. Dean Barker is quoted as describing the similar foils on the AC72 as akin to driving a Formula 1 car with crappy tyres. Stability, such as it is, is provided by what it termed leeway-coupling, where an increase in sail side force causes an increase in leeway angle (and hence angle of attack on the more vertical element of the foil), but because the lifter is upturned its angle of attack is reduced, reducing the lift it generates, maintaining an almost constant flying height. Also, because the configuration is almost a "V" foil, the tip of the foil sometimes breaks surface such that it acts like a surface piercing foil of yesteryear, reducing the lifting area.

Without doubt greater performance could be achieved if the lifting element was angled downwards rather than upwards, but without continuous manual adjustment or automatic height control this has been shown to be too unstable. The new AC48 class proposed for the Cup proper does not allow the automatic control as used by the Moths, nor does it allow the use of stored energy as used by the AC45Fs. Whether there is an opportunity for teams to consider dedicating one crewmember to continuously flying the boat on a more efficient foil, with power provided by others "grinding" the hydraulic pumps, remains to be seen. As it is, because the AC45Fs foils evolved from a rule-dodge they are not a patch on what they could be. Without permitting some degree of development in the AC45 class over the course of the series it is difficult to see what will keep the more technically minded fans interested.

Saturday's Racing

Back in the Fanzone for the racing, the crowds were gathering. Unfortunately the grandstand was ticket-only, so I had to slum it with the lesser mortals but I found a vantage point behind the big screen.

With the 10 – 14 knot wind in the SW, the start was too far away to see, but it became clear that on the first downwind leg the crews had a choice of deploying their gennaker and sailing deep but displacement (or "old-timer mode"), or flying with the small jib – faster but closer to the wind. By the second race there didn't seem to be much in it but by then the conditions were such that they could fly with the gennaker anyway. Once settled on a course, the boats could fly straight and level but if any disturbance occurred (such as hitting a puff or a lull in wind speed), equilibrium was upset and as often as not the boat would rear up and crash down, a sensation I remember from years ago. Not fast, but quite fun to watch and the crowds showed they loved it with their oohs and aahs.

In Race 1 Emirates Team New Zealand took the early lead, but Land Rover BAR overhauled them on Leg 4 and extended away to take the win to a cheer from the crowd. Oracle Team USA came through to take second, powering away from the penultimate mark at 30 knots (according to the press release), while Emirates Team New Zealand finished third.

In Race 2 Land Rover BAR were among the early leaders, but after the first mark Emirates Team New Zealand opted to sail along the shore side and picked up better wind to take a big advantage. Groupama Team France, who had finished a very distant last in the first race, hunted them around the course in second, until Land Rover BAR overtook them at the fifth gate mark, to finish in second. Frank Cammas held on for third.

After two short races the game was over. The local team was declared the winner and everyone left, although those who lingered enjoyed an aerobatic display by The Blades display team.

Sunday 24th July.

The forecast was for rain and a strong southerly. It was correct. The assembled media hunkered down in the media marquee wondering if the news story of the day would be "Media marquee collapses – journalists crushed". It sounded as though a giant fist was hitting the marquee with a correspondingly big stick. The race committee had decided to bring the racing forward in the expectation of a weather window at midday, but at 11.25 we were told that the two viewing zones were being closed to the public, and by 11.30 it was announced that the racing had been cancelled and all areas were to be evacuated. I wasn't even allowed to peer over the ramparts of the castle to see what was happening, but I think the organisers' concern for public safety was probably correct. We never got to see what the AC45Fs can do in a good breeze.

Closing remarks

That there was so little racing for such a big build up was disappointing. The lack of any match racing at all was an even bigger disappointment. Maybe the foil rake batteries only last two races! The forecast for bad weather on the Sunday had been consistent for several days so the race committee should have held more races on the Saturday. The official figures are that 67,374 people watched the Saturday racing from the designated viewing zones, 22,000 from boats shepherded just outside the race area and a further 49,067 from other areas on land. Close on ¼ million are believed to have attended over the four days, so in commercial terms it was considered a success.

Of the teams taking part, Land Rover BAR must be a strong contender with some of the best and brightest recruited to the project. The emphasis for the development effort going into the new Cup class of 48' foilers will be on the wing and foil *control* systems – hence the involvement of specialists from the aviation, automotive and Formula 1 sector – much else is effectively one-design to keep costs down. Because of the reduced costs, Groupama and Softbank Team Japan have been able to join in, with Team Japan being the most recent, recruiting a number of Cup veterans from New Zealand. Groupama will be one to watch – Frank Camma's ruthless domination of the C-Class regatta in Falmouth two years ago was a wake-up call for anyone doubting the intentions of the French.

The Louis Vuitton World Series' next regatta is in Gothenberg, 27th – 30th August, followed by Bermuda 16th – 18th October. The teams return to Portsmouth next summer and it is expected that other regattas will be held before the challenger series and Cup racing proper begins in 2017.

Joddy Chapman
7th August 2015

STELLA-F1 ("Tinfoil") –

Diary: May 2014 – May 2015

My aluminium catamaran, unpainted and shining in all its glory, was given the name of *Tinfoil* by an AYRS member during the Weymouth speed week.

This unfinished catamaran was shown the water for the second time at Weymouth in order to test the structural strength of the foils and the deck. The hulls are designed to fold up when a latch is released and this allows the foils to rise into a safe zone suitable for access to shallow water and for beaching. On the first test in May last year, the design of these latches proved to be inadequate and one latch snapped at 5 knots. A new stronger latch was installed and showed no signs of weakness when towing was again carried out. Towing stopped at 8 knots when a weld gave way on the port side. An inspection of all the welds resulted in a trip to the fabricators and any suspected weakness was beefed up. During both trials last year, the buoyancy looked good and the drag appeared low. For the moment these designs appear to be coping.

A temporary tiller was installed but this has now been replaced by a pair of rudders, one on each stern, and they are part of the fold up unit. This all fits in well with the boom poles and the deck arrangements.

Interestingly, at 8 knots the very top of the foils, where they join the hulls, had just become visible above the waterline and this showed that the load on the foils was nearing its required maximum.

Tinfoil is now ready for towing on the water but we do need a custom designed launching dolly. In the time between now and the May trails, when AYRS will next be at Weymouth, much more can be achieved.

To have the mast, sails, and rigging in place will make the trip to Weymouth an amazing event and will also provide the opportunity to verify the spectacular new arrangement of the sails. We need to put this system on the water in order to show the benefits.

AYRS have a history of probing into unknown territory and the Stella-f1 foils are a typical example. Over the last year the boat has moved on past the hulls and deck structure and is close to the stage one target. Stage one being, "ready for sailing".

Stage two will be all about modifications affecting handling, control, safety, and improvements on design and speed. But first we need to sail her.

I am immensely grateful to AYRS for their support [*a Howard Fund grant – Ed*] and I will make every effort to bring the whole boat to the May get-together.

Charlie Coish

Wingsails etc

I've read your edition 49 (May 2015) with great interest, and you'll see that I've emailed Mike Howard about the Northwest Area's various references to Yuloh. Am now writing separately about the extensive coverage in the same edition devoted to the wingsail.

I don't pretend to have digested all the information on pages 3- 19 of edition 49, but wonder if I'm your only reader to have raised her/his eyebrows on seeing the asymmetrical cross-section in Dave Culp's figure on page 3? Surely wingsails must

(a) be symmetric about the chord to get equal effectiveness on either tack, and

(b) have only convex surfaces if the shrink-fitting technique is to be used for the outer skin. ?

Another thought that crosses my mind is:

(c) that the adoption of ' Mast at 20% chord' (Fig2, p7) needs consideration. 20 % seems too little, especially if a trim-tab (Fig3, p 10) is to be added. Won't the centre of pressure then be well aft of the mast, so needing a long sheet, which Dave is understandably anxious to avoid?

The method of construction of my yuloh blades may be worth sharing, much as this differs from the wingsail. Weight – or more strictly mass -- was less of a problem for me, although ideally I'd like to achieve a geometry in which the centre of gravity is below the crutch, so the loom rises to near-upright when released, thus freeing the hands for other tasks and feet from risk of tripping and the paddle floats if accidentally dropped in the water.

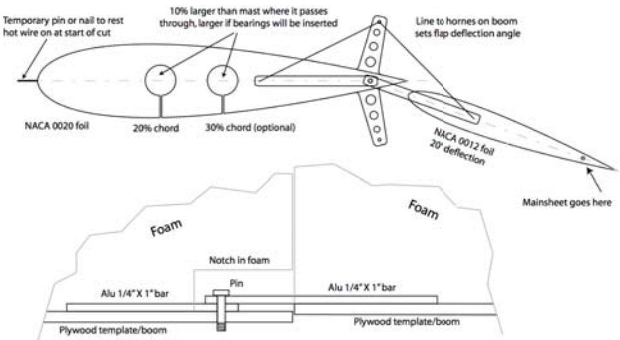
In rudder design a common practice is to position the centre of rotation about 25% the chord back from leading edge, to avoid either over- or under-steer. In the belief that similar considerations applied to my yuloh blade, I experimented with small variations in the range 23-27% (as my blade is wooden, this could be implemented using the Vernier principle). I wonder if similar questions were in Dave's mind in specifying both a 20% and a 30% chord in his fig 3 (p10)?

In the event, the performance of my blade seemed pretty robust in the face of this and other dimensional variations. Indeed, I remember another article in Catalyst 'how sails work' in which it was argued that, irrespective of the cross-sectional shape, lift would occur provided the air molecules on the lee surface 'overtook' those on the windward side. That is why I continue to feel the '25% chord' needs further thought.

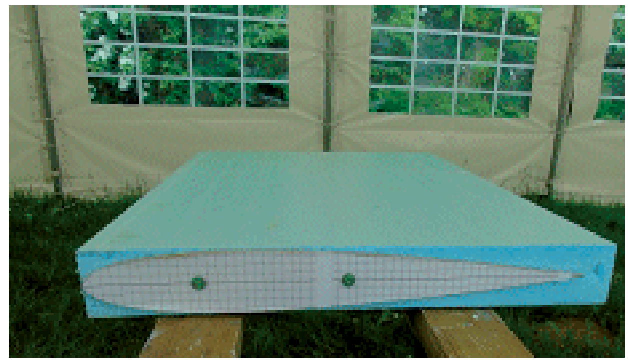
Mike Bedwell

Workshop to construct a Foam Wing Sail

On Sunday May 24th we held a workshop with the intention of building a wing sail as described by Dave Culp in Catalyst 49.

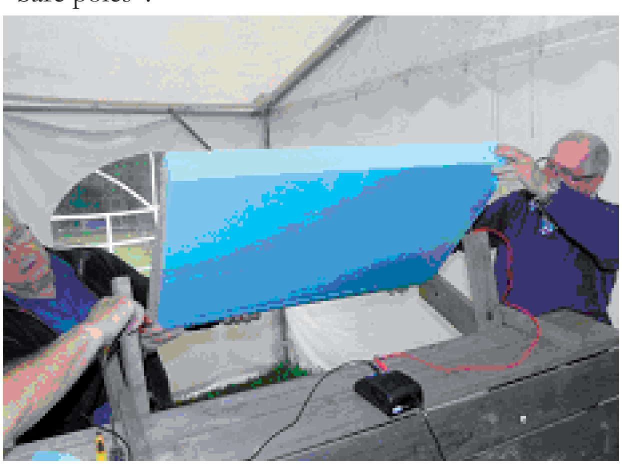


The plan view of the mechanism above gives general idea of how the wingsail works.

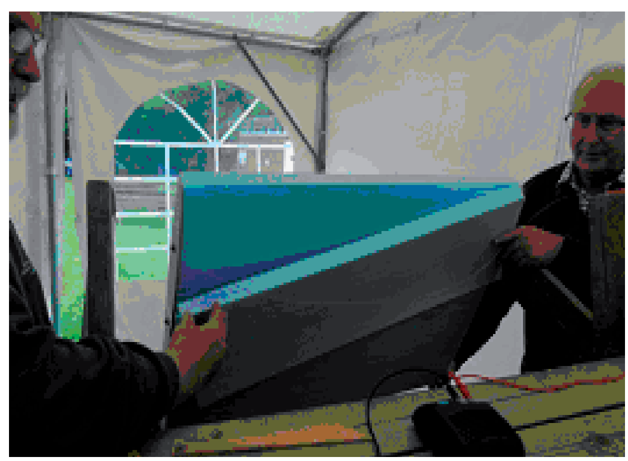


Template in place on the end of a foam blank

The idea was to use blue extruded polystyrene foam, which is manufactured for building insulation, and carve sections of a wing sail using a hot wire cutter. The sheets came approximately 2.4 metres long about 0.9 metre wide and 10cm thick. The scheme was to produce two sets of three 1 metre long slightly tapered symmetrical aerofoil sections, which would make a two-part wing, with a hinge mechanism separating the two parts. A camber could thus be induced gradually, developing a slot as the camber increased thus increasing lift. With no camber induced and a slack sheet, the wing would be extremely low drag and certainly no worse than "bare poles".



Starting a cut



Ending a cut

The first block of foam cut out with a template of the section fastened to it, at the other end a similar slightly smaller template was also attached.

The sections had been obtained from a web site and printed out having established the correct scale to be able to get the computer to print the sections full size, the paper was then stuck to plywood and the template cut using a band saw.

The hot wire was arranged between the legs of a picnic table on its side (it was handy and suitably rigid and gave enough working space; as on the trial run the wire appeared to lengthen when in use a pulley and weight system was set up to maintain constant tension and two people gradually lowered the block of foam guiding the cut with the templates trying to keep the direction of cut vertical to avoid getting a bow in the hot wire. The first attempt was not perfect as the wire had obviously dragged off course towards the end of the cut; but each subsequent cut was better.

That was the result of a days work but a great learning experience thanks to the hospitality of Simon and Sheila Fishwick at the Barton Turf Adventure Centre.

Lessons learnt? More practice needed, probably a thicker wire would generate more heat and allow greater tension and less deviation from the guidance of the template.

Fred Ball

Slight imperfections should sand out

Two sections showing the way the wing grows

Update: January 2016

Things have not progressed very far since the workshop last year. In fact the wingsail sections are still sitting in BTAC's workshop held by the same work pressure as has held this Catalyst.

I have a couple more sections to cut of the front foil the rear "trim tab" to make, and then I need to fix the imperfections shown in the picture above left. My idea here is not to sand them out, as that would reduce the foil section and might mean it will not all fit together. Instead I will glue the cut-off pieces back on and recut the section.

For the record the cutting was done using a 1.0m length of 28swg (0.375mm dia) Constantan* wire with a resistance of about 4 ohms per metre. With a 12 volt (variable) power supply attached we could cut the foam slowly but effectively although the wire did tend to drag in the middle making a curved cut at the final edge. As Fred noted, a hotter wire might have been better, but it must not be too hot else the whole lot melts away!

For the next cuts I intend to up the voltage to a maximum of 24 volts by connecting a 12v car battery in series with the power supply.

I still have the hinges and things to fabricate from plywood sheet, and find a suitable mast - probably a length of alloy tube.

I should end up with a sail of about 37sq.ft (3.5 sqm) which is comparable with the Optimist sail I have used on my sailing canoe.

Simon Fishwick

* Constantan - a copper-nickel alloy used for heating elements etc.

Morley Tethered Kite Sail Project – Final Report

Michael John Howard

EXECUTIVE SUMMARY:

Trials were conducted onshore and afloat. The results were both confusing and inconclusive. Whilst the onshore trials clearly showed that the Morley Tethered Kite Sail had the ability to self-trim, the trials afloat did not positively confirm this feature. The Morley Tethered Kite Sail rig remains unproven at full scale.

Moreover, in my opinion, as a small boat sailor with over fifty years experience, the Morley Tethered Kite Sail requires an inordinate amount of equipment and time to rig and is sensitive to adjustment for it to produce its maximum potential. It is not practical to mount this rig on a conventional sailing dinghy.

PREAMBLE:

The Morley Tethered Kite Sail was first brought to my attention in March 2010 during the inaugural meeting of the North West Local Group (NWLG) when Dr John Morley made a presentation to the members.

Dr Morley, a mathematician and Industrial Scientist of some standing, presented a very convincing argument to prove that his invention - the Morley Tethered Kite Sail - is a stable, highly efficient and self trimming rig, offering unique benefits to the small boat sailor. Dr Morley has spent the last twenty years perfecting the design of his rig with both manually adjusted and radio controlled static scale models.

I am neither a mathematician nor am I a scientist. I understand the fundamental Principles of Naval Architecture, Structural and Mechanical Design, Material Properties and the Laws of Nature. I spent my working life as a 'nuts and bolts' Design Draughtsman. I have been a small boat sailor, on and off, since the age of eleven.

Having established the credentials of the two parties involved in the Full Scale Trials of the Morley Tethered Kite Sail I can now freely admit that I was very interested in helping him to develop the idea further. In due course, a near full size Static Demonstrator (picture left) was designed and built by myself with the assistance of several members of the AYRS NWLG.

The trials of the Morley Tethered Kite Sail Static Demonstrator were designed to prove the concept of the rig, an invention developed by Dr John Morley over a period of twenty years.

The trials were conducted on Ainsdale beach, a large area of flat tidal sands bordering the river Mersey estuary, with open water to seaward. Five trials were conducted between the 9th April 2011 and the 2nd May 2011. Each trial lasted between two and three hours. Wind strengths of between eight knots and thirty knots were experienced, verified by the use of a hand held anemometer. Spring balances were used to measure the forces on the mainsheet and bending forces on the free standing mast. The trials highlighted weaknesses in the rig and several breakages were experienced. Modifications were ongoing until the final trials when the rig was almost tested to destruction in the strongest winds encountered (see Catalyst 42 & 43).

DESCRIPTION OF FULL SCALE RIG:

The Full Size Demonstrator of the Morley Tethered Kite Sail Rig was designed to be adaptable so that it could be fitted into any suitable sailing dinghy. In the event, an Enterprise Class sailing dinghy was chosen as the donor and a suitable dinghy purchased in December 2011.

Mast Support:

The mast support frame was designed to support an unstayed mast six metres in length. It was constructed from a modular aluminium extrusion system.
A centre rectangular section supported two non metallic bearings and was braced on each side by adjustable hinged and angled arms which rested on and where clamped to the forward thwart. A horizontal brace was located in the mast heel fitting on the foredeck. This was later through bolted to prevent undue movement. These were the only holes drilled into the Enterprise's structure.

Mast:

The mast was manufactured from a five metre length of 40 mm x 40 mm x 1.6 mm hollow square section aluminium. Two full length internal halyards and turning sheaves, top and bottom, were fitted and cleats provided on the outer side faces for belaying the halyards. A full length track with two integral sliders (Barton) was bolted to the forward face of the mast. The mast was braced by a steel wire rope 'diamond stay' on the aft face of the mast. The stay was tensioned with a stainless steel bottle screw, which was terminated on a circular flange which, in turn, was bolted to the upper bearing. The mast foot located in the lower bearing. A split pin prevented the loss of the mast in the event of a capsize. The mast location flange was provided with a horizontal 'steering wheel' constructed of 25 mm x 25 mm x 3.2 mm hollow square section aluminium on which was bolted a horizontal plate to support two combination fairlead/cam cleats, on which the two ends of the mainsheet were secured. Eyes were provided on the mast for a flag halyard, a turning block for the endless main sheet and the boom downhaul.

Boom:

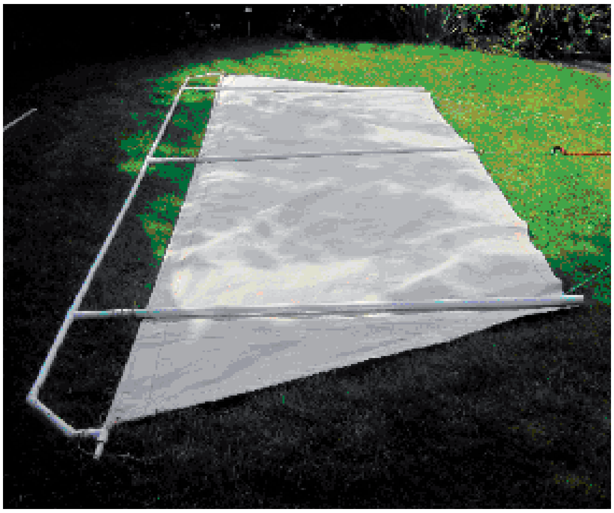
The boom was constructed of 25 mm x 25 mm x 1.6 mm hollow square section aluminium with a short length of track with integral slider (Barton) on its outer upper face. A special lug to suit the lower of the two sliders on the mast track was welded to the inner end of the boom. Because of the strain this lug imposed on the slider a clamp to hold the boom square to the mast was later manufactured and fitted. An eye was attached to the underside of the boom close to its inner end to which was attached a steel wire rope downhaul.

Luff Spar:

The luff spar, to which the sail was attached, was made from a length of 19 mm diameter GRP rod. The luff spar was connected to a swivel (Barton) at each end. The upper swivel was connected to the upper of the two sliders on the mast track while the lower swivel was connected to the slider on the track at the outer end of the boom. The sail had a luff pocket into which the GRP luff spar could be inserted.

Single Sail:

The sail was basically rectangular with the upper and lower short edges cut off at an angle. The sail was provided with a luff pocket and three full width horizontal batten pockets and GRP battens. In additional a uPVC frame was fitted to the sail to aid tacking. This device was christened the 'bowstring' (pronounced as in bow and arrow) and comprised a length of 20 mm bore uPVC pipe fitted parallel and forward of the luff of the sail. This tube was cranked at each end so that the uPVC pipe fitted



over the GRP luff spar. The tube was held in place by three lengths of 20 mm bore uPVC pipe bolted through the sail and the ends of the sail battens. The uPVC pipe was reinforced internally at its centre span with lengths of 12.7 mm diameter GRP rod.

Mainsheet:

The mainsheet comprised a 5 mm diameter synthetic braided rope (Dyform). Each end was attached to the sail with the bight passing through the two combi fairlead/cam cleats and then passed through a turning block suspended by a bungee cord from a fitting on the aft face of the mast. This arrangement kept the bulk of the mainsheet out of harm's way.

Bulls Horns:

These components were manufactured to facilitate mounting three sails in parallel. They were rigged at an early stage of the onshore trial fit. However they were never deployed in the sea trials. They comprised a 'bicycle handle bar' shaped arrangement of short lengths of 25 mm diameter aluminium tube connected together with a series of aluminium proprietary handrail fittings which were secured to the tube with grub screws. Lugs were welded to the centre section of tube of both the upper and lower Bulls Horns to connect to the Barton swivel mounted on the mast track slider and the swivel on the boom track slider.

Triple Sail:

Although one sail was ever produced, the original rig was designed to accommodate three sails in parallel. The centre sail (used in the trials) was slightly larger than the two wing sails.

Rigging The Sail:

The luff spar was first inserted into the sail luff pocket. The uPVC pipe assembly was then slotted over each end of the luff spar protruding from each end of the sail.. The horizontal uPVC tubes, which were permanently secured to the sail battens were then located in the relevant fittings positioned along the length of the parallel uPVC tube, forming a rigid assembly.

The swivel on the mast track slider was attached to the upper end of the luff spar and the sail hoisted until the lower end of the luff spar could be attached to the swivel on the boom track slider. The sail was then fully hoisted until the boom was pulled horizontal. A fixed span steel wire rope downhaul, attached to the lower face of the boom close to the mast, was then connected and the boom halyard tensioned to hold the boom in the horizontal position.

The Morley Tethered Kite Sail (one sail) took two people, working together, between 45 and 50 minutes to rig and about half that time to unrig and stow away. This is approximately twice the time it takes to rig the Enterprise sailing dinghy with its conventional Bermudan sloop rig, including erecting the mast.

Although the triple sail rig was never used in any trials, the time for one person to rig just the spars alone took well over an hour. I estimate it would take two people at least an hour to fully rig a triple sailed version of the Morley Tethered Kite Sail.

HISTORY OF PROJECT:

In 2011 I applied for and was fortunate in being granted £3000 from the AYRS Howard Fund (see Catalyst 38 & 39). The grant was to enable the manufacture and trials of a full scale demonstrator to take place. Dr. Morley had agreed to fund any shortcomings in the finance required to bring the trials to a satisfactory conclusion. I had agreed to give my time free of charge.

Following the successful completion of the Static Demonstrator trials, design work was immediately commenced on the Full Scale Demonstrator. Although the AYRS Grant had been awarded to me personally, due consideration was given to advice given by the inventor, Dr. Morley. As well as a continuous dialogue between us, Dr Morley provided a wide range of freehand sketches. These sketches were used as the basis for the production of a full engineering design, using my own extensive practical engineering knowledge and my sailing experience. The design was carried out using Autodesk INVENTOR solid modelling software so it was possible to produce not only 2D engineering drawings but fine detail for discussion as 3D images.

I was very careful not to produce a design which infringed on the basic concept of the invention. Whenever practical engineering problems were encountered, alternative solutions were presented to Dr Morley for discussion and agreement. Over the course of the project, I managed to fill three Lever Arch files with correspondence, sketches and other relevant paperwork. Although the design phase was completed during the Summer months of 2011 the manufacturing phase was interrupted by a personal health issue. As a result the full scale rig, which was designed to be installed on an Enterprise sailing dinghy was not completed until the late Spring of 2012, as during the first few months of the year we had experienced severe winter weather.

During the Summer of 2012 the additional supports, the 'Bulls Horns', for the three sails were manufactured and assembled. Only the centre sail was procured initially so that preliminary trials could be held before ordering the other two sails. After several attempts to rig the dinghy with the triple sail system, I decided to revert to only the centre sail for the preliminary sailing trials. These were due to be held on my return from my Summer holidays at the beginning of September 2012.

Unfortunately, we were delayed until mid October, the weather had deteriorated rapidly, and at this point I decided sailing trials were impossible so the project was 'put to bed' for yet another year.

During the early Spring of 2013, in an attempt to push things forward, I decided to rig the Static Demonstrator sail on a Seahawk 400 inflatable dinghy which I owned at the time. I was reasonably confident that I could handle this four metre dinghy with a three square-metre sail in a safe manner, if necessary, single handed. I had viewed this dinghy, rigged with a simple sail rig on the Internet (www.SailsToGo.com) so I was confident that I could configure it to sail with the Morley Tethered Kite Sail.

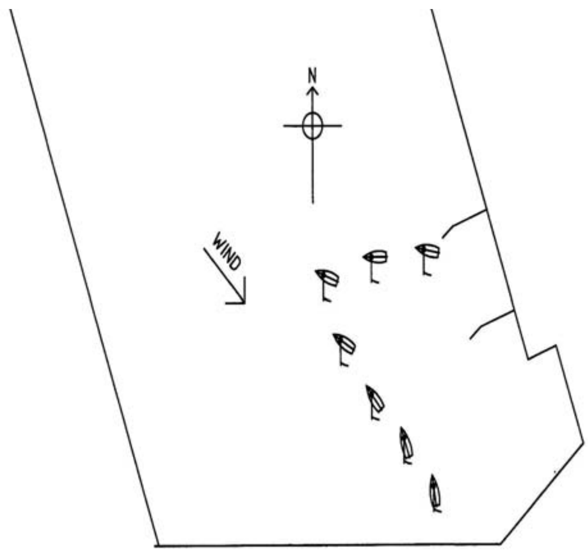
A timber frame, which supported the old bike frame pivot system from the Static Demonstrator, was made and secured to the inflatable dinghy with tensioned nylon straps. Two plywood leeboards were also made. The mast step could be attached to the wooden frame either way around, thus altering the relative position of the mast in relation to the bow of the dinghy. The hinged leeboards were secured to a pair of drilled aluminium angles so their positions could also be adjusted along the length of the dinghy. Steering was effected by coupling the two paddles together, one each side of the stern, in the same way as was demonstrated on the SailsToGo sail kit video.

SAILING TRIALS:

Between the 15th June and the 10th August 2013 seven separate trials were performed. Unfortunately, due to ill health, Dr Morley was unable to witness these trials. Several of the early trials resulted in gear failures or breakages. Most of the trials were conducted in two or three separate sailing sessions during the day, where adjustments were made to either the location of the mast step or the leeboard position relative to the mast step, in order to find the right combination.

The Morley Tethered Kite Sail was always deployed exactly as it was on the Static Demonstrator, that is to say, the two mainsheets were led back to the mast and secured there. At no time were the mainsheets deployed as per the Swing Sail or as in a conventional dinghy sail rig. The mast/boom and sail were, at all times, free to rotate independently.

When the sail is at rest, head to wind, and the mainsheet is slack, no forces are generated by the sail



Plot of Lake and Actual Course and Set of Sail

and it is free to flap like a flag. One or other of the main sheets must be tensioned in order to fill the sail with wind, thus allowing the sail to find its optimum angle between the wind direction and the sail by the entire rig rotating about the vertical centreline of the mast, until the sail finds its point of equilibrium.

In light airs, it was proven on the Static Demonstrator that the leeward sheet (the one going around the back face of the sail) required tensioning. This had the effect of drawing the boom forward and allowing the sail, once settled, to make an angle of approximately 80 degrees with the boom.

In a steady breeze, such as was encountered during the majority of the Seahawk Sailing trials, and likewise proven on the Static Demonstrator, the windward mainsheet required tensioning in order to fill the sail with wind. This has the effect of drawing the boom aft allowing the sail, once settled, to make an angle of approximately 100 degrees to the boom.

In every case when the sail was set, the mainsheet was tensioned at the absolute minimum to successfully fill the sail with wind.

All seven trials resulted in the same conclusion. In each case, when the dinghy was pushed away from the landing and the sail trimmed, the sail apparently continued to swing aft until it began driving the dinghy backwards. On several occasions, way on was produced by paddling the dinghy upwind with the sail full of wind. However, once the paddling was stopped the sail appeared to swing aft, pushing the dinghy backwards.

ANALYSIS OF SAILING TRIALS:

The explanation of what had really happened during the Seahawk 400 trials at first eluded me. I could only visualise the action and reaction as a crew member aboard the dinghy and I was convinced that the rig had continued to rotate until it had aligned itself perpendicular to the wind direction.

It was only when I adopted the role of a shore based witness and plotted the actual course on a plan of the lake did I begin to realise that rather than the rig rotating about the mast, the rig, in fact, had remained in a stable position 'on the wind' and it was the dinghy which had rotated about the rig, as illustrated in the Diagram shown left. If the sail had in fact rotated such that it was perpendicular to the wind, the dinghy would have finished up in the South East corner of the lake.

After much deliberation, I am of the opinion that while both the Theoretical Calculations and the Static Trials prove the Morley Tethered Kite Sail rig will work, the hydrodynamics of the Seahawk dinghy were incompatible and were unable to cope with the forces subjected on the hull shape and its appendages by the rig.

Having retraced my steps and analysed the results of the Seahawk Sailing Trials in more detail, first off, it is fair to say they failed primarily for the following reasons:

a. More attention should have been given to the relative positions of the C of E and C of LR under the different wind conditions.

b. A large and efficient rudder should have been installed.

c. An equivalent sail area closer to that normally employed in the dinghy's rig (4 to 5 square metres) should have been fitted.

To go back to basics using the 'rule of thumb' generally adopted for balancing a typical dinghy sail plan; the rig is positioned longitudinally, such that the Centre of Effort of the sail or the combined Centre of Effort of the sails, where there are more than one, is aligned vertically with the Centre of Lateral Resistance of the hull and its appendages. In all cases the rudder is ignored in this exercise so only the immersed hull and the keel, dagger board, centreboard or leeboard, are relevant. The side elevation of the dinghy with the rig aligned with the centre line of the dinghy, effectively head to wind, is used in this exercise as shown in FIGURE (1) .

In the case of the Morley Tethered Kite Sail rig a 'head to wind' side elevation would not be suitable as

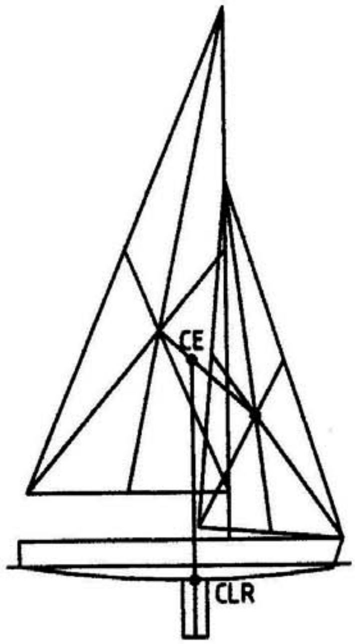


FIGURE (1)

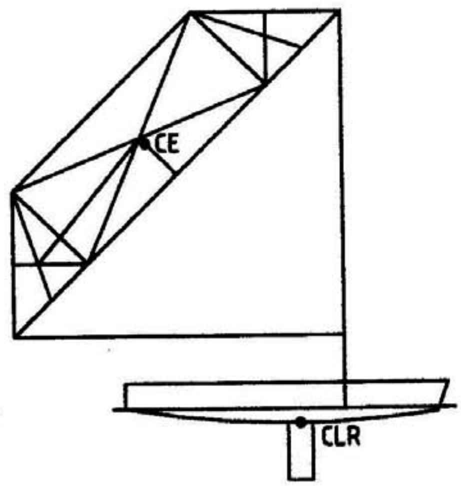


FIGURE (2)

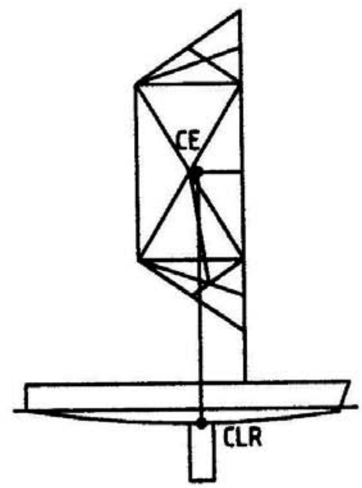
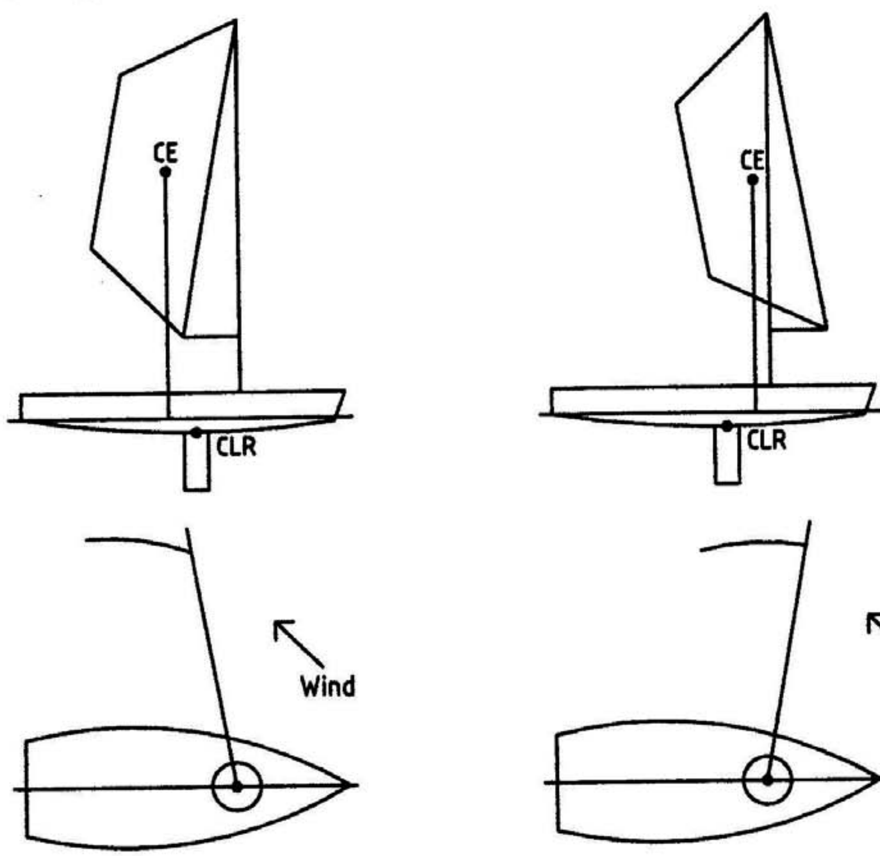


FIGURE (3)



Rig Position - Moderate Breeze

Rig Position - Light Airs

FIGURE (4)

illustrated in FIGURE (2). Instead I used an artificial side elevation where the boom was perpendicular to the centreline of the dinghy and the sail parallel to the centreline of the dinghy, as if head to wind with the boom held at right angles to the centreline of the dinghy, as shown in FIGURE (3).

Now, if we take a conventionally rigged sailing dinghy and push off from the shore, as the sails are trimmed the C of E moves forward of the C of LR, turning the bow away from the wind. As soon as steerage way is established the rudder can be activated to bring the dinghy back 'on course'. The rudder, being located at the maximum distance from the C of LR, provides the greatest lever arm possible for course correction, while the sail exercises a much shorter lever arm as the C of E is quite close to the C of LR.

As the dinghy heels the aft windward quarter looses buoyancy and the lee bow is immersed as a result of the shift in the Centre of Buoyancy which, in turn, relocates the C of LR forward of its original position. This gentle shift in the relative positions of C of E and C of LR creates slight weather helm, which prevents the dinghy from heading up into the wind. As any dinghy sailor knows, when a dinghy is overpowered by the wind, if the helm is released, the dinghy automatically comes up into the wind, often with quite dramatic results!

Now let us look at what happens when the same dinghy is fitted with the Morley Tethered Kite Sail Rig. As the dinghy pushes off from the shore and the sail is trimmed, a natural oscillation takes place before the sail finds its optimum position. As the boom travels through a thirty degree arc equally divided either side of a line drawn perpendicular to the centreline of the dinghy, the C of E of the sail is sometimes forward of the C of LR and sometimes aft of the C of LR.

If the boom settles say ten degrees aft of this perpendicular line, then the bow of the dinghy is turned into the wind. The rudder is much less effective in this scenario as both rudder and sail are acting on the same side of the C of LR whereas, in the conventionally rigged dinghy, they were acting on the opposite sides of the C of LR. The final effect was witnessed during the Seahawk 400 trials - the bow was turned to face into the wind and the dinghy, now offering no lateral resistance, was propelled stern first, to leeward. In fact, using a ten degree offset as illustrated in FIGURE (4). The C of E is between 350mm to 400 mm from the C of LR, creating a substantial rotational force.

However, whilst I believe that the above theory partially explains my failure to get the Seahawk dinghy to sail, Dr Morley has very different views. He has dismissed my theory, stating that as the two main sheets terminate close to the vertical centre line of the mast, the C of E of the sail acts at some point along the mast centreline. If indeed he is correct, then applying the same 'rule of thumb' for balancing a dinghy sail plan, then the C of E would always have been forward of the C of LR and the bow of the Seahawk dinghy would have been turned away from the wind and the dinghy would have been driven bow first to leeward.

He also believes that I failed to understand how the rig works, even though he had witnessed me trimming the very same sail on the Static Demonstrator on the many occasions when we carried out the land based trials on Ainsdale beach. Furthermore, Dr Morley believes that the rig, having been trimmed incorrectly, did, in fact, continue to rotate so that it finished up acting as a spinnaker, thus carrying the Seahawk dinghy stern first downwind as I originally believed it had. He has confirmed his theory by calculations, stating that excess trimming of the windward main sheet will result in the lowering of the Lift/Drag Ratio resulting in the rotation of the rig about the centreline of the mast.

In the October 2014 edition of the CATALYST magazine (Number 48), in the records of the AYRS North West Local Group meeting of the 28th June 2014, I commented about the failure of the Morley Tethered Kite Sail sailing trials; stating that, 'after last year's trials, using the original demonstrator sail mounted on an inflatable dinghy, I had failed to get the rig to set. I was now not convinced that the system would work'.

These comments were partially influenced by the disastrous results of the Seahawk Dinghy Sailing Trials themselves and by a series of articles I had studied on the Internet. The article by Steve Curtiss, a professional Engineer and small boat sailor, centred around his development of a small car toppable fast sailing craft. I believe this article has some relevance to the failure of the Morley Tethered Kite Sail to 'set' when mounted on a 'floating vessel'. The article and both my comments and Dr Morley's comments can be read in APPENDIX J to the full report which will be posted on the AYRS website.

FULL SCALE SAILING TRIALS:

On the 14th August 2013 an attempt was made to sail the Enterprise dinghy with a single Tethered Kite Sail. This resulted in gear failure when the mast support came loose from the foredeck structure. This was fairly easily remedied and a further trial was attempted on the 30th August 2013. On this occasion the wind increased to over 22 knots and I called off the trial. This was the last time I attempted to carry out trials of the Morley Tethered Kite Sail.

FINAL CHAPTER:

During the early Spring of 2014 I began to realise my sailing days were over. Whilst I remain reasonably fit and healthy, my confidence and ability to control a sailing dinghy was placed seriously in question. A lot of soul searching resulted in me making the decision to quit active water sports. This decision, obviously meant the end of the trials of the Morley Tethered Kite Sail Project.

After announcing my retirement from the Morley Tethered Kite Sail Project, Dr. Morley decided to try one last idea. In the Spring of 2014, I designed another full size rig for him. This time it utilised a 5.4 square metre windsurfer sail, where the boom was extended to windward to provide a seat for the helmsman. I oversaw the manufacture and assembly of this new rig together with its delivery on the 14th April 2014 to the Douglas Boatyard in Hesketh Bank, Lancashire. The rig was to be mounted on a lightweight four wheeled yard trolley and was to be sailed like a land yacht. No conclusive trials have been conducted (*and with Dr Morley's death (see below) it is unlikely that they will be - Ed*).

ORDER OF COSTS:

At the time the Grant from the AYRS Howard Fund was applied for, a preliminary budget of between £3,700 and £4,700 was estimated. At the termination of the project on the 5th July 2014 a total of £5,118.57 had been spent.

Of the total cost of £5,118.57, £3,000 is represented by the AYRS Grant from the Howard Fund. The balance of £2118.57 was funded directly by Dr. Morley. The costs include the purchase of the Enterprise dinghy and its combi road trailer, all materials, fabrications and proprietary parts, special tools, dinghy insurance, lake fees and maintenance. My time and all my associated travelling costs were given free of charge and amount to many hundreds of man-hours and a not so insignificant amount in fuel costs, spread over the three year period of my involvement in the project.

The costs do not include the original Static Demonstrator, the recent land based Full Size Demonstrator or the radio controlled model, all of which fall outside the remit of the Sponsor's project and were fully funded directly by Dr. Morley.

The overspend is directly attributable to the deviation away from a single sail configuration to the triple sail configuration which in the event proved too cumbersome for practical use. The Final Accounts can be viewed in APPENDIX H.

LESSONS LEARNED:

The first thing I have learned is how difficult it is to conduct any kind of experiment without the support of at least one other able bodied person, who is eager to share the workload. Often the simplest of tasks took ages to accomplish with only one pair of hands. I have to say, in his defence, that while I received a great deal of moral and technical support from Dr. Morley, he was around ninety years of age and unsteady on his feet and so was unable to assist me in any practical way with the manual tasks.

I also realise now that I should have been more insistent that a 'design freeze' was established early on in the project. Whilst some practical improvements were made to the rig during its development, the concept of the triple sail should have been abandoned at an early stage. It eventually consumed a vast amount of man-hours and considerable extra expense only to be finally set aside.

CONCLUSION:

The conclusions that I have drawn from the project are:

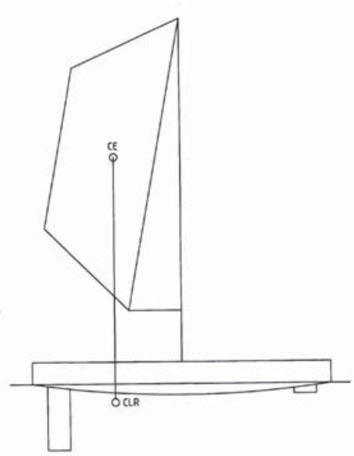
- The Invention, in its current form, is unproven at full scale. It is a disappointment to me that no definitive conclusions were reached.
- The project was allowed to deviate from the original programme on several occasions, resulting in the elongation of the original timeframe and a consequential overspend.

In hindsight, a more structured approach, disregarding the Inventor's many improvements and modifications, may have resulted in a more positive outcome and less wasted time and expenditure. However, as the object of the exercise was to prove or disprove the practicality of the Invention, the Morley Tethered Kite Sail, it was only fair to succumb to the Inventor's whims to allow him the maximum technical input.

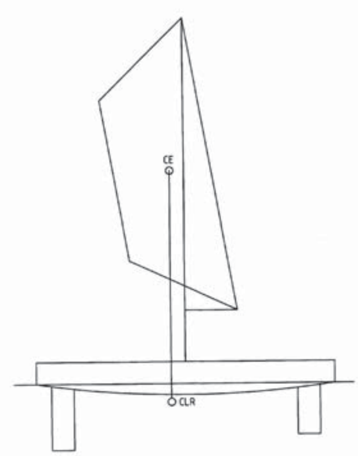
With regards the suitability of the Morley Tethered Kite Sail as an alternative to the conventional Bermudan sloop rig normally fitted to a sailing dinghy, I have to say that I found that the Morley Tethered Kite Sail required more individual parts, took longer to rig, and involved several 'fiddly' connections where small pins and pin locking rings required the involvement of two persons.

Dr Morley maintains the Morley Tethered Kite Sail is very sensitive to adjustment in order for it to be set efficiently. This is not a trait that is acceptable in a sailing dinghy. The normal Bermudan sloop rig of a typical sailing dinghy is very forgiving and to be faced with the situation where the dinghy is being blown mercilessly downwind due to badly adjusted sails is intolerable.

Finally, we come to how a sailing dinghy fitted with a Morley Tethered Kite Sail can be 'balanced'. There is no doubt in my mind that the rig finds different points of equilibrium in differing wind conditions. In order to provide a 'variable geometry' keel, I would like to suggest that two keels, each set on the centre line of the dinghy at a maximum distance apart may be required. This set up lends itself to using a proa type of craft, where the vessel is shunted rather than tacked into the wind. The mast would be set at the centre of the main hull (ama) and the sail would always be to leeward, out of harms way. A pair of vertical sliding dagger boards, hinged centreboards or leeboard,s would be positioned at each end of the windward float (aka). The two retractable keels can also be used for steering the proa, which is a well established method.



C of LR aft of midships in a steady breeze



C of LR close to midships in light airs

My final word, if nothing else, the AYRS Howard Fund has allowed this project to go ahead. It is a shame that more projects, whether deemed practical, foolhardy or downright stupid do not apply for funding from what remains a largely untouched 'pot of gold' held by AYRS for this very purpose.

THE TETHERED KITE SAIL PROJECT

J G Morley

[This article was John Morley's response to Mike Howard's final report on their prokect. In his covering email Dr Morley gave a clear indication that he hoped the work would continue. Unfortunately Dr Morley died in January 2016 so these are his last words on the subject - Editor]

In the account of the North West Forum meeting of 15th March 2014, published in Catalyst (October 2014) the tethered kite sail project was discussed. I was not present at the meeting but the general consensus, as reported by Mike Howard, was that the system would not work as designed. As a consequence it was suggested to me that the failure of the kite sail experiment should be written up so that others can learn what went wrong and not try to reinvent it. Owing to my age and general infirmity, I was not present at the trials reported on by Mike Howard and so cannot comment from first-hand experience. However I remain convinced that the concept is viable. Its theoretical basis is sound and is based on elementary mathematics. The action of the sail has been confirmed using working models and test rigs of various sizes. In my view the most likely reason for the reported failure is a lack of a complete understanding of the operation of the sail. The various opinions being put forward at the meeting seem to support this view. I have tried to describe the sail in some detail in this article in the hope that all confusion will now be eliminated.

The objectives of the design are as follows:-

To provide considerable aerodynamic lift so that hull drag is reduced to very low levels.
To reduce heeling to negligible levels.
To provide automatic stabilisation against sudden gusts of wind from the wrong direction.
Because the rig is designed to be partially airborne it is desirable to reduce its weight as much as possible. There are potential applications in the wind surfing area where the self-stabilising mechanisms reduce the need for athletic prowess. (All the Thrills without the Spills or Wind Surfing for Wimps).

GENERAL DESIGN

A simple working table top model of a tethered kite sail rig has been constructed in order to explain the mode of operation of the design. This is shown in Figs.1, 2, and 3. The model simulates the Static Demonstrator Sail for which I produced the basic design and which Mike Howard constructed and tested successfully, with my participation, in April 2011. It was this rig that he subsequently found impossible to set when fitted to an inflatable boat.

The North West Group seem to have had some difficulty in constructing table top working models which operate with a desk fan, so I will describe the construction of this example in some detail. As shown in the photographs of the model, the mast is unsupported and the sail assembly is free to rotate about the mast. In the model the mast is formed

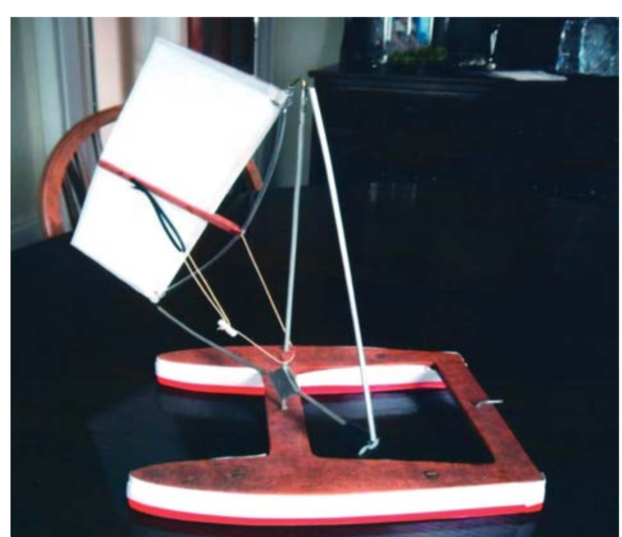


Fig 1

from a length of steel wire (a bicycle wheel spoke) round which a small bore aluminium tube forms a loose fit. A small metal plug at the top of this tube acts as a bearing rotating against the sharpened tip of the steel wire mast. The rest of the structure utilises small bore aluminium tubes, obtained from a model shop, and forms two triangular structures one on each side of the mast. The lower section of the 45 degree section forms the boom. The luff spar of the sail is formed from another aluminium tube of slightly larger diameter than those forming the rest of the structure. It fits over the 45 degree spar thus allowing the sail to be rotated about its luff spar whilst the luff spar maintains an angle of 45 degrees to the vertical. Three battens support the sail material. The offset angled sail produces a lifting force which opposes the heeling effect. By a suitable choice of geometry the lifting force can be made to cancel the heeling effect.

The sail needs to be rotated about its luff spar to various fixed positions. This is achieved using two main sheets one on each side of the sail. These are shown tensioned by rubber bands in the model. The line forming the main sheets takes a few turns about the foot of the mast to form a frictional grip due to the tension generated by the rubber bands. It is held in position there by a conical wooden block.

The operation of the main sheets is facilitated by the curved spar, carried forward of the luff spar, round which the lee main sheet passes. This feature was added to the static demonstrator sail by Mike Howard. The weight shown at the apex of the smaller triangular structure simulates the position of the helmsman. His weight balances the off-axis weight of the sail. Photographs of a test rig demonstrating the feasibility of this arrangement are shown on Figs. 4 and 5. In this rig windsurfer deck plates were used as bearings and the mast consisted of concentric aluminium tubes. A length of stainless steel tube was inserted into the lower part of the mast to strengthen it. The rig shows the proposed position of the helmsman. A windsurfer sail was utilised. The behaviour of this test rig supports the concept of a small catamaran comprising two surf boards and a large windsurfer sail.

MODE OF OPERATION OF THE SAIL

If the sail is fixed, so that it lies in the same plane as the boom and the rest of the framework, the sail assembly will rotate about the mast so that the sail is downwind in a wind-vane position. (see Fig. 1). If the sail is now rotated about its luff spar to a new fixed position a sideways force will be generated and the sail will move away from the downwind position. (see Figs. 2 and 3). The mechanism of this process is described below.

We first have to consider the basic aerodynamic characteristics of a sail. Fig 6 shows a flat plate aligned at an angle θ (angle of incidence) to the air flow. The airflow produces two forces - Lift (L) acting perpendicular to the air flow and Drag (D) acting parallel to the air flow. These can be taken as acting at the Centre of Effort (C of E) of the system. The position of the C of E will depend on the actual shape of the aerofoil and generally

Fig 2

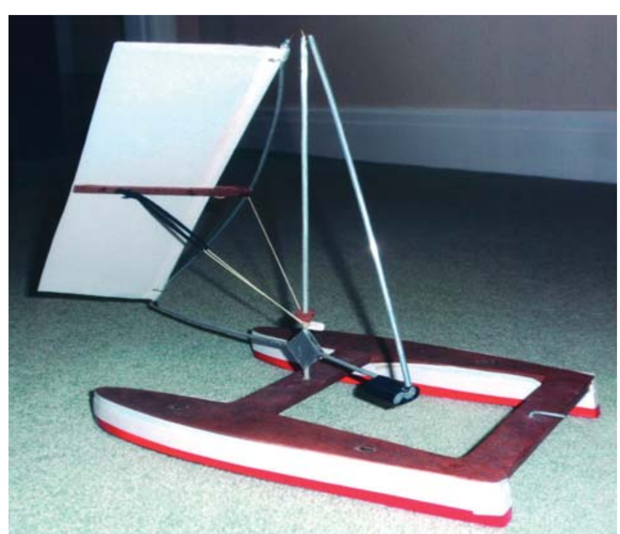


Fig 3

on the value of the angle of incidence but will be approximately one third of the distance from the leading edge to the trailing edge.

Theoretical values of L and D (measured in pounds) can be obtained from the following formulae.*

$L = 0.00119 \times C_L \times S_A \times V^2$ 1

$D = 0.00119 \times C_D \times S_A \times V^2$ 2

where C_L and C_D are coefficients which depend on the aerofoil in question and have to be obtained experimentally. S_A is the area of the sail in square feet and V is the velocity of the wind in feet per second. Conversion factors are necessary if other units are used.

In Fig.7 values of C_L and C_D are shown for a Finn sail* as a function of θ the angle of incidence. C_L is small when θ is small. (Theoretically it should be zero when θ is zero). It increases rapidly as θ increases. C_D has a finite value when θ equals zero and increases less rapidly as q increases. It follows that the ratio C_L/C_D will increase initially as θ increases as shown in Fig.7. The values of L and D in equations 1 and 2 above change similarly with changes in θ. Eventually the ratio L/D reaches a maximum value. Further increases in θ cause increases in C_L but the corresponding increase in C_D reduces the value of C_L/C_D and hence the ratio L/D.

*C. A. Marchaj. Aero-Hydrodynamics of Sailing. Second Edition. Reprinted 1993 Published by Adlard Coles Nautical. 35 Bedford Row, London WC1R 4JR

EQUILIBRIUM CONDITIONS

We now consider the equilibrium of the system. Fig.8 shows the sail in plan view. The mid-section of the sail is shown as representative of the whole. The sail has been rotated about its luff spar by an angle ϕ from its initial wind-vane position. As a consequence it now has an angle of incidence θ to the wind direction. The boom and the rest of the assembly have been rotated through an angle λ. We now have a lift force L_H developed at the Centre of Effort of the sail. The subscript denotes the horizontal component of the lift force. It is the horizontal component of the lift force which causes the sail assembly to rotate about the mast. This will change as the angle made by the sail to the vertical changes. This needs to be considered because the angle made by the luff spar to the vertical, when viewed down wind, changes as

Fig 4

Fig 5

the angle λ changes. When λ is zero, the luff spar is vertical. When λ is 90 degrees the luff spar makes an angle of 45 degrees to the vertical. For intermediate positions the luff spar makes an angle ψ to the vertical where ψ is given by the expression:
$\tan \psi = \sin \lambda$
The drag force D is unaffected by the angle of the sail to the vertical. It too acts at the centre of effort of the sail.

The horizontal component of the lift (L_H) therefore varies between 100% and about 70% of L as λ changes from 0 to 90 degrees. This implies that the sail will exert an overturning force at small angles of λ. However, for these conditions, the angle of incidence θ is very small as is the value of L. The overturning effect is negligible because L is negligible. The value of L only becomes significant as λ approaches 90 degrees. For these conditions the inclination of the luff spar approaches 45 degrees so that the overturning force and lifting force come into balance.

Returning to Fig.8. The sail has been rotated through an angle ϕ from its initial wind-vane position and prevented from further rotation about its luff spar. As a consequence the angle of incidence θ will change as the angle λ changes. A horizontal lift force L_H and a drag force D are produced. Both of these can be assumed to be acting at the Centre of Effort of the sail. We first assume that the ratio C_L/C_D is less than C_L/C_D max. The force L_H tends to rotate the sail in an anticlockwise direction and the drag force D to rotate it in a clockwise direction. The magnitude of these effects is given by their couples, defined as the force multiplied by the perpendicular distance between its line of action and the axis about which the system rotates. These are therefore L_H x p and D x q. (p and q are effectively the lever arms on which the forces L_H and D are operating). At equilibrium these two couples must be equal in magnitude and opposite in sign. If ϕ is increased to a new set position, θ is also increased and L_H is increased. From Fig.7 it can be seen that C_D, and so D, will also be increased but by a much smaller amount. The overall effect is to cause the sail assembly to rotate in an anticlockwise direction increasing λ. As λ increases θ is reduced so that L_H falls. Eventually equilibrium is again restored. The value of λ can be increased in this way, by increasing ϕ, until θ has been increased to the point at which C_L/C_D (Fig.7) is a maximum. This is the optimum situation for sailing into wind. Further increases in ϕ will now cause a reduction in λ because the ratio of C_L/C_D is now less. Increases in ϕ produce increases in θ and hence higher values of L but the corresponding larger increases in D cause the ratio L/D to fall further thus reducing the magnitude of λ. Equilibrium can still be maintained given appropriate conditions. These are discussed below as an aspect of stability. It will be remembered that it is the horizontal component of the lift L_H that is instrumental in causing the sail assembly to rotate.

STABILITY

So far only equilibrium conditions have been discussed. In order for the sail to be stable, a restoring force must be generated if the sail is

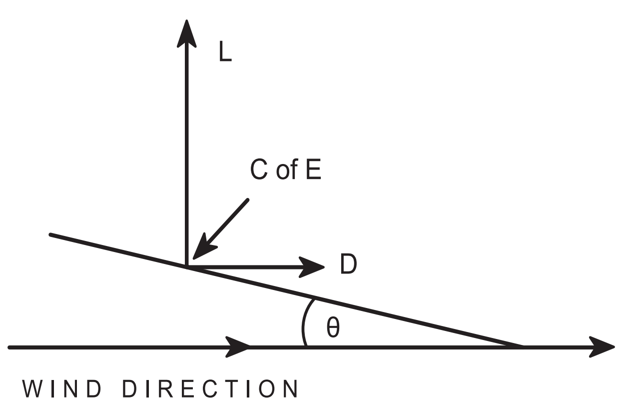


Fig 6

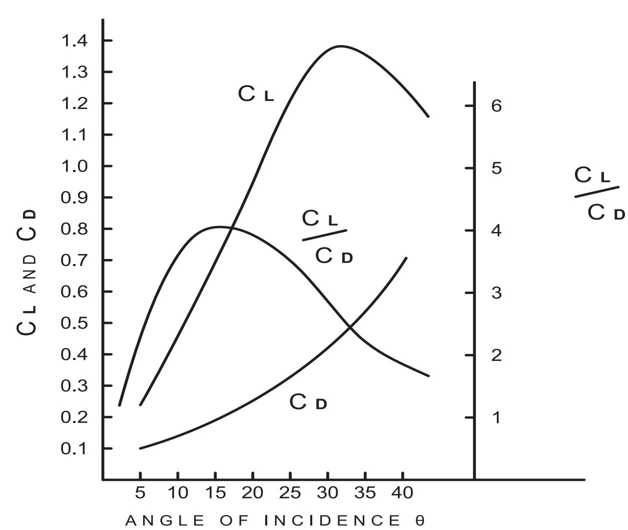


Fig 7

displaced from its equilibrium position. We first consider the equilibrium position to be set with C_L/C_D less than C_L/C_D max. From Fig.8 it can be seen that such a force will be generated if there is a sudden change in the direction of the wind. This will have the same effect as a sudden deflection of the sail assembly with the wind direction held constant. The overall result is to rotate the sail assembly about the mast so that it takes up the same equilibrium position but now relative to the new wind direction.

We first consider a change in the wind direction which has the same effect as the sail assembly being deflected in an anticlockwise direction. As λ is increased the angle of incidence θ will decrease since ϕ is fixed. This reduces L_H. As λ is increased, p will also be reduced. Meanwhile D and q remain substantially unaltered. This effect will increase the greater the displacement so producing a restoring force. The reverse happens if the sail assembly is deflected clockwise so that λ falls. The angle of incidence θ now increases as does L_H and also the arm of the couple p. Thus the sail assembly will return to its set equilibrium position relative to the new direction of the wind.

Other factors become important when the fluctuations in wind direction become large. These depend on the aerodynamic characteristics of the sail. It can be seen from Fig.7 that, for a Finn sail, the angle of incidence θ can increase by a considerable amount beyond C_L/C_D max with little change in the C_L/C_D ratio. We consider a sudden change in wind direction which produces this level of change in θ and the corresponding change in λ. The ratio C_L/C_D is little changed but the distances p and q have changed considerably. (Fig.8). Thus a restoring force is generated. If there is a sudden large wind change in the other direction the sail may produce a negative lift. It can be seen from Fig.8 that this will augment the drag force D in restoring the sail to its equilibrium position Another factor which has to be taken into account is the movement of the Cof E of the sail towards its geometric centre as the sail becomes face on to the wind. If all else fails the sail could be rotated about its luff spar to the wind-vane position and then reset as necessary. It is of interest to note that the desk top model shown in Figs. 1, 2 and 3 will reset itself after very large changes in wind direction.

We now have to consider the effect of fluctuations in the velocity of the wind. This is important since the boat is proposed to be partially airborne. A sudden gust of wind could produce lift off. What is required is an automatic mechanism which will cause the sail to spill wind as the wind speed increases. This can be done most conveniently by arranging for the main sheets to have an elastic component. This is shown as a rubber band in Figs 1, 2 and 3. In this model the main sheets are attached to the sail near its centre of effort so that the windward main sheet carries most of the aerodynamic load. As the load increases, the elastic insert extends thus reducing the angle of incidence of the sail, and spilling wind. With a suitable level of elasticity the boat can be prevented from becoming airborne whatever the wind speed.

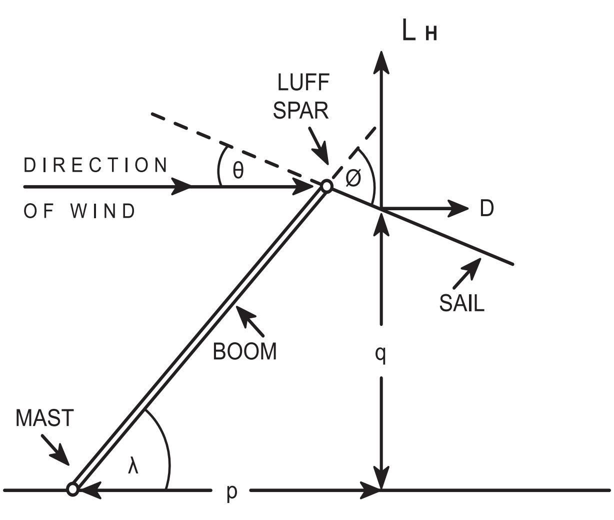


Fig 8

APPLICATION OF THE SAIL

Because heeling is reduced to negligible values a much larger sail could be utilised than would be practicable in a conventional rig. Also, because the sail is self-setting, changes in course do not require resetting of the sail. Tacking is, of course necessary, the sail being rotated about its luff spar through the wind-vane position to be set for the opposite tack. The sail differs from a conventional rig in that, under working conditions, the aerodynamic forces generated by the sail are delivered at a point at or near the foot of the mast. It is envisaged that the directional stability of a boat will be maintained by using a dagger board, positioned aft of the mast, together with a rudder, positioned further aft. This configuration is currently under investigation using a radio controlled model. It is hoped that a report on this work will be available shortly.

APPENDIX

Since preparing the detailed account of how the Tethered Kite Sail is designed to operate, I have received further information from Mike Howard regarding his unsuccessful trial of the rig. This was carried out using the original demonstrator sail (Catalyst, July 2011. p.14) mounted on a Seahawk 400 inflatable dinghy.

Mike had rigged the sail so that it had headed into wind with the boom approximately at right angles to the fore and aft axis of the dinghy. This would approximate to the optimum condition for sailing into wind. In order to obtain more thrust from the sail he gently hauled in the main sheet, increasing the angle ϕ (Fig 8) and the angle of incidence θ. This increased the aerodynamic force developed by the sail but reduced the Lift to Drag ratio. This caused the sail and the boom to move aft as predicted by the theory. The sail will continue to head into wind provided that, if θ increases further, the fall in the Lift to Drag ratio is more than compensated for by an increase in the ratio p/q (Fig 8). However, at some value of ϕ this will no longer be the case. Beyond this point the sail would be expected to continue to swing downwind with θ continuing to increase as λ falls. This corresponds to the situation that Mike encountered "the boom and the sail rotated towards the stern of the dinghy until, very full of wind, it pushed us backwards". This situation can be reproduced using the table top working model described above. The sail now acts much as a spinnaker driving the boat downwind.

Of further relevance is the fact that the sail area used by Mike is comparable in size to the profile of the dinghy. This would add considerably to the aerodynamic drag and increase the difficulty of sailing into wind.

JGM

JOHN GODFREY MORLEY – An obituary

John was an Industrial Scientist and worked on many 'cutting edge' projects including the carbon fibre fan blades for the Rolls Royce RB211 jet engine. In fact, he designed and helped set up the first carbon fibre production unit in the UK.

In retirement, John had been pursuing his dream of seeing his invention - The Morley Tethered Kite Sail - demonstrated at full scale. Over the last twenty years he had witnessed several abortive attempts to produce the result he so desperately desired. The last series of trials were conducted by a fellow AYRS member with the aid of a grant from the AYRS Howard Fund.

John was a founder member of the AYRS North West Local Group and attended regularly until poor health intervened. He utilised his vast intellect to comment on most of the subjects discussed at the AYRS local meetings, although not always agreeing with the majority. He died on the 12th January 2016 aged 91.

The Hebridean wind vane.

John Fleming

The "Hebridean"™ Wind Vane was brought to AYRS' attention during 2014 and we exhibited an example at the subsequent London Boat Show. It is unusual in that it is designed for amateur construction and John Fleming (an AYRS member) sells plans and some hard-to-source parts. It is subtly different to other vanes we have seen in that it is a single unit that all pivots on a bearing on the stern of the boat steered. This article explains how it works.

The Principle

There are 3 main components to all servo pendulum wind vanes including a Hebridean:

1. The vane (which deflects one way or the other when the boat is off course)
2. The vane support assembly
3. The pendulum (which swings from side to side pulling lines to the tiller to correct course when the vane deflects)

and a push rod often housed in the vane support, very often within a tube which links the system together.

Almost all servo-pendulum wind vanes (except a Hebridean) have the vane support assembly fixed rigidly to the boat. The pendulum pivots on it when it swings. As a result the connection between push rod and pendulum is difficult for DIY sailors to construct. (See Fay Marine or Walt Murray designs which are complex). Most servo-pendulum designs consequently use gears to connect the push rod impulse to the swinging pendulum but these cannot easily be duplicated for DIY construction.

The Hebridean is different. The vane support is not fixed. It is a wooden frame that supports the vane at the top hanging in the air, and the pendulum below dipping into the water. The whole assembly pivots on the stern when the pendulum swings. When the pendulum swings, the push rod swings with it; so the connection is simply achieved with just one lever.

The Pendulum.

This dips 600mm into the water at the stern edge on in the direction of flow. When it is rotated about an axis parallel to the leading edge of the pendulum the water flow pushes the whole wind vane assembly to the side about its pivot. How far it swings depends on how much the push rod has rotated the pendulum. There comes a point when the face of the pendulum blade is in line with the water flow, and then will not swing any more. This is because the pendulum slants back in the water by 32 degrees from the vertical. Otherwise, if the pendulum was vertical in the water, it would swing out of the water altogether. The maximum the pendulum can swing to the side is 30 degrees because the pendulum rotation is set at no more than 30 degrees either way.

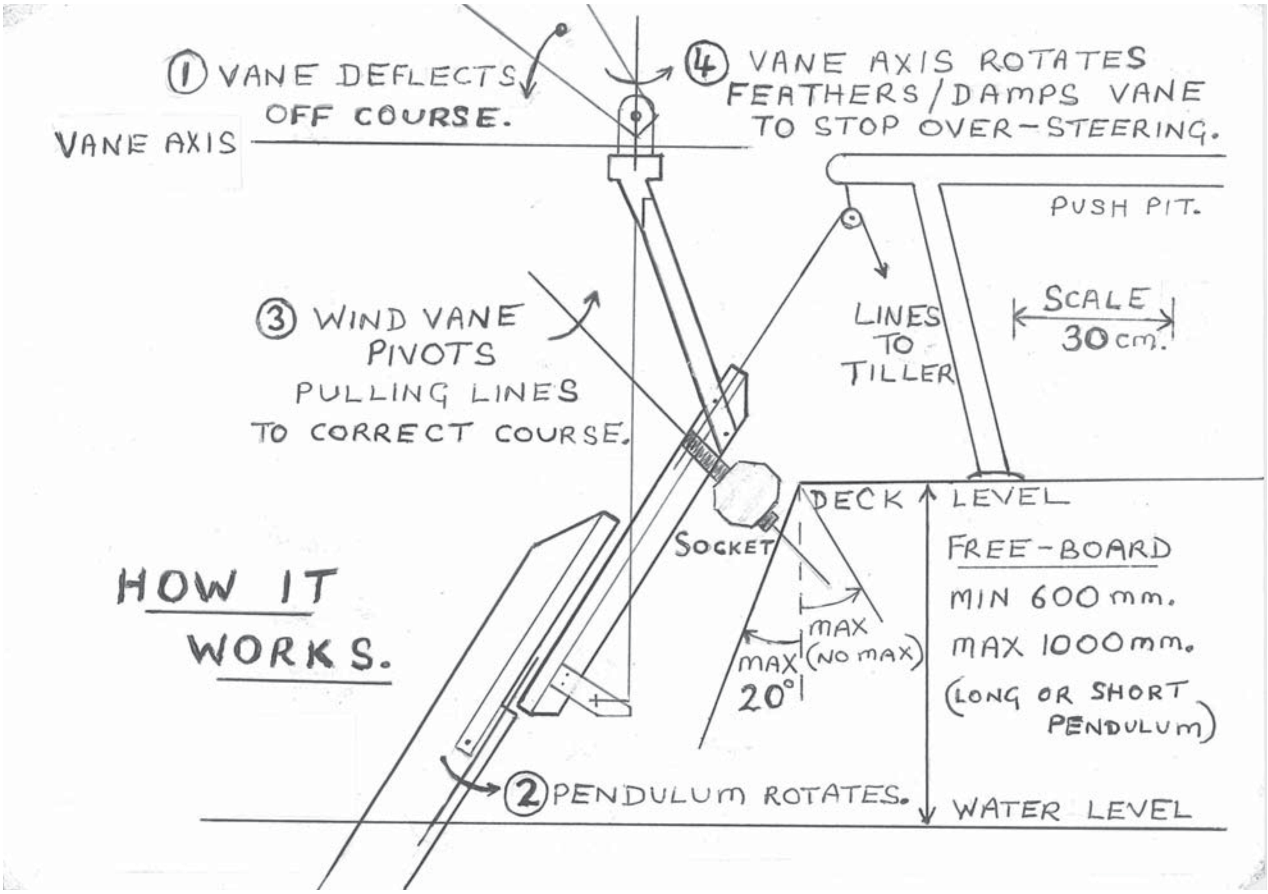
The vane

All servo pendulum wind vanes incline the axis on which the vane deflects at an angle to the horizontal (except the Hebridean where it is truly horizontal). This varies as the boat heels but it is generally about 20 degrees with the boat level. As a result, the rudder angle (R) is proportional to the degree the boat is off course (W, wind course error). The more the boat is off course the greater is the rudder angle, and as the boat returns to the correct course the rudder angle reduces. With the boat off course the vane deflects and there comes a point when the vane "feathers", and will not deflect any more. As the boat approaches its correct heading, the vane is pushed upright in the wind bringing the pendulum and tiller back in line. As a result the boat is steered the same way a good helmsperson does, under control with the rudder angle reducing as the boat approaches its correct heading. A vane that deflects on an axis that is horizontal does not normally do this. The vane does not "feather" when it deflects. There does not come a point when the vane is edge on into wind. As it deflects the wind continues to push it down with no limit. It only returns once the boat is back on course, which is too late. It steers the boat by pulling the tiller full-over one way or the other and never for long in between. It over-steers. There is no damping of the wind vane.

The vane axis of the Hebridean is horizontal but when the pendulum swings it rotates the vane axis into wind. This is what "feathers" the wind vane. This damps the vane (as others do) and stops it over-steering the boat one way or the other on the tiller. As you see from the diagram "How it works", the vane is feathered by the swing of the pendulum. In conventional wind vane systems the vane is feathered (damped), then the pendulum swings, pulling lines to the tiller, so correcting the course.

The advantages of a Hebridean's horizontal vane axis

- It is more sensitive in adverse wind and wave conditions.
- The vane is only damped when the pendulum swings. Until it swings vane deflection is unlimited. The more delay there is in pendulum swing the more the vane deflects rotating the the pendulum. The more it rotates the quicker it (and the tiller) swings.
- If the boat is moving fast through the water this delay is minimal, so vane damping is rapid as the pendulum corrects course. The slower the boat is through the water the more is this delay allowing more time for the vane to deflect rotating the pendulum. In difficult wind and wave conditions (with the boat moving slowly throught the water) the sensitivity of the system is used to advantage keeping the boat on course with more pronounced rudder movement.



- With the Hebridean normally R (the rudder angle) is three-quarter of W (the angle off course); but in these situations when vane damping is delayed, R can momentarily be more than 3/4W, correcting the course faster. A vane mounted on an axis inclined 20 degrees to the horizontal cannot do this.

Construction

The construction is simple for the DIY sailor. The wooden frame that pivots in a socket pulling lines to the tiller to correct course, not only supports the pendulum as it rotates in the water but also the vane as it deflects in the wind. So the push-rod connection between the two is easily achieved.

There are 30 metal items ready cut to length from standard stainless steel sections, rods, bars, nuts and bolts, all provided in the kit. They need drilling, shaping and bolting to the frame. No bearings are incorporated and no welding is required in its assembly. Carbon fibre is provided for the push rod and vane. No part of the wind vane is manufactured by machine operators or specialists. All of it has to be self-built from the kit, and has been designed with that in mind. The tools you need are what you would find in any reasonably good workshop at home. There are some you might need to buy such as a hole cutting set worked off a drill, some taps for threading holes in metal and a good quality set of drills. A reasonable skill in woodwork is an advantage, and the ability to saw and drill accurately is fairly important. Written guide-lines and drawings as to how to achieve this in all cases are in the manual.

For more details contact John Fleming directly or visit his website www.windvaneselfsteering.co.uk.

Triumph – a 12 ft Marine Ply Kite Towed Trimaran

Chris Watson

I produced this design just before I retired from teaching to enable a group of students to build a small boat during the school activities week on a very limited budget of well under £100. There were 23 students and their ages ranged from 11 to 18. It was essential to have a simple design and method of construction, but at the same time, one that kept them occupied with numerous small tasks that were both interesting and would produce quick results.

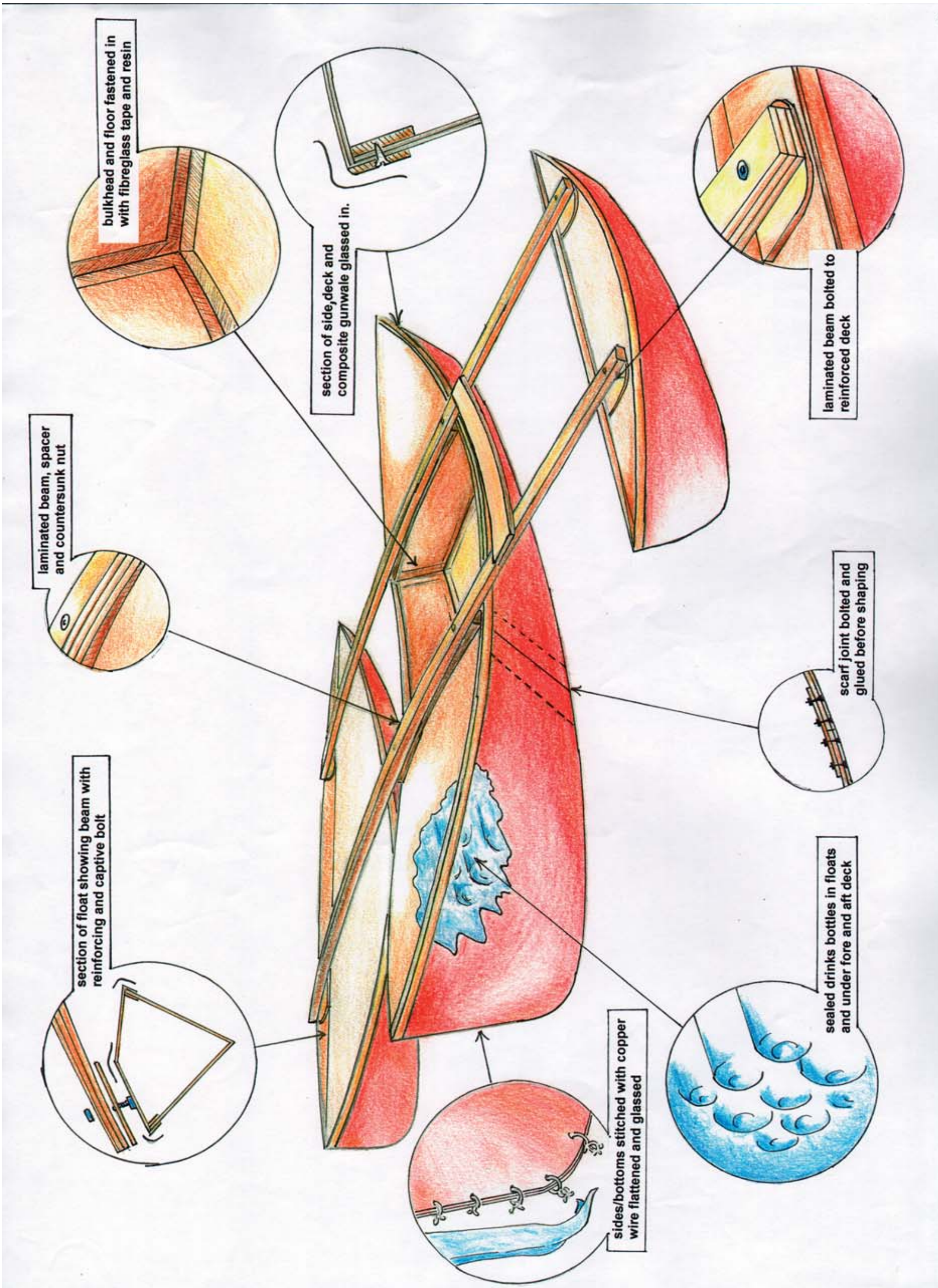
The hulls were completed in 4 school days, which amounted to 24 hours. When not working on the main project, the younger children each made a fibreboard model boat. In the meantime we made the two large "Eddy" kites out of industrial nylon on a school sewing machine rather than attempt to make a set of spars and sails.

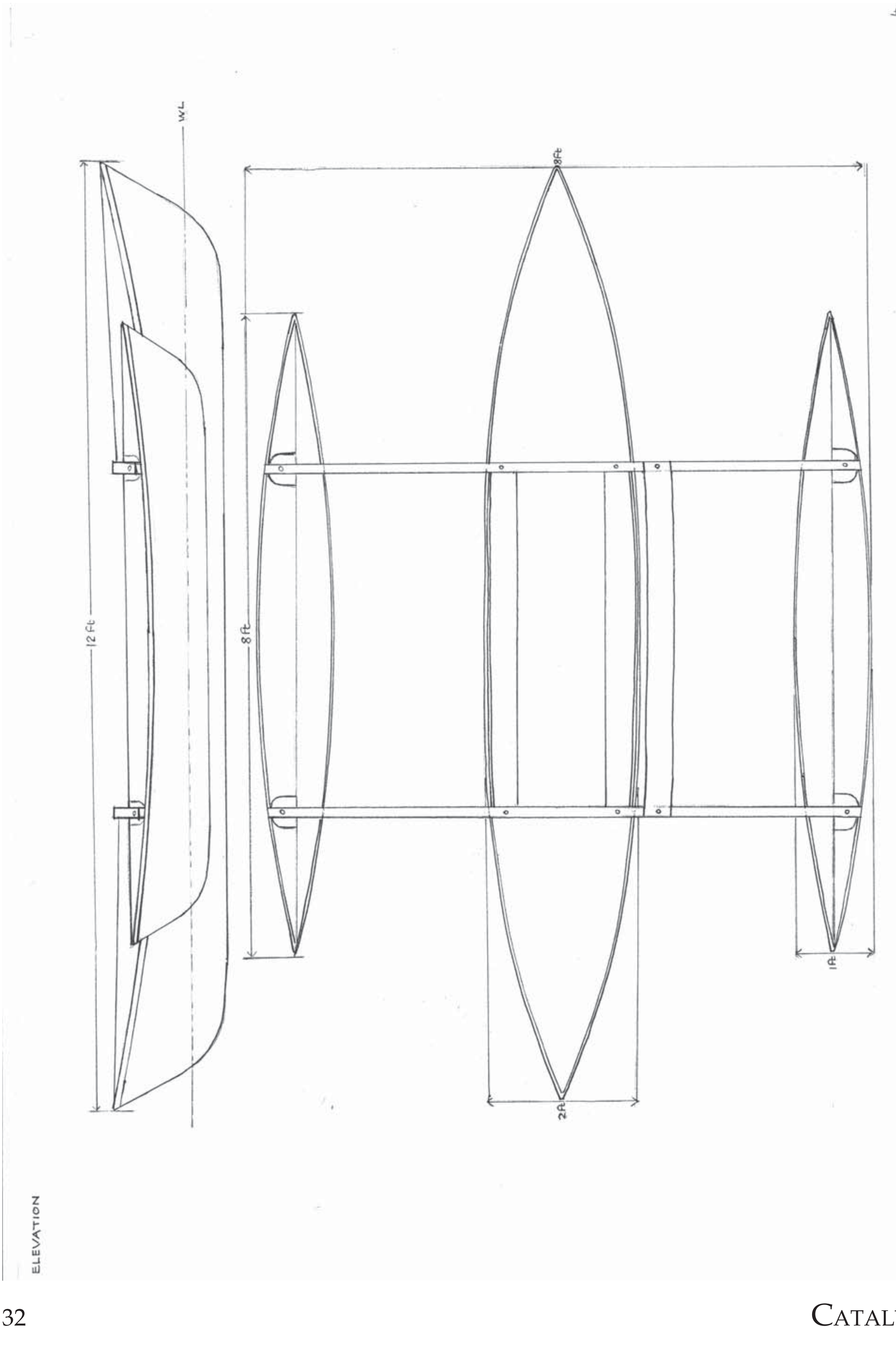
On the 5th day the trimaran was launched on the school out door swimming pool and proved to be very stable, keeping a reasonable amount of freeboard with one adult and one child on board.

The project was a great success with these students and it created a lot of local interest. Although they were not able to use it off the school premises, they were very proud of their achievements.

I built another 2 of these trimarans and sailed them with my daughter on the Deben and Orwell Rivers. We used the same kites and travelled very fast on a reach or down wind. However, I now realise that because of its symmetry, we could have dispensed with the rudder and sailed it like a proa, at the same time keeping both floats for safety and stability.

The readily available airfoil kites attached to the floor of such a stable craft by a moveable tether on a longitudinal rail would provide an excellent performance. Alternatively, with its three narrow hulls and its deep V lateral resistance, windsurfing would be much easier than on a typical board. If fitted with a rudder and conventional rig a good turn of speed could be expected from this little trimaran.


section of float showing beam with reinforcing and captive bolt
laminated beam, spacer and countersunk nut
bulkhead and floor fastened in with fibreglass tape and resin
section of side, deck and composite gunwale glassed in.
laminated beam bolted to reinforced deck
scarf joint bolted and glued before shaping
sealed drinks bottles in floats and under fore and aft deck
sides/bottoms stitched with copper wire flattened and glassed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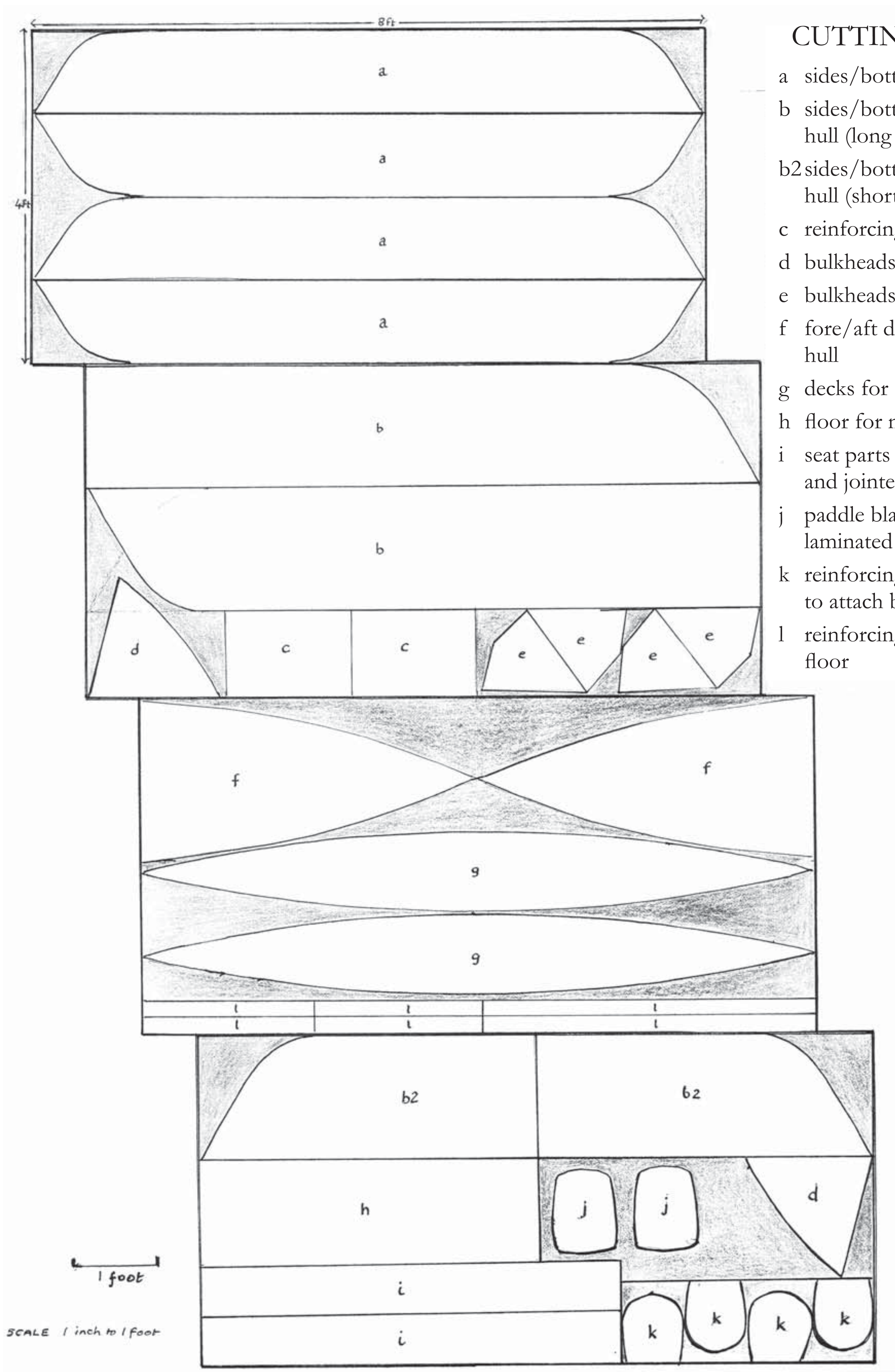
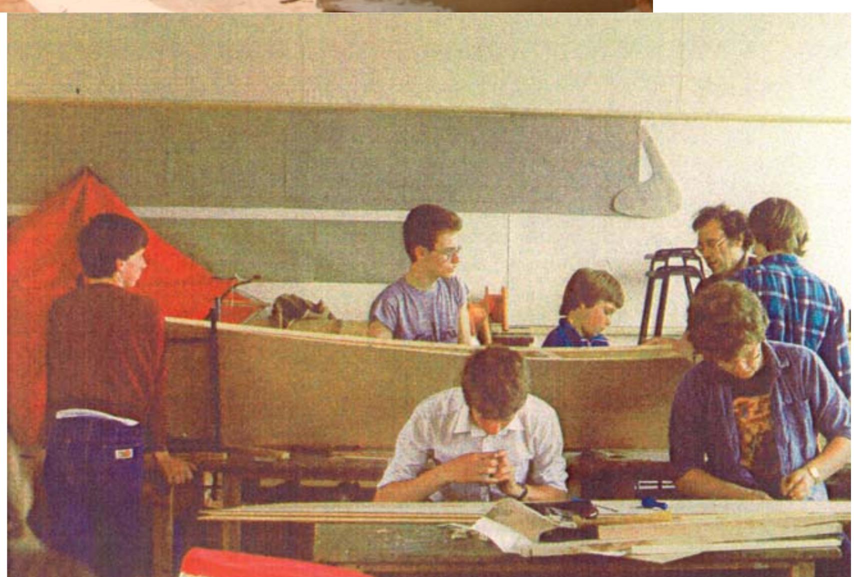


CUTTING PLAN

- a sides/bottoms of floats
- b sides/bottoms of main hull (long section)
- b2 sides/bottoms of main hull (short section)
- c reinforcing for scarf joint
- d bulkheads for main hull
- e bulkheads for floats
- f fore/aft deck for main hull
- g decks for floats
- h floor for main hull
- i seat parts to be framed and jointed
- j paddle blade to be laminated and carved
- k reinforcing for float decks to attach beams to
- l reinforcing and bearers to floor



Development of a Foiling Laser

Dr Ian Ward, Glide-Free Designs

World's first foiling Laser, using centreline foils in 2010

Introduction

The development of foils for the Laser dinghy began in late 2009. No one had done it before, so it would really be a challenge to make something that seemingly should not fly, perform the impossible. It was also felt there was an opening to place simple foils on a standard type of boat that anyone can sail without too much difficulty, in order to enjoy the pleasure and fun of foiling.

Development

To make foiling simple, practical and fun in a Laser, it was necessary to address the many limitations of today's foiling dinghies. Ideally the "criteria" for a successful foiling Laser should include: simple to rig and easy to launch from a trolley in shallow water, able for any sailor to manage, automatic control with no need to 'tweek' the settings on the water, easy to clip on without altering the existing boat and robust construction.

This development meant that it was not just a matter of copying what has been used before to achieve these criteria. A completely new foiling system has been developed with flapless foils and integral wand which utilizes many unique design features. These features enable easy launching in shallow water, safe efficient and fast foiling, along with good displacement sailing performance in light winds.

Retractable rudder & centreboard makes rigging and launching in shallow water simple

Launching

The unique design of the retractable foils has removed the inherent barriers to launching a foiling craft. Launching and retrieval is a major issue even for Moths, which must rig on their side and are then carried (35Kg all up) into the water sideways by one person until neck deep in water, before leaping aboard. This is quite impractical with a Laser.

Launching is normally performed from the standard trolley. The boat is tipped on its side and the centreboard inserted from underneath. The rudder neatly retracts backwards in the existing rudder box. Even with the centreboard foil fully retracted, it easily clears the boom, so you don't have to worry about surprise gusts hitting the boom on the centreboard and capsizing when launching.

Just as the first windsurfers were so popular reaching back and forth in a nice breeze for the pure fun of it! The Laser dinghy has been chosen because it is by far the most popular single handed sailing dinghy, it is relatively simple and cheap, easy to sail and yet has sufficient power to enable foiling.

Performance

With double the weight, half the beam and a smaller sail you could never expect a Laser to perform as well as a Moth. Takeoff is normally on a reach, but it is impressive what can be achieved once the boat is up and going!! Surprisingly, Lasers are not such a bad foiling platform after all. They actually have less wind drag than a Moth, which at 20kts makes up around half the total resistance. Speeds of up to 25kts on a Laser may sound unrealistic, but we believe it is quite possible.

At present, only a few speed measurements have

Launching from a beach trolley

Inserting centreboard in shallow water

Start

10 seconds later!

been taken, as we have focussed on production and testing of the foiling kit. GPS measured speeds of over 17kts are easily achieved in 12-15 kts of wind and just recently 23-25kts was estimated by an experienced skipper in stronger winds.

The speed of a foiling Laser is over three times that of a standard Laser on the same heading and breeze.

The foiling Laser lifts out of the water at around 7-8kts hull speed in 10-12kts of wind, can easily jibe on foils with an experienced skipper and can even sail upwind with skill. By any measure this is exceptional performance for such a simple, low cost boat.

Another way of looking at this is that foiling cats generally improve their displacement sailing speed by around 25-30%, the Laser improves its displacement performance by well over 200%.

Centreline foils

The application of foils to the centreboard and rudder of dinghies offers the unique advantages of low drag and also the ability to heel the boat to windward of the centre of lift of the foil. This results in the weight of not only the crew, but also the rig and most importantly the hull itself in contributing to the righting moment. This ability provides a new level of efficiency, beyond that of existing sailing craft.

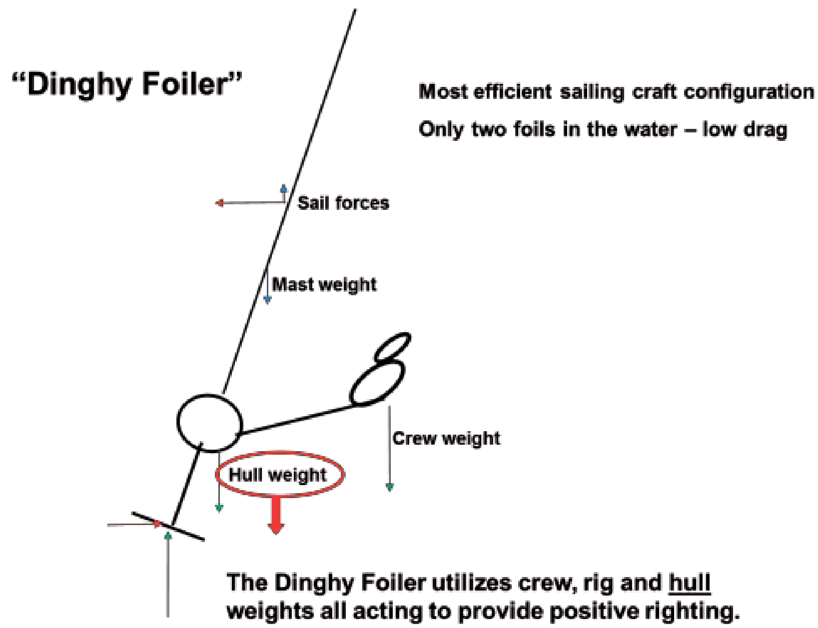
Interestingly, heavier boats such as Lasers, once foiling, can provide even more stability than light boats with only a small windward heel angle. In fact a Laser generates twice the increase in stability per degree of windward heel when compared with a Moth, simply because the Laser is heavier. This effect is a key reason that it has been possible for a Laser to foil at speed, even upwind.

Foiling Laser in action

Auto rotation

During takeoff, the main lifting foil is held at a high angle of attack. As the boat builds speed, the bow lifts, automatically increasing the angle of attack of both foils, which lifts the entire boat. This is a form of "auto rotation" as used in aircraft design, making takeoff very efficient. This effect has been utilised in the design, which is so important with the Laser's heavy hull and small sail area.

Optimising the size of the rudder was also important, as it controls the degree of rotation. Too small a rudder and the main foil will stall, too large and it reduces the amount of rotation possible and its beneficial effect on lift off. Once clear of the water the boat levels out and the wand very quickly drops the angle of attack on the main foil to its optimum low drag configuration.



The heavy Laser hull provides a significant contribution to the righting moment

Flapless foils

As the angle of attack of the lifting foil increases, so does the amount of lift, in direct proportion. Flapless foils have been chosen for the foiling Laser, as they are particularly efficient and provide several significant engineering design advantages when applied to the Laser.

Drag is reduced as shown in the practical experiments of Beaver et al [1], who conducted tests on Moth foils. For the same lift, the maximum foil efficiency, L/D ratio, is achieved when the flap is at zero deflection.

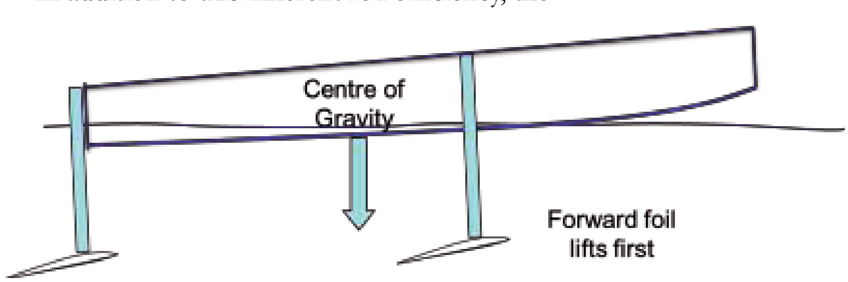
At takeoff, with the flap at 9 degrees the Lift/Drag ratio L/D is some 11% less efficient (higher drag) than for a flapless foil carrying the same load.

In addition to this inherent foil efficiency, the presence of the flap joint across the full width of the foil produces parasitic drag, which does not exist with the flapless foil.

The improved performance of the flapless arrangement has been recently analysed by James McKenzie [2] at the Australian Maritime College in Launceston, who has concluded that "The flapped foil generates a greater drag force for most angles due to the drag created just aft of the flap hinge and the effective bending of the flow and the inherent gap between the flap and the vertical strut. The un-flapped foil experienced a higher lift/drag ratio at flow angles above 2.5 degrees." Typically the foils work in the range of around +2 degrees at high speed through to +9 degrees during takeoff on the Laser.

Symmetric foils

Contrary to conventional wisdom on hydrofoil design, symmetrical foils have been chosen. Symmetric sections not only provide low drag, but also provide a unique level of stability in terms of the flow over the foil and the position of the centre of pressure as the velocity increases. This makes it easy for the foil control system to provide a constant feedback to the sensing wand at all speeds.



Autorotation of the boat as the forward foil lifts

McKenzie [2] also noted:

"The centre of pressure on a symmetric aero foil typically lies close to 25% of the chord length behind the leading edge of the foil. As the angle of attack changes for a symmetrical foil, the drag and lift forces change along with the torque generated on the foil. The location of the torque will remain in the same location.

On asymmetric foils the centre of pressure will shift as the angle of attack changes. Typically on asymmetric, cambered foils at a high angle of attack, the centre of pressure is located just aft of quarter chord location. As the angle of attack reduces, the centre of pressure will move towards the trailing edge.

Stability of this centre of pressure is important, especially on a fully articulated flapless foil, as it maintains a constant restoring force via the pushrod to the wand at all speeds.

With flapless foils, the entire foil rotates. There is no flap and no joints across the foil to cause drag

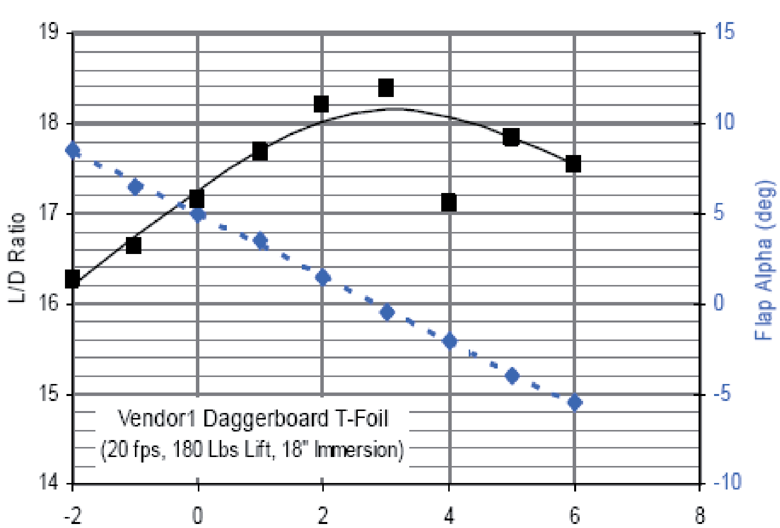
Flapless, symmetric lifting foil

Pitching moment

On a cambered, asymmetric foil operating at zero degrees, a nose down pitching moment is created by the higher velocity on the upper surface and a slower velocity on the underside of the foil. This nose down pitching moment causes tail wings on airplanes to run at negative angles when compared to the main wing to correct this problem.

If asymmetric foils are used, when the main foil is disengaged for launching and displacement sailing, this pitching moment results in the foils automatically rotating. This creates suction, significantly slowing the boat, making it difficult to handle. At speed it can even suck the foil downwards, out of the boat.

Symmetric lifting foils overcome these issues completely, providing good light wind displacement performance, as well as making it easy to launch and retrieve the boat without fighting the foils.



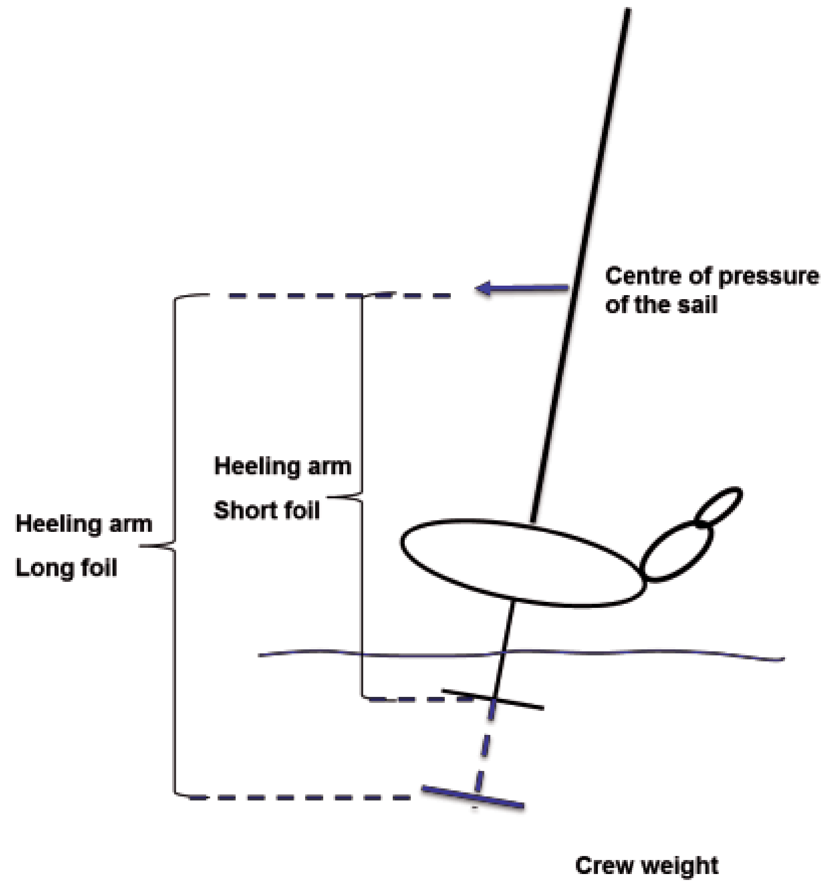
Lift/drag data for flapped foils Beaver et al [1]

Centreboard height

The centreboard and rudder have been designed with a relatively short vertical height for many practical reasons. The principle benefit is that short foils help to significantly reduce the heeling moment, as the sail is not as high above the centre of lift as with deep foils. This is very important as the Laser is quite narrow and we did not want to add leaning racks or a trapeze to provide the necessary stability.

While the vertical foils are smaller in chord than the standard Laser boards, they are sufficiently large to provide excellent displacement sailing performance upwind without the need for excessively deep foils. This is extremely important in difficult launching locations making possible to sail away from a shallow lee shore. Shorter foils are also small, light and stiff, reducing the need to use exotic construction materials. They are also easy to transport and handle.

Fully retracted short foils do not hit the boom and so the boat will not capsize when the boat is hit with gusts which push the boom from side to side. When displacement sailing, it is even possible to tack and gybe with the foils fully retracted, without hitting the boom.



Short foils significantly reduce the righting moment required to hold the rig upright

Height control

To enable low level flying with short foils, it was necessary to develop a unique height control system. It was not possible to use the same arrangement as the Moth, as the linear control reaction requires very deep foils and consequently high ride heights. It was found during practical trials that in order to foil close to the water surface a rather coarse control is required, which results in poor flying stability and hobby horsing.

To address these conflicting requirements a non-linear cam arrangement has been developed, which enables very rapid reaction for take off and recovering from a dive, but a very fine reaction for high speed foiling downwind. Finding the critical gain control was extremely difficult, but has proven to be a key to the success of the Glide Free Foils, making practical Laser foiling possible.


Shallow centreboard clears the boom, even when fully retracted

Control & Trim

The fully articulated flapless foil arrangement is unique and does not require any "tweeking" of the rudder trim while sailing, as it is always operating at the lowest drag configuration. As the boat speed increases, the wand adjusts the entire main foil to the optimum position.

There is no need to fight the lift of a fixed section of the foil with flap and therefore no need to trim the rudder at high speed to keep the boat in the water or optimise the flap position for the lowest drag position.

The entire control process is simplified and automatically produces optimum performance at all times. Using your body weight to trim for and aft is also an important control which adds a challenge to skill level of the skipper.

Wand system

Controls used on traditional flapped systems such as wand shock cords have been eliminated by the special design of the integrated wand. The upward pressure from the main lifting foil provides an automatic, positive restoring force for the wand against the surface of the water. There are only two moving parts and as the system is always in compression there is no need to have linkages which both push and pull. This eliminates any slop in the control system and gives an accurate tracking of the water surface.

Location of the wand on the centreboard places it exactly where height sensing is critical. Moving the wand further forward provides little benefit at the high speeds experienced when foiling, as the wand is mainly responding to the average height of the water below the boat.

The wand is fully integrated within the centreboard, making the system simple, reliable, easy to attach and operate. There is no need for separate fittings or connections to the boat. The wand neatly retracts within the centrecase along with the centreboard when it is retracted and deploys automatically with water pressure when the centreboard is lowered. When the board is raked aft, the wand simply disengages from the main foil, allowing it to float freely and trail with minimum drag.

The main lifting foil also disengages and trails freely with minimum possible drag as it is specifically designed to have zero pitching moment. This unique system ensures the best possible performance both when foiling and in displacement mode, while maintaining simplicity.

Rig size

To enable early takeoff in lighter winds, we have trialled larger rigs up to 9.0 sqm. While it may make 1-2 kts difference in the critical wind for takeoff, these larger rigs very quickly become overpowered and difficult to handle once up and going. The key to good all round performance is definitely efficiency, not power.

Wand retracts neatly within the centrecase

The standard Laser rig is a reasonable size for most skippers, enabling the boat to pop out of the water in just 10-12 knots of wind and it remains manageable up to around 18-20kts of wind speed, provided it is trimmed appropriately and the luff tension is applied heavily to flatten the sail.

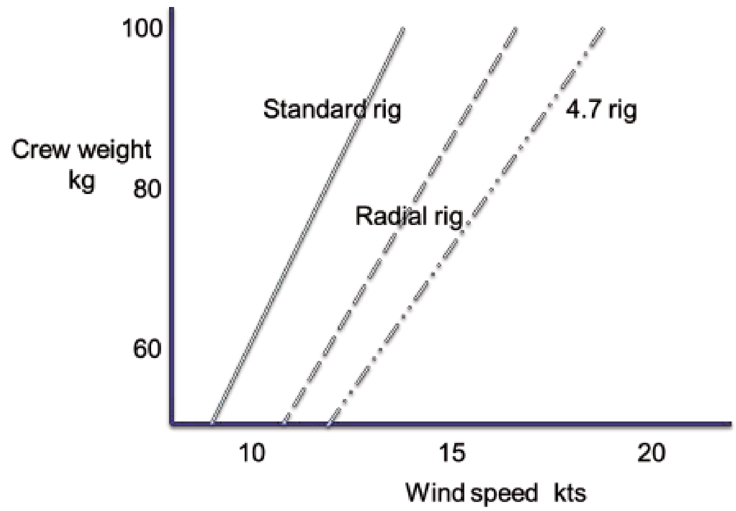
Surprisingly we have found that the smaller rigs, especially the Laser radial, only requires an extra 1-2 kts of windspeed for takeoff, but has significantly lower drag and heeling moment, making it far more manageable and faster than the bigger rig. In strong winds it has even been possible for a 96Kg skipper to takeoff with a Laser 4.7 rig, achieving speeds of 23-25kts.

Soft rigs

There is a general perception that foiling requires solid wing rigs or fully battened sails with pocket luffs and camber inducers to work at all. Much of this misconception is based on what we see in the sailing press. The reason that AC72 and AC45 cats have solid wing sails is that it is mandated by the rules. In both Moth and A class cat classes where these solid wing rigs have also been trialled on a fair basis of comparison, the standard rigs have proven superior across the wind range, and are of course far more practical.

While the soft sails used on Lasers are generally heavily criticised as being 'inefficient', they are regularly sailed in strong winds with quite reasonable performance. In fact the major issue is with the sails in our experience is with them being too full, rather than any inherent issue with the soft sail itself being 'slow'. Our trials with the standard Laser rigs have proven good performance, even in strong breezes, provided the correct rig size is selected and that it is adequately flattened using the luff, foot and vang controls

We have no doubt that it will be possible to further improve the performance of rigs using similar techniques employed by sailboards and Moths, but the existing standard Laser rigs have proven more than adequate for fun foiling, without any alteration.



Estimated windspeed to enable takeoff with the standard Laser rigs for different crew weights.

Challenge

An interesting challenge for foiling Laser sailors, is that in 1972, when the Laser was first produced, the world 500m sailing speed record was held by Crossbow at 26.30 kts. It may now be possible to achieve this speed in a boat of the same vintage.

Could it be that with hindsight and the help of Glide Free Foils technology, the Laser may have held the world speed record in the year it was developed?

By any measure these are significant steps in performance showing just how efficient this form of sailing is.

Result

The result of the Glide Free Foil development is a boat which is easy to launch in shallow water, safe, efficient and provides fast foiling, along with good light wind performance in displacement mode.

At the same time the boat has become more stable, easier to sail and right after a capsize, with a lighter helm and an impressive turn of speed. We truly feel that we have met and even exceeded our original requirements.

References;

1) "Full Scale Measurements on a Hydrofoil International Moth." John Zseleczky, U.S. Naval Academy Hydromechanics Lab, Annapolis, MD; The 19th Chesapeake Sailing Yacht Symposium. Annapolis, Maryland. March 2009. Bill Beaver, U.S. Naval Academy Hydromechanics Lab, Annapolis, MD

2) "Can a Flapless Hydrofoil Provide a Realistic Alternative To a Standard Moth Foil with a Flap?" James Robert Mackenzie, Australian Maritime College Project Researcher, Thesis & Journal article, 2013.

Can a Laser on foils beat the World speed record of Crossbow in 1972?

The Vampire project

William Sunnucks
May 2015

The Vampire first flew in Brightlingsea in July 2014. Downwind speeds are consistently over 20 knots peaking at around 30 knots. Upwind speeds are 17-20 knots when foiling, but foiling is inconsistent. When the development work is complete the technology should be transferable to other catamaran platforms such as the Tornado, F16 and F18.

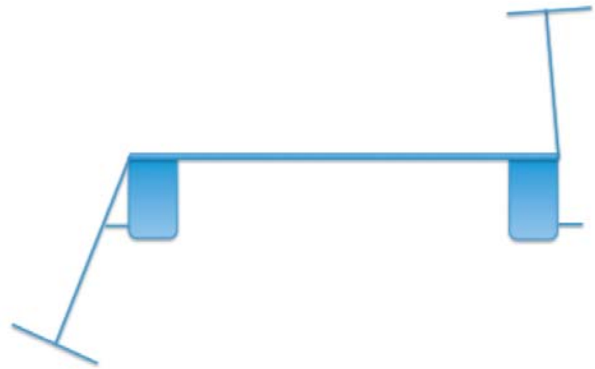
This is the first catamaran in recent years to be fitted with canted T foils. The outwards cant of 20 degrees has a similar impact to the windward heel needed to sail a moth fast upwind.

The windward foil can be hoisted out of the water without disconnecting the control wand mounted on the bow – a gull wing system that may well be another first. The gull wings have other advantages:

- There is no need to insert the foils from the bottom of the boat, allowing it to be easily assembled and launched from a beach.
- Light wind performance is enhanced by withdrawing the foils completely and using conventional daggerboards.

The Vampire, originally an M20 from Marstrom Composites in Sweden, is 20 foot long and 10 foot wide sporting a 27sqm rig, and a further 20sqm spinnaker. Over the last five years it has taken line honours in the major UK and North European long distance races such as Round Texel, Raid de Houat, Kent Forts Race and the Three Piers Race.

The Vampire foiling in light winds



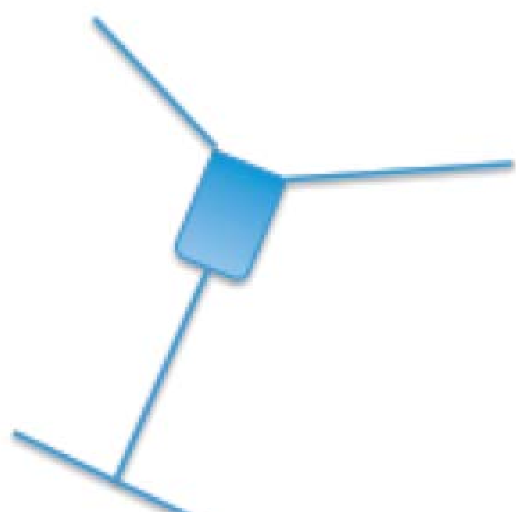
Vampire foil configuration with windward board raised

The development team

William Sunnucks has been seeking a way to combine Moth and catamaran technology since learning to sail a Moth in 2009. Further inspired by the 2013 C Class championship in Falmouth, he drew up the canted T foil concept to be built on the Vampire as the test bed.

The concept was developed by fluid dynamicist Kevin Ellway, designer of the Exocet International Moth, the first to be designed completely using mathematical models. Scores of virtual moth designs were "flown" before putting the final design into production, and the same general approach has been taken with the Vampire project.

The foils have been built in Brightlingsea Essex by Graham Eeles a specialist boat builder engaged in a number of innovative projects. He has converted the desktop theory into strong and practical foils and has been coaching for the early test outings.

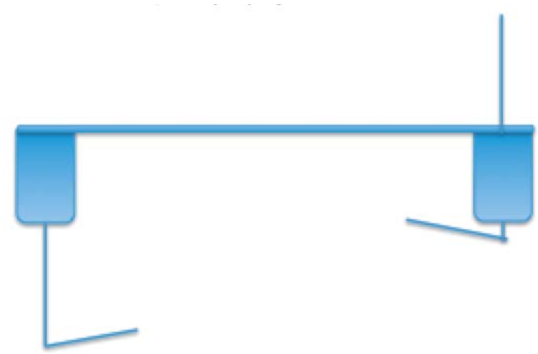


Notes on foiling configurations – for information

The International Moth class started foiling at speed about 10 years ago. It has now established itself as the fastest sailing dinghy with a Portsmouth number of 590, nearly 15% faster than an F18 catamaran. They use T foils with a wand to control the ride height.

T foils are believed to have been first applied to a racing catamaran by the "Off Yer Rocker" C Class team in 2007. The foils were vertical and both remained in the water. The boat flew, but was never thought to be fast. More recently the Whisper project supported by Southampton Solent University has been following this line of development.

J foils: The 2013 America's cup saw 72 foot catamarans foiling at 40 knots downwind. Similar shapes were used in the C Class Championship, "the LittleCup", at Falmouth in September 2013. Commercial production has started using the same principles on the Flying Phantom and Nacra FCS.



Enquiries to William Sunnucks, East Gores Farm, Coggeshall CO6 1RZ or William@sunnucks.co.uk or 07771940763. At present the photos and video footage are rudimentary, but better ones will be available in due course.

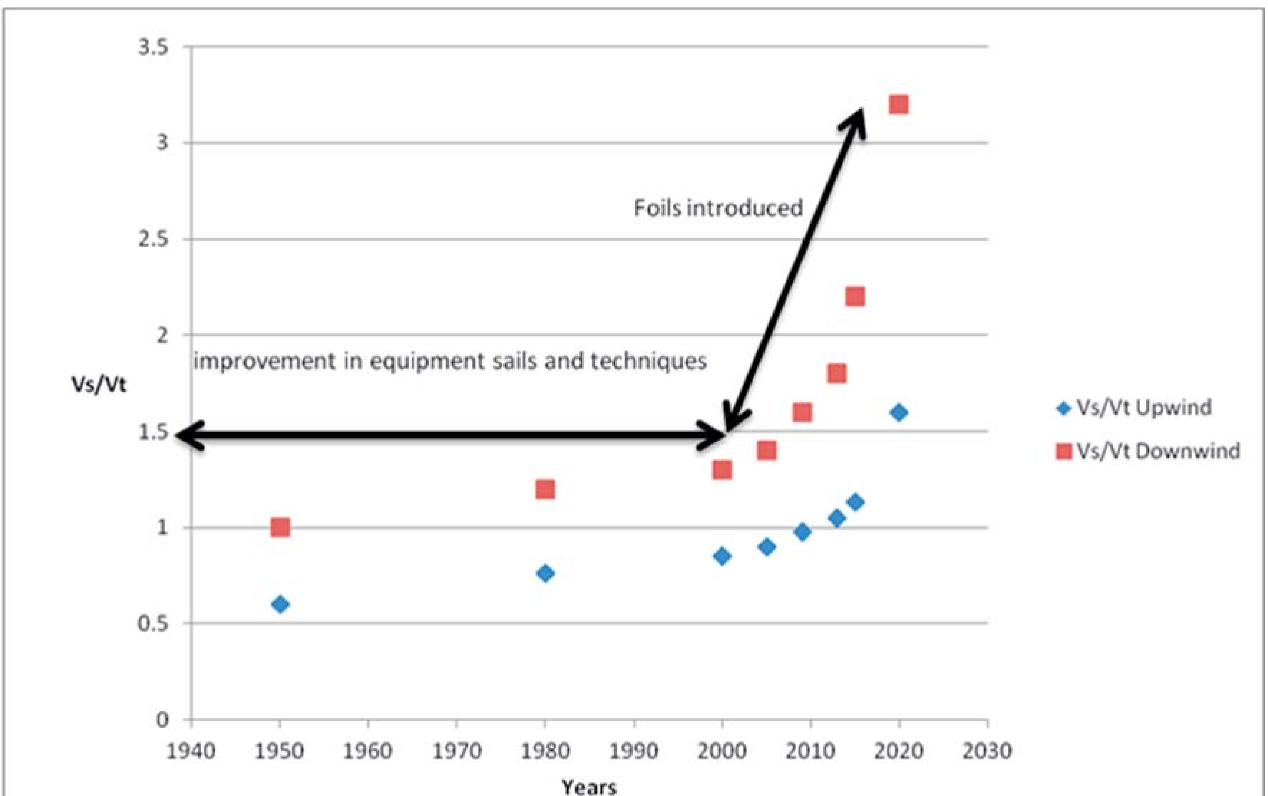
The Foiling Revolution

By Alan Smith

Over the last decade there has been a revolution in the performance of a sailing yachts; America Cup catamarans down to the International Moth class

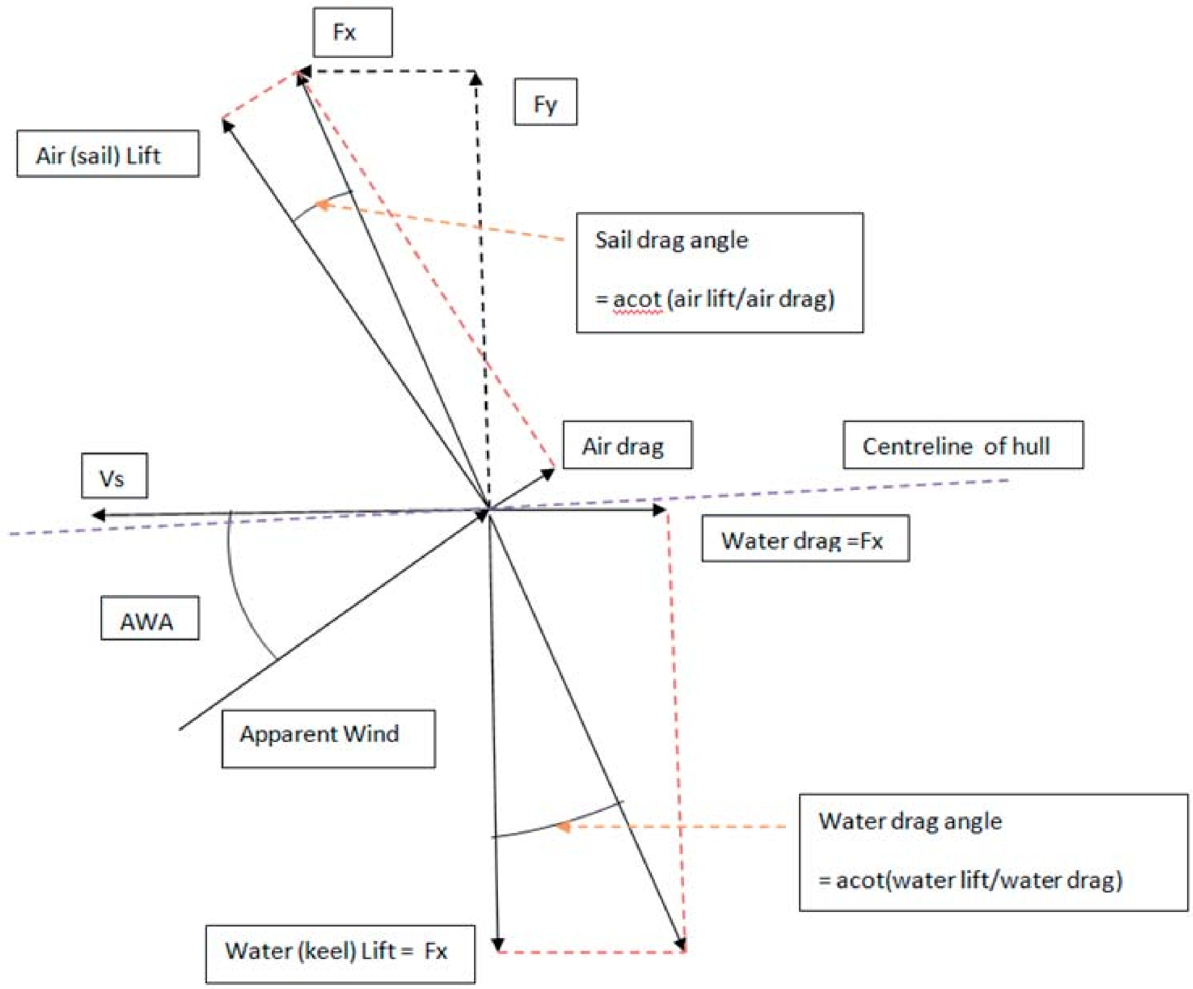
The high-speed sailing world is on the brink of sailing speeds of Vs/Vt above 2.0 becoming commonplace. The foiling kite boarders are already there, and there is no reason why Catamarans and a few mono hulls cannot achieve these speeds in the coming few years.

To understand why this is possible it is necessary to be familiar with the mechanics as well as the fluid dynamics of sailing.



Nomenclature

Vs	Boat speed (may be a vector)
Vt	True wind speed (may be a vector)
TWS	true wind speed (scalar quantity)
TWA	true wind direction (angle)
AWS	apparent wind speed
AWA	apparent wind direction (angle)
L	lift
D	drag
CofG	centre of gravity
CofE	centre of effort (usually refers to sail centre of area)
CofLR	centre of lateral resistance



Sailing force vectors in the horizontal plane

$$AWA = atan\left(\frac{drag}{lift}air\right) + atan\left(\frac{drag}{lift}water\right)$$

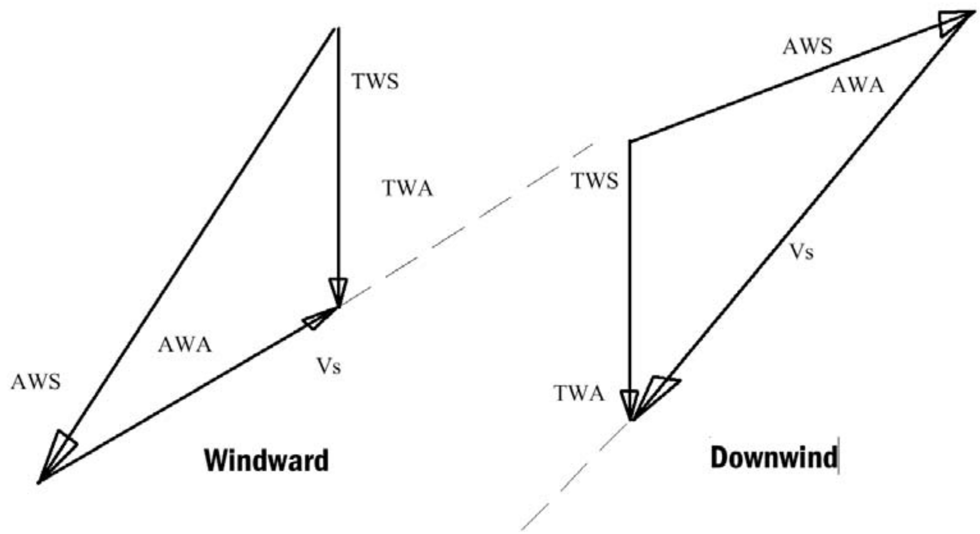
To achieve high Vs/Vt ratios it is necessary to understand the force vector contributions and their relationship to apparent wind angle (AWA). Yacht performance is defined by the horizontal plane forces as shown in the above diagram and how they control a sailing yacht. Apparent Wind Direction AWA. To be able to sail at a high Vs to Vt ratio and hence a low AWA the lift drag ratios of the water and air components must be high. Ice yachts achieve Vs to Vt ratios of 4.0 under ideal conditions.

Now it is necessary to look at the sailing speed vectors

The graph opposite illustrates the relationship between Vs/Vt ratio over a range of True wind angles. Currently the International Moth is achieving 1.25 (TWA 50 degrees) to windward and 1.8 (TWA 130 degrees) downwind in suitable conditions. The AC72's were doing even better but again they were in suitable conditions. Potentially a purpose designed catamaran is capable of achieving Vs/Vt = 2.5.

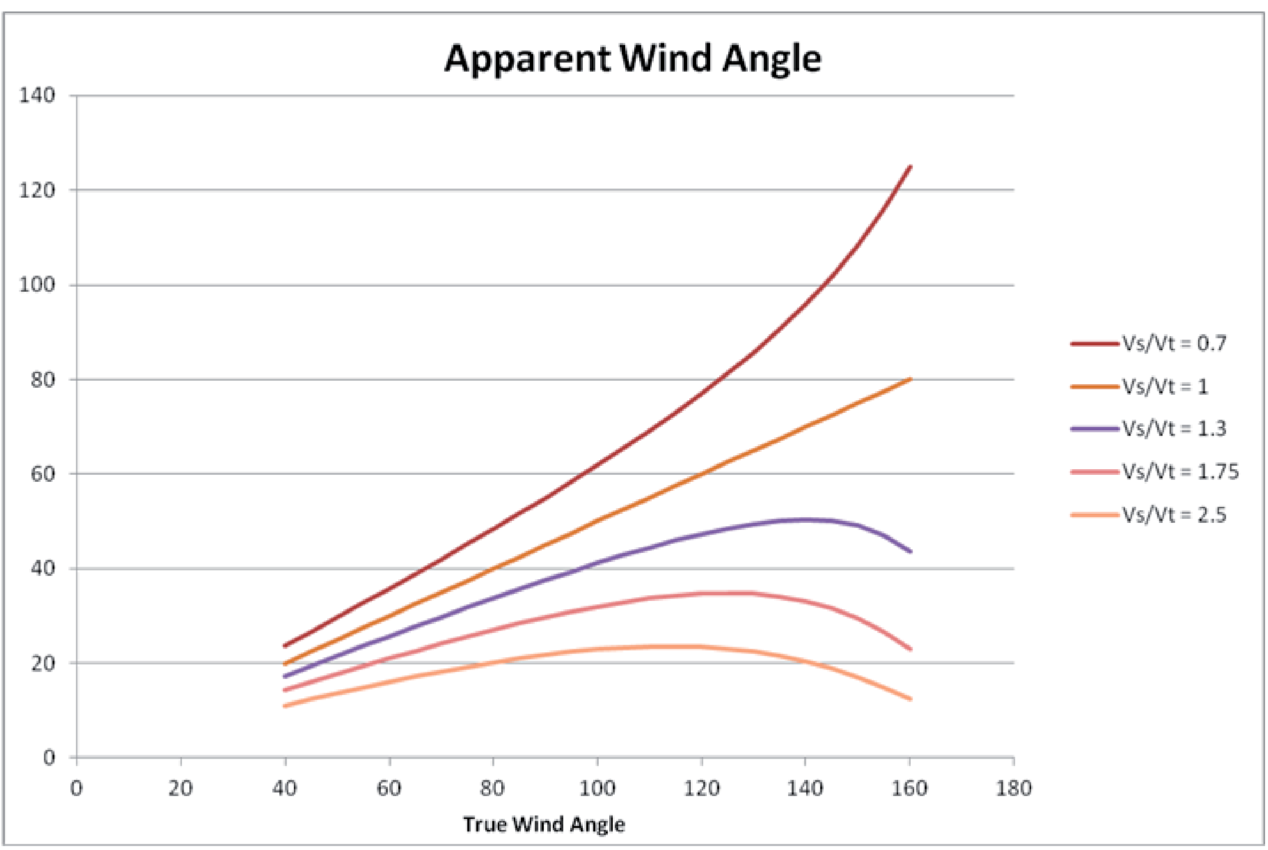
The above discussion establishes the operating environment. It yields the relationship between velocities, the direction the forces act in and provides key equations necessary for calculating performance.

We may ask the question "what is required to achieve high lift/drag ratios, that is to achieve low apparent wind angles?"



$$AWA = \operatorname{atan}\left(TWS * \frac{\sin(TWA)}{(Vs + TWS * \cos(TWA))} \right)$$

$$AWS\verb|^|2 = (TWS * \sin\,(TWA)\,)\verb|^|2 + (Vs + TWS * \cos(TWA))\verb|^|2$$



Once on foils the drag has two main components, *induced drag* (that drag that occurs as a function of generating lift) and a more complex component that is "the rest" of the drag. In simple terms the induced drag is an inverse function of foil span (actually induced drag is proportional to the square of the weight carried by the foil divided by the square of the span of the foil) and the "rest" is a function of wetted area, with Reynolds Number, surface finish , foil section, foil depth, surface spray, junctions etc being factored with wetted area and running surface length (chord). Reducing induced drag is important at lower speeds and reducing wetted area important for high speed.

It is possible to sweat blood trying to reduce "the rest of the drag". With carbon fibre it is easy enough to increase span, but increasing sail lift by increasing sail area yields the best returns provided the boat has the righting moment to manage the increased area. In the International Moth class "Veal Heel" results in an 18% increase in speed in 14 knots of wind. Bums over the side are very significant!

The two figures below show the contributors to drag of the International Moth and from them we can derive a prediction of performance using a Velocity Prediction Program (VPP)

The graph opposite is typical of VPP output data for a Moth. Fx is the force in the forward direction and Fy the force to leeward. The VPP determines the set of the sail where RM=HM and the point where Fx = Drag . This is the predicted speed. The drag "polar" is of interest as it shows drag at low speed as dominated by induced drag and at high speed by form ("the rest") drag.

$$\text{Lift} = 0.5\times\text{density}\times\text{velocity squared}\times\text{area}\times C_L$$

$$\text{Drag} = 0.5\times\text{density}\times\text{velocity squared}\times\text{area}\times C_D + \text{lift}\times k_1\times C_L$$

$$C_L = mg/(0.5\times\text{density}\times\text{velocity}^2\times\text{area})$$

k_1 is an inverse function of aspect ratio

Aspect ratio (AR)= Span squared/area

$k_1\times C_L$ is then a function of

$$(\text{area}/\text{span}^2)\times mg/(0.5\times\text{density}\times\text{velocity}^2\times\text{area})$$

which simplifies to:

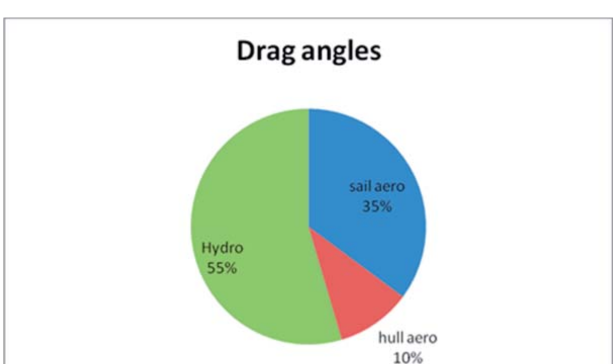
$$mg/\text{span}^2/0.5/\text{density}/\text{velocity}^2$$

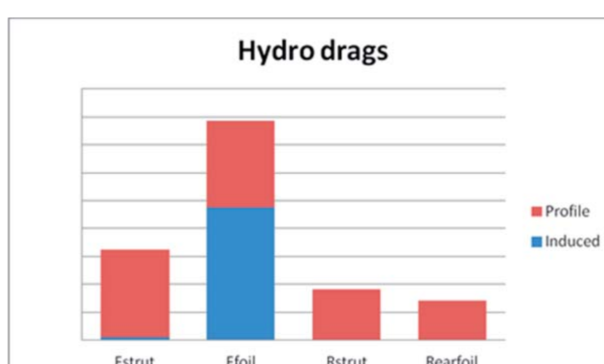
Area has very little effect on induced drag. Area is required primarily to keep the lift coefficient (C_L) below the stall boundary.

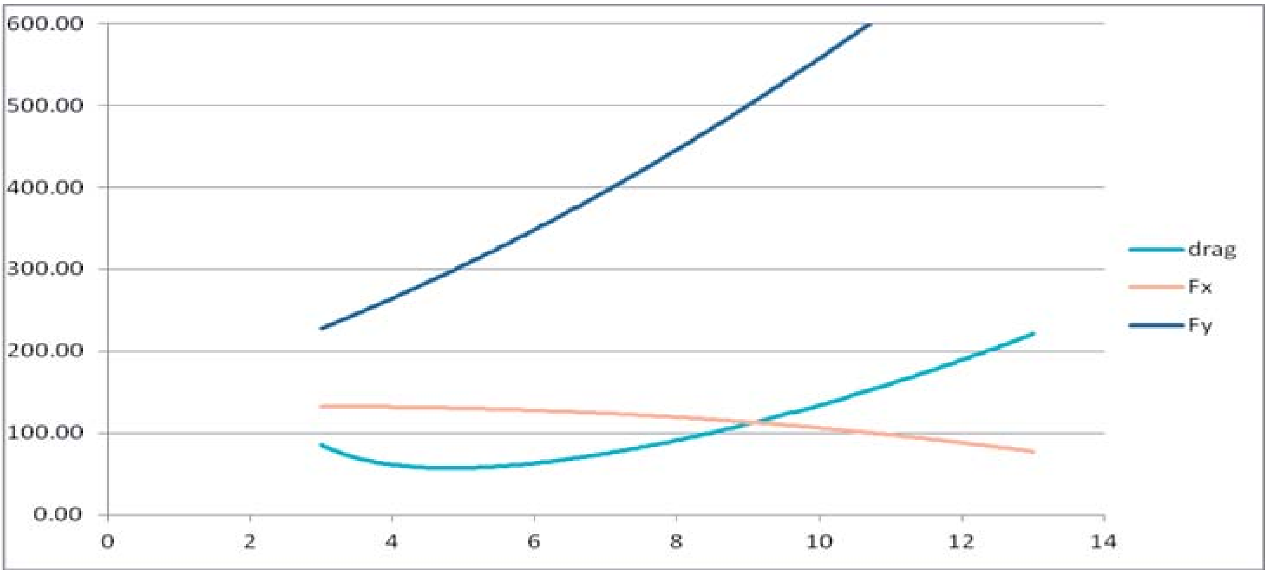
These equations are applicable to all lifting surfaces, however C_D is a function of several variables including C_L. Sails are more complex than foils when considered over a wide range of C_L (0.3 to 1.5). Where the above gives C_{DI} as $k_1\times C_L^2$ closer analysis necessitates C_{DI} being a function of:

$$k_2 * C_L + k_1 * C_L^2$$

where k_2 is typically a small negative constant.



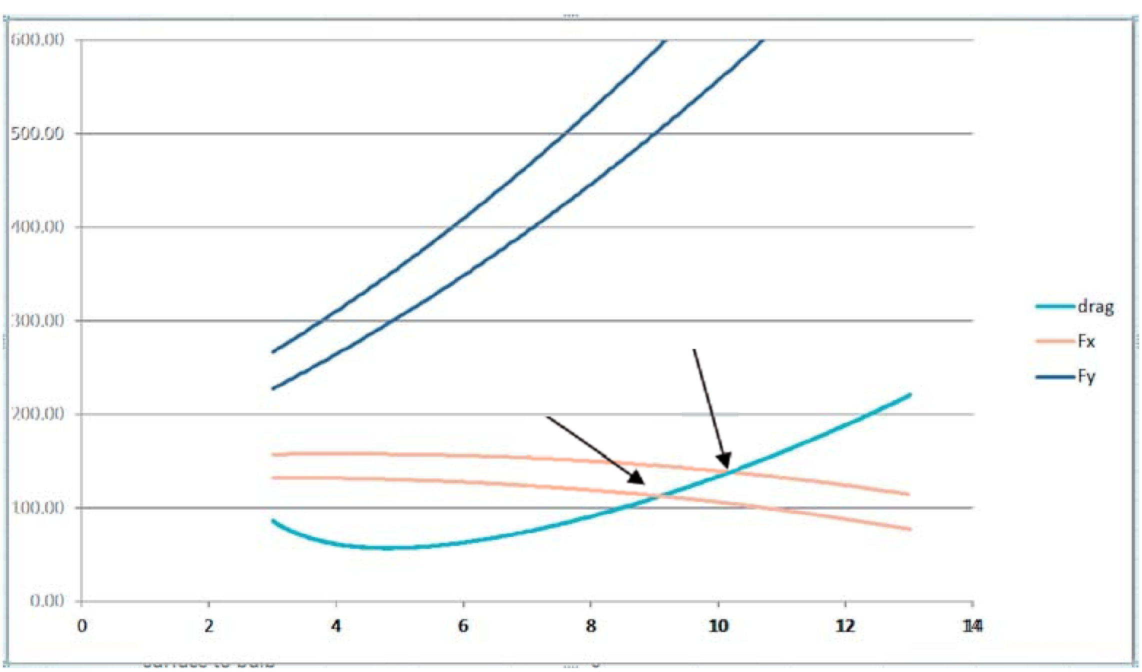


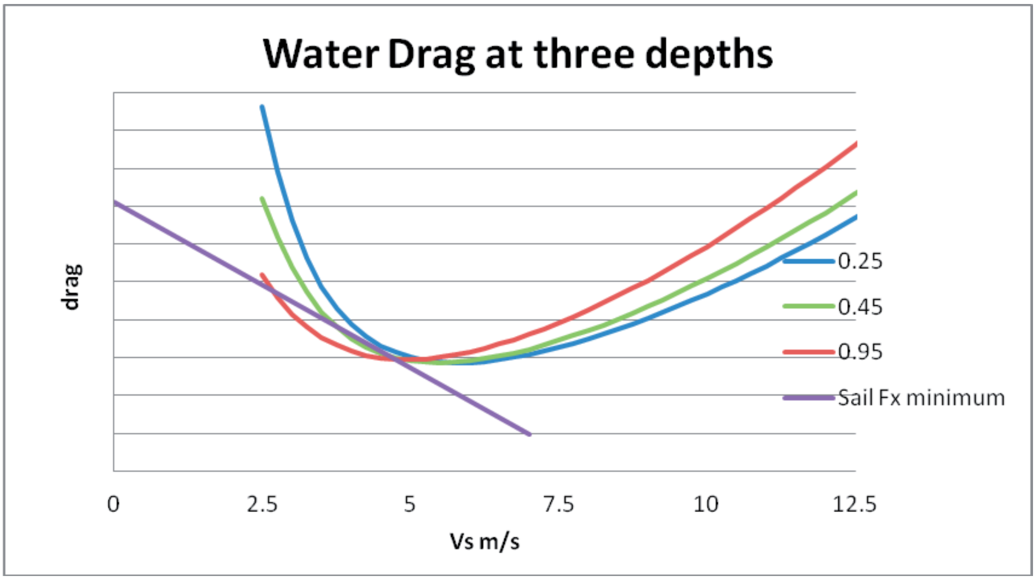


In order to increase Lift there are two choices – 1) increase sail area or 2) increase the sail's angle of attack. Either way this means increasing the available righting moment, and in the second case it is easy to move above an optimum angle of attack which increases the sail's induced drag or even stalls the sail. Ideally to achieve the best Vs to Vt ratio the induced drags and the form drags would be all equal. In practice this optimum can only be achieved under very specific circumstances. Normally the sail induced drag and the foil form drags dominate.

Just while we are here if the wind was 18 knots and the helm of the Moth could sit a further metre outboard the graph below would be the result. The boat speed would increase from about 18 knots to 20.5 knots as shown by the arrows.

The graph at the top of the next page shows the effect of foil depth on drag. At low speed induced drag dominates but induced drag increases as depth decreases. The barchart below it shows a typical distribution of the contributions to drag of Moth foils. The "sail Fx minimum" line depicts the nominal thrust expected when the sail force is restricted by a limit of righting moment. This level of thrust could sustain foiling at about 10 knots but is insufficient to enable lift out.





Now it is necessary to look at the balance of moments (See figures on the next page).

Up to this point the forces and moments have been identified and it is possible to calculate an operating condition where all the forces and moments are balanced one against the other. This type of calculation is known as a Velocity Prediction Program or VPP.

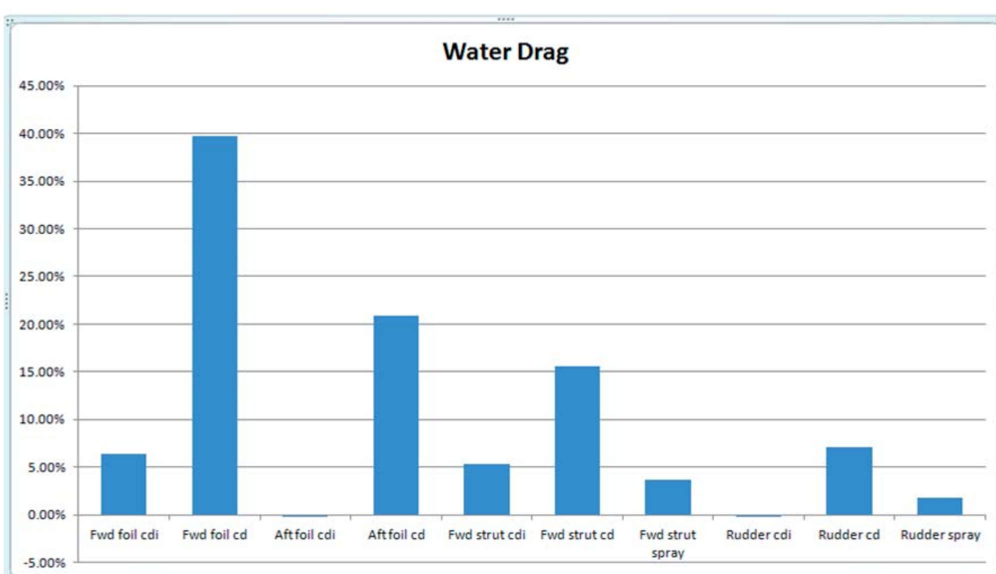
And what does the VPP math model give us?

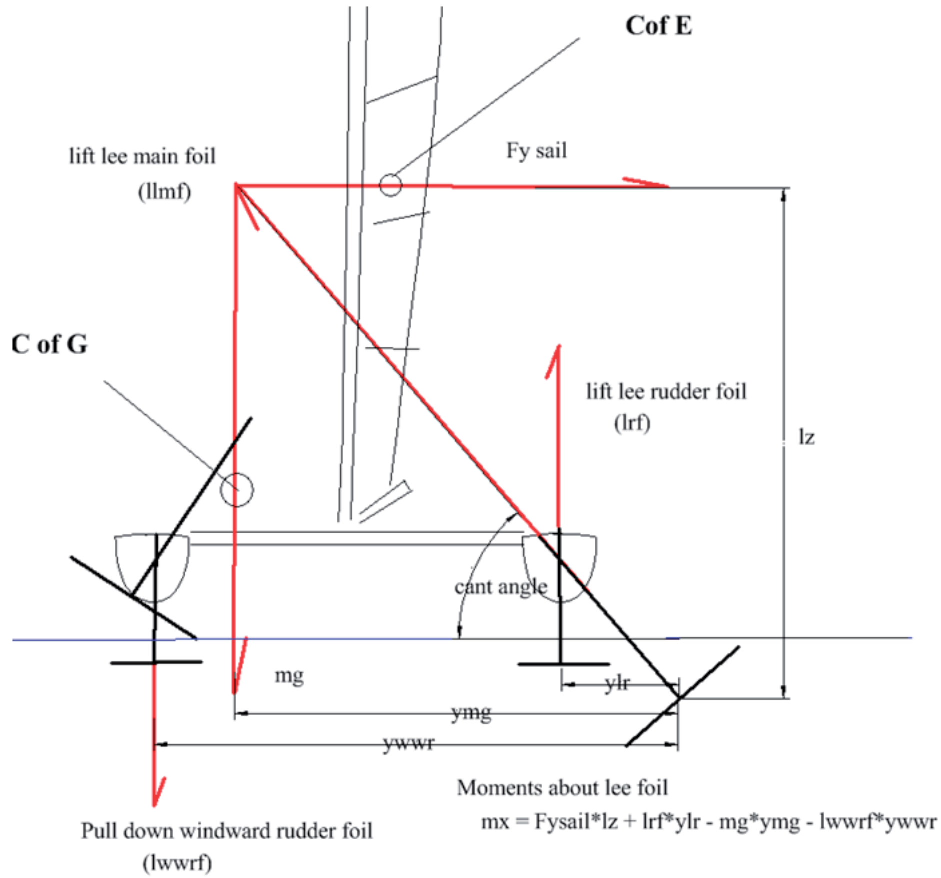
It provides an understanding of what each aspect of the design contributes to performance. It answers many of the "what if" questions; if span is changed what is the effect? if area, if weight, if lateral CofG position, if longitudinal CofG, heel angle; etc etc etc. Take each input to the VPP and ask "what if?"

Hence the design can be optimized, performance improved and sailors advised on how to obtain best performance; this approach is largely responsible for the dramatic speed improvement of Moths over the last five years

What the VPP does not do is indicate if the design is dynamically stable. Can it be sailed with an acceptable level crashes? A dynamic simulation model is require for those answers.

It is dynamic modeling that shows up the weaknesses of "J" foils and the significant superiority of the "Moth" wand to flap height control system. The Moth response to height change is nearly five times quicker than a "J" foil approach and is many times better damped.





True wind speed
True wind angle
Wind gradient
True wind direction
Heel angle

Longitudinal distance relative to Fwd foil CofLift
- Centre of gravity
- CofLift aft foil (rudder)
- CofE sail function of Cl

Heights
- Fwd Foil depth
- Fwd Foil to sail CofE
- Aft foil depth
- Fwd foil to CofG
- Length of fwd strut

Areas
- Sail
- Fwd foil
- Aft foil

Drag contributors
- Reynolds Number
- Surface finish
- Thickness to chord ratio
- Foil depth
- Foil section
- Sail characteristics
- Hull and crew

Widths
- Beam
- Helm CofG to centreline
- Fwd strut (chord)
- Aft strut
- Fwd foil span
- Aft foil span

Thickness to chord ratios
- Fwd foil
- Aft foil
- Fwd strut
- Aft strut (rudder)

Other characteristics
- Oswald number fwd foil
- Oswald number aft foil
- Downwash ratio

Mass
- Crew
- Boat

VPP Input Data

Regarding stability and limit conditions, stability is a very miss understood term; many people make the mistake of believing any balance of forces and moments establishes stability. In actual fact you need, as a minimum, to calculate the first derivatives of your balance equations and hence establish whether you are at a stable trough not an unstable pinnacle. The established aerospace way of doing this is to solve the differential equations in all six degrees of freedom.

> Up until now it has been high-school maths but now it truly becomes rocket science; but don't despair, it can be cut down to manageable sections.

We saw earlier that

Lift =0.5*density*velocity squared*area*C_L

Now we look at C_L in some detail

$$C_L = C_{L_0} + (d.C_L/d.\alpha)*\alpha$$

where α is angle of attack and C_{L_0} is the lift coefficient of a cambered section at $\alpha = 0$

$\alpha = \tan^{-1}(w/u)$ in the x-z plane and

$\tan^{-1}(v/u)$ in the x-y plane

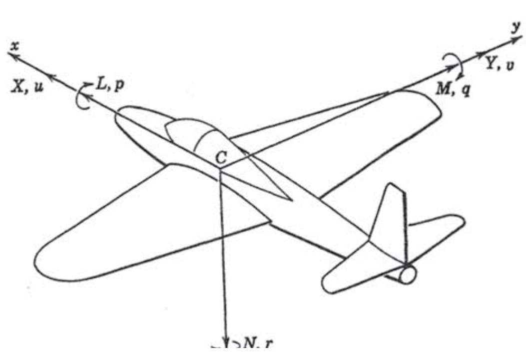
and the forward velocity V is given by

$$V^2=u^2+w^2+v^2$$

When you consider rotational rates then part of α may equal rotational rate*moment arm/velocity hence the rotation p, q and r all create transient angles of attack until a steady state occurs. These are the variables that determine the dynamic stability of a body in motion.

Any flying machine, flight vehicle, and a hydrofoil yacht is a flight vehicle, has 6 degrees of freedom as shown in the figure below.

A right hand axis system has the X-axis pointing forwards, Y to the right and Z vertically down.



Linear velocities are *u, v,* & *w* respectively and rates of rotation are *p, q, r*. Similarly there are defined Moments L, M, N and forces Fx, Fy, Fz about and along the axes.

The dynamic motion of the "flight vehicle" is determined by the following equations of motion and the calculation of the three forces and three moments.

Simplification of these equations.

Nearly all yachts enjoy large values of heel (roll) damping resulting docile roll motion in a well handled boat hence *p* can be considered to be zero and as boats are close to symmetrical in the x-y and

$$\begin{bmatrix} F_x \\ F_y \\ F_z \end{bmatrix} = m \begin{bmatrix} \dot{u} + qw - rv \\ \dot{v} + ru - pw \\ \dot{w} + pv - qu \end{bmatrix}$$

$$\begin{bmatrix} L \\ M \\ N \end{bmatrix} = \begin{bmatrix} I_{xx} & -I_{xy} & -I_{xz} \\ -I_{yx} & I_{yy} & -I_{yz} \\ -I_{zx} & -I_{zy} & I_{zz} \end{bmatrix} \begin{bmatrix} \dot{p} \\ \dot{q} \\ \dot{r} \end{bmatrix} + \vec{\omega} \times \begin{bmatrix} I_{xx} & -I_{xy} & -I_{xz} \\ -I_{yx} & I_{yy} & -I_{yz} \\ -I_{zx} & -I_{zy} & I_{zz} \end{bmatrix} \begin{bmatrix} p \\ q \\ r \end{bmatrix}$$

$$= \begin{bmatrix} I_{xx}\dot{p} - I_{xy}\dot{q} - I_{xz}\dot{r} \\ -I_{xy}\dot{p} + I_{yy}\dot{q} - I_{yz}\dot{r} \\ -I_{xz}\dot{p} - I_{yz}\dot{q} + I_{zz}\dot{r} \end{bmatrix} + \vec{\omega} \times \begin{bmatrix} pI_{xx} - qI_{xy} - rI_{xz} \\ -pI_{xy} + qI_{yy} - rI_{yz} \\ -pI_{xz} - qI_{yz} + rI_{zz} \end{bmatrix}$$

$$= \begin{bmatrix} I_{xx}\dot{p} - I_{xy}\dot{q} - I_{xz}\dot{r} + q(-pI_{xz} - qI_{yz} + rI_{zz}) - r(-pI_{xy} + qI_{yy} - rI_{yz}) \\ -I_{xy}\dot{p} + I_{yy}\dot{q} - I_{yz}\dot{r} - p(-pI_{xz} - qI_{yz} + rI_{zz}) + r(pI_{xx} - qI_{xy} - rI_{xz}) \\ -I_{xz}\dot{p} - I_{yz}\dot{q} + I_{zz}\dot{r} + p(-pI_{xy} + qI_{yy} - rI_{yz}) - q(pI_{xx} - qI_{xy} - rI_{xz}) \end{bmatrix}$$

the y-z planes the cross products of inertia I_{xy} and I_{yz} can be taken as zero. Similarly we can expect the helm to keep yaw rate *r* to near zero.

The equations above become

and $M = I_{yy}*(d.q/dt)$

or $M = I_{yy}*\theta''$

$$\begin{bmatrix} F_x \\ F_y \\ F_z \end{bmatrix} = m \begin{bmatrix} \dot{u} + qw - \cancel{rv} \\ \dot{v} + \cancel{ru} - \cancel{pw} \\ \dot{w} + \cancel{pv} - qu \end{bmatrix}$$

This math model now has 4 degrees of freedom - *q u, v,* & *w*.

And even then in the case of the Veal Heel Moth the variations in *v* are negligible

Hence a three-degree of freedom model is adequate for configurations such as the International Moth. Catamaran dynamic analysis however necessitates all four. However as Vs/Vt increases the boat's ability to carry way improves and as a consequence limited analysis can be achieved assuming the boat is travelling at constant speed (u=0)

Some insight into the vehicle's stability is provided by calculating the position of the "neutral" point of the balance of moments in pitch only (single degree of freedom $\int q$ dt. This is a simple test which indicates that stability is probable if the centre of gravity is forward of the neutral point. In doing this calculation for "wand control" the gearing and geometry of the flap motion as a function of boat attitude must be taken into account.

An interesting aspect which has a minor effect on stability, a slightly large effect on lift out is known as "Kramer's Effect". It is an important part of the aerodynamics of insects and was a setback to man powered flight. It is experienced when a sail or rudder is "pumped". There is a mass of fluid surrounding the lifting surface that has to be moved laterally as the lifting surface moves laterally. It approximates to a fluid volume equal to the product of span and five times chord squared, about 32 kg in the case of a Moth fwd foil. It is a mass that inhibits lateral acceleration but not longitudinal acceleration. It adds to the pitch inertia.

What does the dynamic simulation provide beyond what the VPP provides? -

- the effects of wand to flap gain
- the importance of variable length wands
- the effects of wand to flap non linear characteristics
- the importance of CofG to wand pivot separation
- limitations on aft foil area
- etc etc

Why Wand to Flap control rather than the "J" foil approach

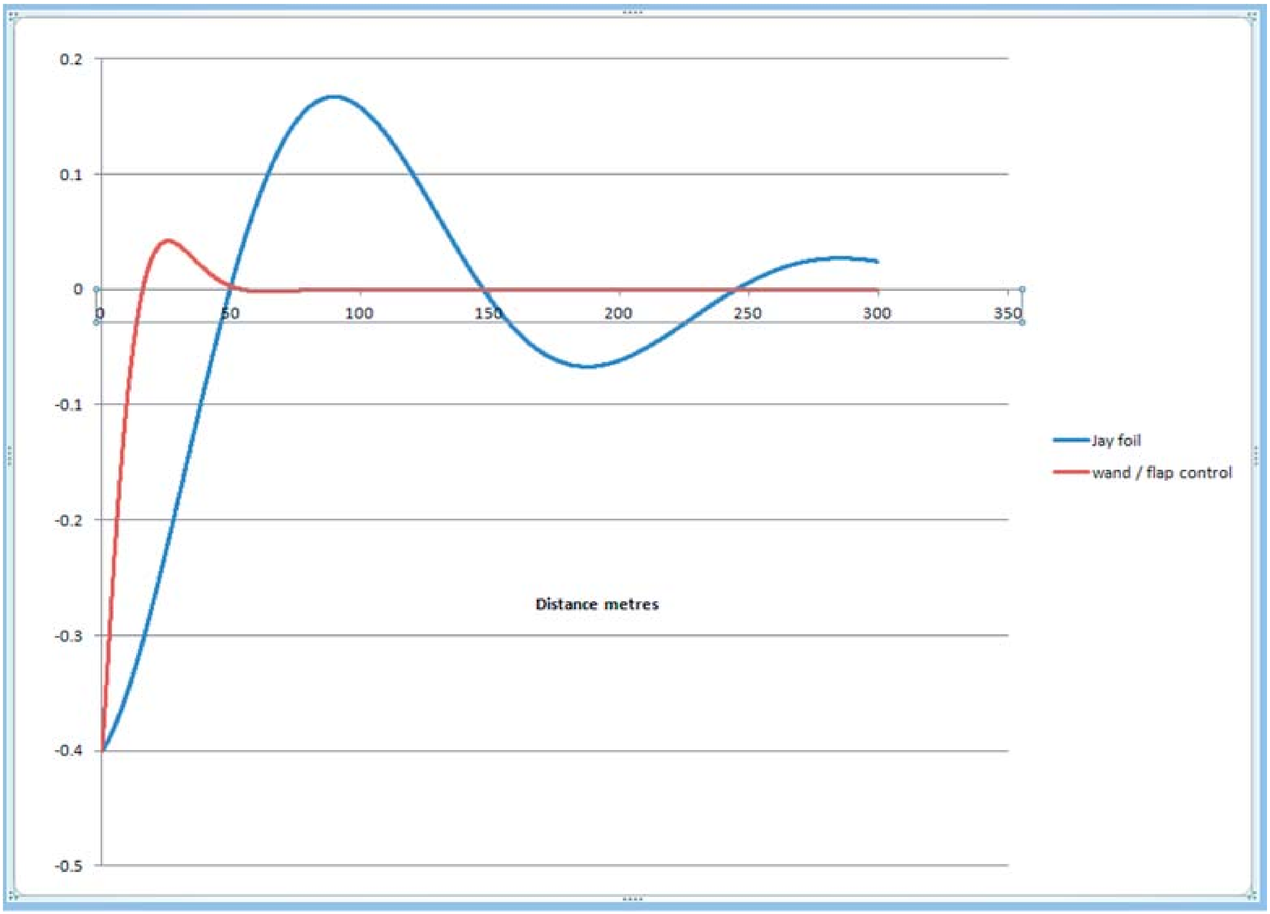
To achieve fast and stable response of the boats attitude and height to sudden changes in the wind and water environment the variations of foil lift need to be considerable and need to be not only a function of height but also rate of change of height. There is also a necessity for any rate of change of attitude to result in a significant opposing pitch moment. The latter is primarily achieved by having the forward and aft foils well separated.

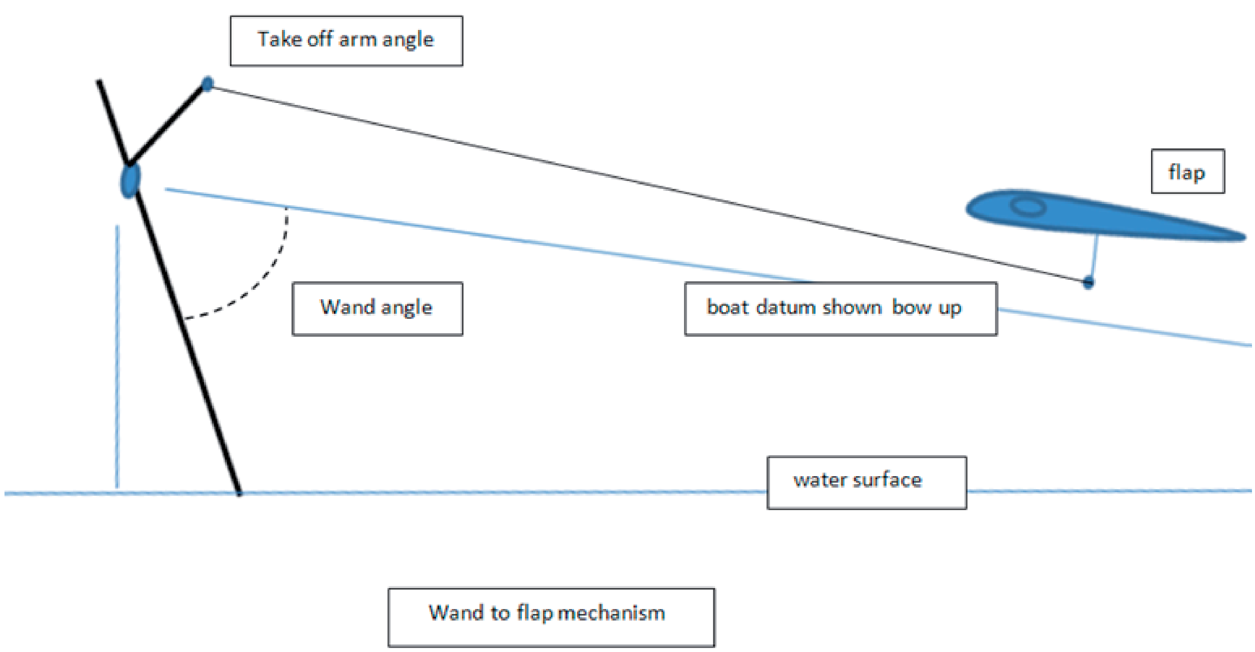
Now let's look at the "J" foil technology. These foils regulate lift by what is termed 'leeway coupling'. Basically, once the windward hull is lifted, the foil has to resist the more or less constant side-force that is developed by the rig. As the boat rises higher out of the water, there is less of the vertical section of strut in the water so the boat makes more leeway. Now the trick the America's Cup designers used was to inversely link the vertical lift produced by the foils to the amount of leeway. If you take a pure L foil, the lift on the horizontal section is augmented by the suction on the windward side of the vertical section that is produced as a consequence of leeway. So with a pure L foil, the vertical lift increases as the leeway increases. This is the opposite to what is required and it would be unstable. So the designers started to reduce the angle between the vertical and horizontal sections of the foil, so that the lifting part points up towards the water surface at a dihedral angle. We now have the J foil. If we just look at the dihedral part of the foil, then as leeway is increased, the flow angle it sees (angle of attack) reduces, and so the lift decreases; but the suction on the windward side of the vertical strut is still acting to increase lift. So we have two components that are fighting one another. The result is a foil system that has the following characteristics:

1. When the foil is deeply submerged (eg hull just clear of water), the change in leeway with height is small, and so the change in lift with height is small and flight is unstable.
2. The change in lift with height becomes sufficient for stable flight only when the boat is very high and making significant leeway. In these circumstances the two parts of the foil fight each other seriously reducing the foils efficiency particularly at lower speeds.

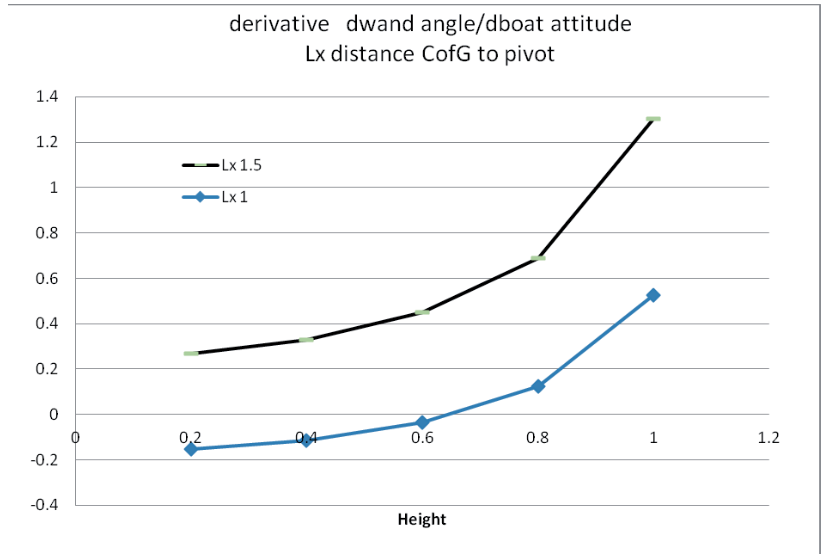
At minimum foiling speed and fixed rake angle (angle of attack) the foil just supports the boat's weight at full submerged depth with a small margin to spare (5%) and at foiling height the lift balances the weight. This very low lift to weight ratio is demonstrated by the very slow rate of climb achieved by "J" foilers. Because steady state foiling speed will always be above lift out speed mechanically raking the foil can improve these numbers but not markedly. The "J" foil has a further disadvantages, the centre of lift is much further inboard than can be achieve with a flapped foil.

As the boat starts to gain height the lateral area decreases and in combination with some increased side force the lift of the foil increases. This is the exact opposite of what is necessary for stability. The rate of climb needs to decrease the lift force not increase it. The saving grace is that the rate of climb reduces the foils effective angle of attack and coupled with a reduction in lift of the lower part of the "J" a stable height keeping results albeit very sluggish. The figure overleaf compares the two systems for the same boat at 20 knots.





Height of wand pivot = height of CofG + distance to pivot × boat atttitude
Wand angle to boat axis = aSin(height of pivot / wandlength) - boat attitude
Flap angle ~ gain × Sin(wand angle + takeoff angle - 90 degrees)



This comparison is from a constant speed two degree of freedom mathematical model.

In the real world the rate of climb during the oscillation is extremely small and probably not apparent to the crew. About 0.05 m/s in the example. However the motion is visible in many video clips of "J" foil catamarans sailing and it is this poor damping that results in difficulty in holding constant height and primarily contributes to pitch poling.

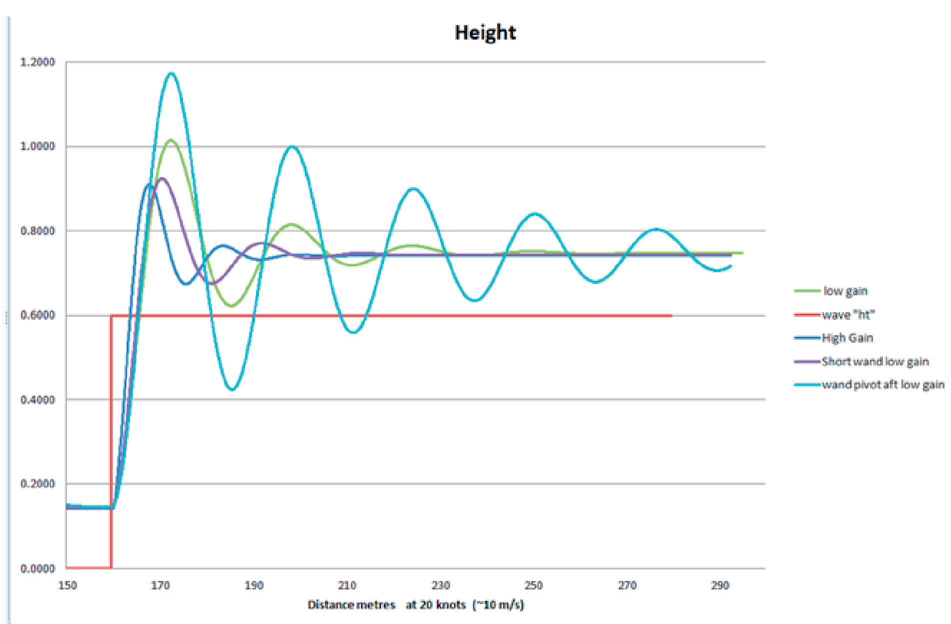
Wand to flap mechanics

Looking at the lower figure the second equation highlights a potential defect in the mechanism. If a situation exist where the boat losses height and the wand angle to the horizontal is reduced, but if at the same time the bow up angle increases, then the wand angle to the boat does not change. In control system terms the term "minus boat attitude" is a positive feedback and very undesirable. This mechanism is only a satisfactory solution while ever the wand pivot is far enough forward of the centre of gravity such that the second term of the first equation is more powerful than this positive feedback term. For the height control to be stable it is necessary for the flap motion to be a function of both height and rate of climb. Boat attitude multiplied by forward speed is an approximation of rate of climb.

Inspection of the second equation shows the necessity of the "aSin" term to dominate boat attitude and shows that shortening the wand length is significant in this regard. Hence there is a tradeoff between flying high (long wand) to reduce wetted area and increase speed and flying low (short wand) and improving stability.

The next graph shows the derivative of wand angle to boat attitude. with the distance from the CofG to the wand pivot set at 1 metre the attitude derivative changes sign at a height just above 0.6 metres. Below this height the attitude term becomes positive feedback.

The graph below show the response of a Moth to 600mm high step function (wave). Step waves do not happen in practice but they are an excellent way of illustrating stability characteristics. The short wand low gain cases shows the superiority of the longer wand at the same gain. The wand pivot aft case shows the importance of moving the wand pivot as far forward of the CofG as possible (within reason).



Disadvantage of high gain.

At low gain the wand will hold height near constant when crossing a wave field of small short wavelength waves. At high gain in long wavelength waves the boat will be near to holding a constant separation between the hull and water surface. Increasing gain increases induced drag and as a consequence gain should only be increased in those circumstances where improved stability is more important than speed:- big seas, high winds, off the wind sailing (AWA = 40 rather than 25 degrees)

Forward foil functions

The forward foil makes the following contributions

- Provides the majority of the lift required
- Provides a small contribution to damping moments as a function of pitch rate
- But it is seriously detrimental to pitch stability because it is forward of the centre of gravity

Flap functions

The flap driven by the wand makes the following contributions

- Because the wand pivot is well forward of the centre of gravity of the flap it provides the moments essential to pitch stability
- As a function of wand measured height it adjusts the list to balance the boats weight
- Because it is forward of the centre of gravity it provides a small amount of "early warning" about wave heights.

Rear foil functions

The aft foil makes the following contributions

- It provides damping moments as a function of pitch rate that are vital for stability
- Provide a small portion of the lift required
- Changing the aft foil angle of attack changes the boats steady state attitude
- If the angle of attack can be quickly changed by crew action it can augment stability and improve sea keeping in larger waves.

Validity of math modeling

To seriously validate a VPP or dynamic simulation requires extensive in the field testing using very accurate instrumentation system. This far beyond anything available from the author's resources. Nevertheless GPS data and video clips provide large databases of circumstantial information that support the accuracy of our models. In reality absolute accuracy is not essential. The important issue is the sign and nominal amplitude of each derivative. It is the "what if" sensitivity numbers (derivatives) that are important. These provide the designer with the road map to improve the boats characteristics.

Sails

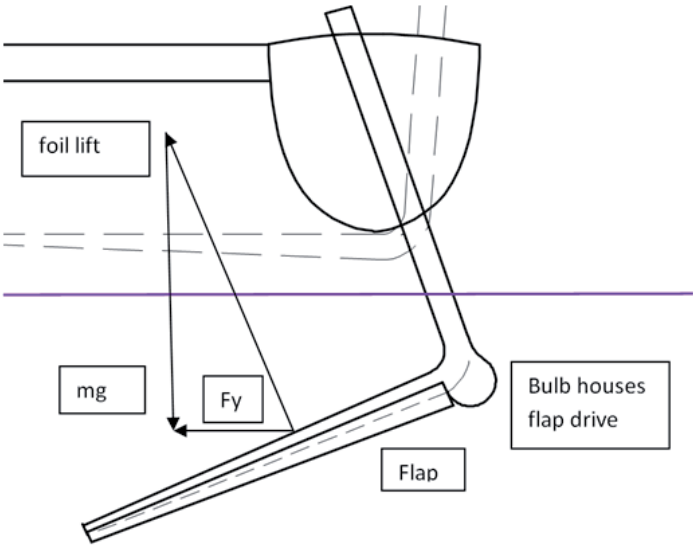
As speed increases are achieved apparent wind angle decreases and heeling moment increases, this necessitates flatter sails with additional twist. Twist in the head lowers the centre of effort and hence heeling moment

- C class Catamarans for many years now have successfully used rigid wingsails primarily to achieve high lift coefficients (C_L) in the order of 2.5. For a C_L as high as this, the Vs/Vt ratio has to be very poor. Once a performance of Vs/Vt = > 2.0 there is no value in a C_L greater than about 1.0
- The trend towards using wing sails in the C_L range 0.3 to 1.0 is driven by the transfer of aerodynamic knowledge to high performance sail design, and that works. Not a lot is actually known (in the public domain) about thin leading edge sails. Modern ice yachts are worthy of consideration. With small section masts and Dacron sails they are achieving Vs/Vt ratios of 6 ($C_L < 0.4$). As a consequence while wing sails maybe superior, "soft sails" cannot be dismissed as unworkable at low C_L. Cost and utilitarian aspects of soft sails should keep them in favor for some time to come.

The future

Most classes do not allow any extensions beyond their maximum beam restriction and personally I do not like any potentially dangerous protrusions. Current "J" foil designs demonstrate that "L" foils are structurally viable, hence the scheme below is my choice. It has less wetted surface than all other options.

I would like to see a design commissioned for an off-the-beach foiling catamaran, say 7 metres long, three metres beam, hiking frames, crew of three, two trapezes and no other restrictions. It is unlikely to have a Vs/Vt ratio of 3 but 2.8 would certainly be within its grasp.



Reference

https://sites.google.com/site/hydrofoilyachts/

About the Author

- 1944 age 9 started to sail regularly
- 1954 Graduated Electrical engineering and joined the design department of the Australian Government Aircraft Organization
- 1956/59 Post grad studies in electronics. Semiconductors had arrived.
- 1956 Read Davidson's Mechanics of Sailing Yachts in which he postulated Vs/TWS ~3 and 40 knots as being possible
- 1954 to 1998 Design and development of unmanned flight vehicles, Malkara, Ikara, Jindivik, Turana and Nulka.(http://www.gunplot.net/nulka/nulka.html.) From electrical servo mechanism design to flight control. Junior engineer to Chief Designer.
- 1952 First dinghy design
- 1960 to 1980 Designed, developed and successfully raced high performance skiffs
- 1966/67 MSc Cranfield UK aeronautical flight dynamics
- 1966/67 Commenced dialogue between the UK international Fourteen association and the Australian fourteen association that led to amalgamation of the two classes in 1995
- 1967 Thesis at Cranfield UK "Dynamic stability of sailing yachts". A unique study for that time.
- 2000/03 Design of foil system for David Lugg's 14 foot skiff. See articles in Seahorse and Australian Sailing May 2003
- 2005 to present Analysis of International Moth Stability and Performance characteristics
- 2008 to present Collaboration with Kevin Ellway focused on moth performance, stability and height control. Development of accurate VPP and a dynamic stability simulation culminating in Kevin's Exocet design and the Canted foil system of William Sunnucks' M20 catamarans. I was not in favour of the name as Nulka was specifically developed to defeat Exocet!

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AYRS News

AYRS North West UK Group Meeting, 13th June 2015

Five members turned up for the meeting. Apologises for absence were received from John Morley and John Shuttleworth. It was a warm sunny day and the meeting was convened around the patio table in Mike's garden. Subjects were many and varied.

The meeting kicked off with Mike Howard reporting on the two boat shows he had visited the previous weekend. Three members of the AYRS NWLG had attended the Beale Park Boat and Leisure Show, which Mike thought had lived up to its reputation with a wide variety of canoes, small dinghies and small coastal cruising sailing boats, many of them of timber construction and beautifully finished. There were several innovative craft ranging from the ORUCANOE, a folding Correx Kayak, to the coracle with a sail. Hardly anyone I spoke to, Mike reported, believed it could sail but the owner insisted that he had placed a video on YouTube showing that it could!

Mike also attended the first Northern Boat Show, which had been held in Liverpool at the same time as the Beale Park Boat Show. The Organisers had promised 150 stands and 50 large boats. There were about 60 to 70 stands and perhaps 40 large boats. Unfortunately, the show was rather fragmented, being staged in three different areas of the Albert Dock complex. Mike said he had spoken at length to two of the exhibitors who were pleased they had made the effort and hoped the show was a success. Adrian Denye commented that the 'Trade' would love a permanent boat show in the North of England as statistics over the past eight years have shown that only 20% of attendees at the London and Southampton Boat Shows are from the North. A show in Liverpool, stated Adrian, would attract would-be customers from the North of England, Scotland and Ireland.

John Alldred followed on by telling the meeting how he had designed and built a Correx catamaran, fitted it with a 36 volt power tool and home made propeller, and had entered FLIPPER into the Cordless Canoe Challenge at the Beale Park Boat Show. He had won his heat but was outclassed in the final. Mike Howard stressed that John's entry was as a privateer and not as part of AYRS, although John Shuttleworth had acted as John's volunteer crew and Mike had assisted shore side. John mentioned he had seen a beautiful propeller constructed of timber at the Beale Park Boat Show but the owner was reluctant to sell it to him. He then tabled a partly constructed propeller he was making himself from several laminated layers of plywood.

After tea and cake (thanks Col), Colin McCowen showed the meeting photographs, drawings and sketches of his outrigger stabilised sailing canoe. He had also brought with him one of the outrigger floats which incorporates a fixed keel. The keel is equipped with a fence on the tip and a depth limiting fence. An inclined rectangular plywood pad, set at an angle acts like a 'waterski' and prevents the emergency float from being buried in the event of severe heeling. Colin has been developing the conversion of his canoe for a couple of seasons and stated he felt very confident in its sailing ability and stability. Colin is the 'daredevil' of our group and he told us how he has continually up-rated the sail area of his sailing canoe and he now sits out on a plank to weather to exert more righting lever.

The meeting then went out to Colin's car, where on the roof rack was secured Colin's latest version of his kite powered hapa. The 'rider' sits in a chair suspended from a 13 square metre inflatable kite while handling the lines connected to the hapa. Colin has not yet embarked upon 'flying trials' - but watch this space.

Adrian then treated us to an update on the America's Cup, which he follows with interest. The political goings-on, the physical and technical restraints now built into the latest AC48 rules and Adrian's views about where innovation and development might take place was accompanied by innumerable questions from his audience.

The final hour of the meeting discussed more general nautical subjects. Mike suggested that an outdoor meeting, where all the members could view and experience the various in-house developments was overdue. Mike also stated he felt a bit of a fraud as his last few months had been more concerned with domestic jobs about the house and garden rather than AYRS related subjects.

Finally, before the meeting broke up, the members remembered Peter Gilchrist, a long standing member of AYRS and a founder member of the NWLG, who sadly died last month. Peter conducted himself with quiet dignity and was always willing to indulge the meeting with his knowledge and experiences. He will be sadly missed by all of us here in the North West Local Group.

AYRS North West UK Group Summer Outing to Manley Mere

This year's Summer Outing of the North West Local Group was planned as a visit to Manley Mere, a man made lake set in the heart of the Cheshire countryside. The venue provides the opportunity for canoeists, kayakers, windsurfers and dinghy sailors to enjoy a day's sailing.

Wednesday 26th August dawned wet and windy but by mid morning, when the Group had assembled at the lakeside, the sun was shining and a brisk wind was blowing. There were five Members present accompanied by their wives and several grandchildren. Brian Shenstone had brought along his Canadian Canoe and he was the first afloat. John Shuttleworth had his home designed and built fourteen foot long sailing canoe and it was interesting to see the various 'gadgets' he has developed. John is a member of the Open Canoe Sailing Group and has many years experience of sailing with them.

Colin McCowen was busily rigging his glass fibre Canadian Canoe which he has converted to both a rowing skiff and a sailing canoe. His outrigger floats, which are minimal, combine an angled dagger board provided with fences. He was busily rigging up a new almost square topped sprit sail of eight square metres area which he had designed and sewn himself. The sail is supported by three full length battens; a rather unique curved sprit, which angles upwards from the mast to the head of the sail and a curved boom which angles downwards from the mast to the clew of the sail. Another unique idea on Colin's sailing canoe was the extremely shallow rudder,

also provided with fences, top and bottom.

Both sailing canoes sailed superbly in the steady breeze; John's lying over at an angle supported in the gusts by its leeward outrigger float and Colin's kept upright by Colin himself, who was perched on a fixed 'sliding seat'. It was quite obvious that Colin's shallow rudder and his outrigger mounted dagger boards worked superbly as he was able to sail upright and to flick his canoe from tack to tack with consummate ease. He made little leeway compared to John's single side mounted dagger board. He was also able to control the superb setting if not rather large spritsail!

After lunch, Colin demonstrated his Hapa by towing it along the edge of the lake. It was quite fascinating to watch the Hapa overtake the 'puller'. The Hapa is designed as a proa, that is, it can be towed in either direction. The Hapa comprises a longitudinal oriented sealed aluminium tube. At each end of the tube a vertical fin supports a narrow horizontal foil. Both foils are provided with fences on their longitudinal edges. In the centre of the tube a vertical fin is mounted. The fin is constructed from a redundant band saw blade and the leading edges are honed to a very sharp point. This immersed blade is hinged vertically about a second fin which protrudes above the water. A second horizontal tube set at right

angles to the main tube carries the two adjustable lines which allows the 'puller' to alter the angle of incident of the hinged vertical blade.

Colin demonstrated, that by carefully adjusting the angle of incident, not only did the Hapa increase its speed through the water but it exerted considerable lateral force at the same time. Colin hopers to combine his Hapa with a inflatable kite, both controlled by the helmsman, perched on a seat several feet above the water. This is an ambitious project and although we often 'take the mickey' out of Colin, he takes it in good spirit and remains determined to succeed.

Both sailing canoes enjoyed a further period of sailing in the steady breeze, with two out of the three small grandchildren enjoying a sail with an AYRS member. My wife and I left with Brian and Beryl just after three thirty so we could take Brian and his canoe home. Being 'boat-less' at the moment, I had volunteered to transport Brian and his canoe as he does not yet have a roof rack on his car. The other members stayed on and continued to enjoy the day. Opinions on the day seemed to support the fact that the venue had been well chosen, with something for everybody. It was certainly interesting to see that the inventiveness within AYRS is still alive and well!

AYRS NW UK Group Meeting, 5th December 2015

The meeting commenced at 12.30 pm with an excellent buffet lunch (Thanks Col!). About half an hour later the meeting settled down. The initial conversation revolved around reflections on our sixth year, with Colin McCowen showing photographs of his latest canoe sail, which he has increased in area by adding a bonnet to the boom so the sail now sweeps the gunwhale. The conversation inevitably led into reminiscing about our youth with a series of stories of 'daring do'. This, in turn, led nicely into the differences between the 'old guard' and young people today and how we could recruit more members into our local Group.

Mike Howard stated that AYRS had abandoned the London Boat Show in favour of exhibiting at the London Dinghy Show. Adrian Denye thought this was a good move as AYRS could help young dinghy sailors improve their rig. Mike then outlined his approach to AYRS and the Committee's approval of his bid to mount a stand at next year's Northern Boat Show to be held in Liverpool between the 3rd and 5th June. Mike explained that he had been involved in a number of trade shows over the years culminating in taking a forty five feet long wide beam canal boat to the Irish Boat Show in 2007. Mike stated that the aim was to recruit at least twelve new members.

As AYRS would be mounting a stand at the Beale Park Thames Boat Show on the same weekend The North West Local Group would have to organise the purchase of another marquee, display stands and display material. Mike outlined what he intended to purchase which included a three metre by two metre heavy-duty marquee with a ground bar system, a folding display stand and foam board display material. He had also looked at using the roller displays. Adrian pointed out that the latter were not very stable in high winds! Mike also stated he had allowed for polo shirts with the AYRS logo to create a corporate image.

Mike stated that he would require everyone to help man the stand. He would produce a rota allowing each member a half day at a time on the stand as it was quite an exhausting process. Adrian, who also has considerable experience with trade shows, agreed. Mike pointed out that when he displayed at the Irish Boat Show the five day event, which was open from 10.00 am to 8.00 pm, required sixteen individuals to man the stand. Mike tabled the stand position and layout and a rough draft of the display material. A long and fruitful discussion then took place with everyone throwing ideas on the table.

All agreed that a key point was to try and convey a modern 'hands on' approach with a catchy display. Mike suggested that a 'moving display' to catch the punters' attention. Mike cited several examples of this involving either 'moving water' or a repetitive sound. Colin explained a 'moving water' display he had seen in the Children's Section of the Science Museum and stated he would have a go at producing one. Mike thought that John Alldred's FLIP FLOP in a clear Perspex tank would look good. Adrian asked if a Correx boat had been constructed and Mike confirmed that John Alldred had constructed a three metre by one and a half metre catamaran dinghy but it would be too large to display on the stand. However, John had many small scale Correx models which they could use to demonstrate the principles of Correx boat construction. John Shuttleworth asked Mike to keep them all informed of progress so that there was the maximum input by the membership into the event, which he stated, he felt very excited about.

The suggestion of flyers was dismissed as a waste of money by both Mike and Adrian. Adrian emphasied the need to get individuals into meaningful conversation about AYRS, signed up and subs paid BEFORE they left the stand. He suggested we might require a card reader as most people used plastic to pay. He also asked if we would have a supply of AYRS Technical Booklets and Catalyst magazines. Mike said he would produce a list of the Technical Booklets and enquire of 'Head Office' how many copies of each they hold in stock.

Having ;'exhausted all avenues' the meeting resolved into a more relaxed atmosphere with lots of questions about projects being asked of the members and ideas being put forward. One such question was from John Shuttleworth who wishes to collect a trickle of water from a small spring and use it to fill a water butt. The idea of using a low capacity water wheel, a ramjet pump and an Archimedes Screw were all put forward and discussed at some length. Finally, around 5.30 pm, the meeting broke up.

There is no doubt in my mind that although our numbers have dwindled over the six years of the existence of the North West Local Group, as a group we are more cohesive than ever and 2016 holds many opportunities for us to expand our horizons.

785326

Report of the Committee of the Amateur Yacht Research Society Limited

The AYRS is incorporated as a Company limited by guarantee and not having a share capital. Company Registered Number **785326**, Educational Charity Registered Number 234081, Registered Office: 9 Lynton Rd. Thorpe Bay, Essex SS1 3BE, UK.

The Committee present their report and the financial statements for the year ended 30th September 2015.

1. The principal activity of the Society, a registered educational charity, is to promote the improvement of yachts and equipment by the use of research and development.
2. The Committee who served during the year were: F C Ball, D Culp, R Downhill, R M Ellison (ex-officio), K Fisher, Mrs S M Fishwick, S N Fishwick, T Glover, S Penoyre, J Perry, M R Tingley and G G W Ward.

Committee's Responsibilities for preparing Financial Statements

(The Committee are the Directors of the Company)

Company law requires the Directors to prepare financial statements for each financial year, which give a true and fair view of the state of affairs of the company for that period. In preparing those financial statements, the Directors are required to:

- select suitable accounting policies and then apply them consistently;
- make judgments and estimates that are reasonable and prudent;
- state whether applicable accounting standards have been followed, subject to any material departures disclosed and explained in the financial statements;
- prepare the financial statements on the going concern basis unless it is inappropriate to presume that the company will continue in business.

The Directors are responsible for keeping proper accounting records which disclose with reasonable accuracy at any time the financial position of the company and to enable them to ensure that the financial statements comply with the Companies Act 2006. They are also responsible for safeguarding the assets of the company and hence for taking reasonable steps for the prevention of fraud and other irregularities.

This report has been prepared taking advantage of the exemptions available to small companies regime within part 15 of the Companies Act 2006, was approved by the board on 25th October 2015, and signed on their behalf.

Sheila Fishwick
Director & Company Secretary

Balance Sheet as at 30th September 2015

2014			2015	
		FIXED ASSETS		
-		Tangible Assets		
		Plant and machinery (Note 1)	-	
		CURRENT ASSETS		
£1,013		Stocks (Note 3)	£1,013.00	
£61,466		Cash at bank and in hand	£61,789.06	
£1,720		Payments in advance	£263.50	
	£64,200			£63,065.56
		CREDITORS: Amounts falling due within one year		
£1,165		Subscriptions in advance	£1,107.04	
£41		Sundry creditors	£142.50	
	£1,206			£(1,249.54)
	£62,993	NET CURRENT AND TOTAL ASSETS		£61,816.02
		RESTRICTED FUNDS		
£36,874		Balance as at 1st October previous (Note 9)	£36,374.04	
£(500)		Increase/(Decrease) for the year	£-	
	£36,374			£36,374.04
		ACCUMULATED FUND		
£26,412		Balance as at 1st October 2003	£26,619.63	
£207		Surplus/(Deficit) of Income for year	£(1,177.64)	
	£26,619			£25,441.99
	£62,993			£61,816.03

The notes on the next page are part of the financial statements.

Directors Statements on Unaudited Accounts

The Accounts are prepared in accordance with the special provisions within Part 15 of the Companies Act 2006 relating to small companies.

For the year ended 5th April 2015 the company was entitled to exemption from audit under section 477(2) of the Companies Act 2006 and no notice has been deposited under section 476.

The Directors acknowledge their responsibility for:
(i) Ensuring the company keeps accounting records which comply with Section 386; and
(ii) Preparing accounts which give a true and fair view of the state of affairs of the company as at the end of the financial year, and of its profit or loss for the financial year, in accordance with the requirements of sections 394 and 395, and which otherwise comply with the requirements of the Companies Act 2006 relating to accounts, so far as is applicable to the company.

These accounts were approved by the Board of Directors on 25th October 2015 and signed on their behalf by:

Sheila Fishwick
Director & Company Secretary

785326

Income And Expenditure Account for the year ended 30th September 2015

2014			2015	
		INCOME		
£4,919		Subscriptions	£4,432.27	
£1,473		Donations	£267.40	
£(348)		Misc Income(Loss) from foreign exchange	£15.88	
£51		Boat Show receipts (Note 6)	£547.75	
£30		Interest received	£30.16	
£132		Sale of publications (incl. Catalyst) & stock	£140.10	
	£6,258			£5,433.56
		Less:-		
		DIRECT CHARITABLE EXPENDITURE		
£761		Printing & copying publications & Catalyst	£1,380.10	
£434		Postage on Catalyst etc	£687.81	
£253		Meeting and room hire	£240.00	
£69		Website & Internet Forum	£69.47	
£459		Support to Speedweek	£426.96	
£-		John Hogg Prize	£-	
	£(1,978)			£(2,804.34)
		OTHER EXPENDITURE		
£203		Administrative & office expenses	£281.98	
£2,587		Boat Show costs (Note 6)	£2,296.62	
£1,243		Insurance	£1,243.75	
£26		Misc	£(15.49)	
£11		Bad debts	£-	
	£(4,072)			£(3,806.86)
	£207	Surplus/(Deficit) of Income		£(1,177.64)

Notes and Schedules to the Accounts for the Year Ended 30th September 2015

1. **Accounting policies**

a) These accounts have been prepared under the historical costs convention.

b) Depreciation was provided on fixed assets until 1994 when the residual value was written off.

2. The Society is limited by guarantee and has no Share Capital

3. **Stocks.** These comprise publications and goods for resale as follows:

Books and publications (nominal value)	£1,000.00
Ties, burgees, etc	£13.00
	£1,013.00

Due to the subject matter and nature of the Society's publications, it has been considered that the value attributable shall be a nominal £1000. In the event of the total cost falling below £1000, then that lower figure will be substituted for the £1000 nominal value.

4. **Remuneration**. The Committee received no remuneration during the year. Receipted expenses were paid to certain members.

5. **Income in US$ and Euros**. Income in US Dollars was $30 (£19.85) being subscriptions paid in advance. The rate of exchange used at the year-end was $1.51138=£1.00. Cash & at bank includes $1049.12 (£694.12) held on 30th September in PayPal, the remainder is in currency notes. Income and Expenditure in Euros was zero, however changes in exchange rates resulted in a loss on paper of £31.55. The exchange rate applied at the beginning of the year was €1.128489=£1.00, and that at the year end was €1.35383=£1.00.

6. **Boat Show**. Receipts amounting to £547.75 were banked from subscriptions, donations, and sales of publications at the January 2015 London Boat Show and have NOT been subdivided in the accounts. Expenditure amounted to £1676.99. The 2015 Beale Park Boat Show cost £142.50 and brought in £142.00.

7. **Sundry Creditors**. Fred Ball paid the Beale Park Show booking.

8. **Restricted Funds**. Some of the funds held by the Society are restricted in their use and not available for the running of the Society. The Committee have also designated £1000 of the general funds held for future awards of the John Hogg Prize.

9. **Balance as at 1st October previous**: The exchange rates used to calculate this sterling balance were those applied at that time: $1.62200=£1.00. €1.128489=£1.00.

Catalyst Calendar

This is a free listing of events organised by AYRS and others. Please send details of events for possible inclusion by post to Catalyst, BCM AYRS, London WC1N 3XX, UK, or email to **Catalyst@ayrs.org**

January 2016

8th – 17th London International Boat Show
EXCEL Exhibition Centre, London Docklands. AYRS are not going this year, instead we are going to the London Dinghy Show (see below)

24th All-Day AYRS Meeting
9.30am-4pm, Thorpe Village Hall, Coldharbour Lane, Thorpe, Surrey (off A320 between Staines and Chertsey – follow signs to Thorpe Park, then to the village). Tea and coffee available, bring your own lunch. Donations invited to pay for hall. Further details from Fred Ball, tel: +44 1344 843690; email: fredball@ayrs.org.

March

5th-6th London Dinghy Show
Alexandra Palace London N22
The RYA Dinghy Show is the only show in the world dedicated to Dinghy Sailing. It's a great day out for all the family and offers visitors the opportunity to:
Listen to inspiring and informative talks from the sport's biggest names on the Suzuki Main Stage;
Attend coaching and top-tips seminars with experts in the RYA coaching area;
Interact and get advice from the RYA and commercial exhibitors and RYA affiliated clubs and class associations; and visit the AYRS on Stand G26!

12th @ 2.00 pm AYRS NW UK Local Group Spring Meeting
Lydiate Merseyside. Contact: Mike Howard, email: ecotraction@aol.com

May

6th – 8th Sailing Trials Weekend Portland and Weymouth Sailing Academy, Portland Harbour, Dorset UK
A weekend messing around with boats in Portland Harbour. For more details contact Norman Phillips email: wnorman.phillips@ntlworld.com

Date TBA AYRS NW UK Local Group Get Together Afloat - Ideas welcome!
Contact: Mike Howard, email: ecotraction@aol.com

June

3rd -5th Beale Park Boat Show
As usual we will have a stand and would appreciate small exhibits and display material and, of course, offers of help to run the stand. Contact: AYRS Secretary, email office@ayrs.org

3rd -5th Liverpool Boat Show
AYRS will also be at this event with a stand run by the North West UK group. So if you are in the North of England (or in Scotland) and find Beale Park too far to go, try Liverpool instead where Mike Howard will make you welcome. He too would appreciate small exhibits and display material and, of course, offers of help to run the stand. Contact: Mike Howard, email: ecotraction@aol.com

18th @ 2.00 pm AYRS NW UK Local Group Summer Meeting, Lydiate
Contact: Mike Howard, email: ecotraction@aol.com

July

19th AYRS NW UK Local Group Summer Outing to ?
Bring your own boat!
Contact: Mike Howard, email: ecotraction@aol.com

September

24th @ 2.00 pm AYRS NW UK Local Group Autumn Meeting
Contact: Mike Howard, email: ecotraction@aol.com

October

8th-14th Weymouth Speedweek
Portland and Weymouth Sailing Academy, Portland Harbour, Dorset UK. See http://www.speedsailing.com/

12th "Speedsailing" - AYRS Weymouth meeting
19.30 for 20.00hrs, Weymouth Sailing Club, Nothe Parade (near Brewers Quay), Weymouth, Dorset DT4 8TX.
Contact: AYRS Secretary, email: office@ayrs.org. Check the AYRS website before going just in case the location changes!

Date TBA Any Ideas for AYRS NW UK Local Group?
Contact: Mike Howard, email: ecotraction@aol.com

November

TBA AYRS London Area meeting
9.30am to 5pm, Thorpe Village Hall, Coldharbour Lane, Thorpe, near Staines & Chertsey
Bring your lunch - tea and coffee available. Donations invited to pay for the hall.
Details from Fred Ball, tel: +44 1344 843690; email fredball@ayrs.org.

Catalyst — *a person or thing acting as a stimulus in bringing about or hastening a result*

On the Horizon . . .

Nothing much really.

Would you like to write something?

Email it to catalyst@ayrs.org please.
Guidance notes are inside the front cover.

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